

**A FRAMEWORK OF INTRA-ORGANISATIONAL
KNOWLEDGE SHARING PRACTICES IN
IMPLEMENTING BIM WITHIN THE
MALAYSIAN CONSTRUCTION INDUSTRY**

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MALAYSIAN CONSTRUCTION INDUSTRY**

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ABSTRACT

The Malaysian construction industry has been urged by the government to implement BIM to become a stable, developed, and modernised country by the year 2020. In the Malaysian context, research has shown that BIM implementation is relatively low and is still facing some challenges. Lack of understanding and knowledge remains a significant barrier to BIM adoption. Meanwhile, knowledge sharing (KS) is acknowledged as the essence of technological capability development to start the dissemination process, preventing the loss of knowledge and lessons learned, and also to increase operational efficiencies. The practice of knowledge sharing will enable learning development in implementing BIM. This will potentially help to avoid the same problems that other organisations have faced, hence speeding up a successful BIM implementation process. However, there seems to be little effort in developing a knowledge sharing framework for BIM implementation. Therefore, this study attempted to expand the literature and to support improvements in construction organisations by developing a framework of intra-organisational knowledge sharing practices for an effective implementation of Building Information Modelling (BIM) in the Malaysian construction industry. This study explored and identified the critical factors of knowledge sharing as the main components of the framework. Since BIM is relatively new within the Malaysian construction industry, a few steps were taken to identify a suitable organisation that has an understanding of BIM and fulfil the research scope. The first step was through a review of implementation cases in publications. The second was by a direct conversation with a gatekeeper who is in-charge of monitoring the development of BIM in Malaysia, and thirdly through preliminary interviews with thirteen (13) organisations identified from all the three steps taken. However, only nine (9) responded, and six (6) matched the scope of this study. This study uses multiple-case studies as a research strategy for the primary data collection through semi-structured interviews with nine (9) respondents across six construction organisations that have implemented BIM in Malaysia. Content analysis techniques were used to analyse data from each case study before it was cross-analysed to determine further results. Then, the findings were discussed and theoretically validated to produce a preliminary framework. Consequently, the final framework was presented after the preliminary framework was validated via peer interviews supported with a questionnaire survey. The framework outlines three elements (people, process, and technology), which consist of eight practices and 32 KS components according to their KS ranking in implementing BIM. Each of the practice describes the KS requirement that the organisation needs to develop to allow the success of knowledge sharing in implementing BIM. It highlights the need for organisations to focus their efforts on eight essential practices; Leadership and management support, Team characteristics and organisation, Individual attitudes and personality, Communication and collaboration, Policy, Operational, IT infrastructure and Appropriate tools. The framework could be used to guide the construction organisations to identify the capability of the organisation in determining the requirement of knowledge sharing practices in implementing BIM. This will improve the workflow and speed up the successful implementation process of BIM in Malaysia.

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“THANK YOU ALL”

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)

Suria Binti Musa

14th May 2019 (Date)

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LIST OF ABBREVIATIONS

2D	2 Dimensional
3D	3 Dimensional
4D	4 Dimensional
5D	5 Dimensional
n-D	n Dimensional
AI	Average Index
AEC	Architectural, Engineering and Construction
AGC	The Associated General Contractors of America
AIA	The American Institute of Architects
BIM	Building Information Modelling
BIM BOK	Building Information Modelling Body of Knowledge
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
CREAM	Construction Research Institute of Malaysia
EPU	Economy Planning Unit of Malaysia
GBP	Great Britain Pound
GDP	Gross Domestic Product
ICT	Information & Communication Technology
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
KM	Knowledge Management
KS	Knowledge Sharing
LOD	Level of Development

MEP	Mechanical, Electrical and Plumbing
MIMOS	Malaysian Institute of Microelectronic Systems
NBIMS	U.S National Institute of Building Information Standard
NIBS	National Institute of Building Science
PWD	Public Work Department of Malaysia
R&D	Research and Development
RFI	Request for Information
RICS	Royal Institute of Chartered Surveyors
RM	Ringgit Malaysia
SIRIM	Standards and Industrial Research Institute of Malaysia
SMM2	Standard Method of Measurement 2
U.S	United States of America
U.K	United Kingdom

CHAPTER 1: INTRODUCTION

1.1 Introduction

This chapter introduces the background of the study and the rationale for the research, the research questions and the research aims and objectives. This structure is followed by a summary of the research methods adopted, the contributions of the study, outline of the overall structure of thesis and concludes with an overview of the next chapter.

1.2 Background of Research

The construction industry plays a vital role in the economic growth for both developing and developed countries. Malaysia is moving towards becoming a developed nation by 2020 as envisioned by its Prime Minister, the Honourable Tun Dr. Mahathir Mohamed. The basis of this vision was to establish Malaysia as a fully developed country, not only improved economically but also developed along all dimensions: economically, politically, socially, spiritually, psychologically and culturally. The need for economic transformation into a knowledge-based economy and the importance of knowledge management was highlighted to achieve the vision (Mohamed, 2014). A rapid rate of economic growth urges Malaysia to make the knowledge-based economy a leading platform to sustain and boost its international competitiveness to achieve the objectives of Vision 2020. In the 21st century, the transition to a knowledge society and a global knowledge economy is the ultimate way to social and economic changes (Rollett, 2003). Therefore, Malaysia must move toward a knowledge-based society and make it the highest priority and target for economic growth. The Malaysian Government supports this initiative via its strategic thrust and strategies, which are productivity, quality, human resources, knowledge, innovation, environmental practices, industry sustainability, and professionalism

(CIMP, 2005) to achieve success. The Malaysian construction industry is a driver for economic development. It is a crucial engine for the overall economy and demonstrates a substantial effect on economic growth. Many other industries also rely on the construction industry; for instance, construction consumes 15 percent of total manufacturing output (Construction Industry Development Board (CIDB) Malaysia, 2015). The demand for innovation is increasing as the economy needs to develop globally and nationally. The construction industry involves a wide range of stakeholders and organisations. These stakeholders and organisations need to adopt innovations through knowledge to grow beyond the domestic market and become competitive.

Innovation is vital for organisational performance in the construction industry. Innovation involves a broad scope either through a new approach or via improvements to existing methods. It can be found in many forms related to new products, new processes, new materials, new methods, and new markets (Yusof, Mustafa Kamal, Kong-Seng, & Iranmanesh, 2014). A paradigm shift is seen as necessary for the construction industry to benefit from innovation. Heightening challenges of sustainability, fragmentation, inefficiency in the construction industry, change stands to improve integration efforts, design, facility performance, project management, sustainability, and legal agreements for construction project delivery (Dubois & Gadde, 2002; Rigby, McCoy, & Garvin, 2012). Various integration practices and management tools have been introduced and used such as value management, constructability, benchmarking, reengineering, partnering and total quality management (McGeorge & Palmer, 1997), lean production, concurrent engineering (Mohamed, 2003) to fully benefit the industry including support and commitment from the top management, workforce, and stakeholders' integration.

Besides the many best practices aforementioned, Mokhtar and Bedard (1995) and Mastura Jaafar, Ramayah, Abdul-Aziz, & Saad, (2007) stressed that these approaches were insufficient without the support of IT when dealing with the complexity of

construction projects. Furthermore, the efficiency and productivity of the industry can be improved by the sharing of information and knowledge when using IT (Mastura Jaafar et al., 2007). According to a study conducted in the UK construction industry by Goulding & Lou (2013), the industry does recognise the result of becoming ICT ready was more driven by the engagement of leadership which aligns change management issues to business processes and strategic vision rather than technology. However, they highlighted that the industry has recognised the importance of using ICT tools to help the industry shape the transition. Research by Mukelas and Zawawi (2012) also reported that it is worthwhile for both construction projects and construction organisations to invest in ICT in project delivery since they encourage useful project activities. As Building Information Modelling (BIM) is IT-based, Li et al. (2014) further supported that productivity is increased where BIM is used to allow easy sharing and high integration of information and convenient collaboration. Thus, Building Information Modelling (BIM) is seen as an innovation is that getting attention from around the world which enables integration to overcome the fragmentation problems that have long existed in the global construction industry. It is believed that BIM is the future. In every country, more than 90% of industry stakeholders expect to be using BIM within three years (RIBA, 2014).

In the Malaysian context, many conflicts have arisen in the construction industry that led to poor quality in project outcomes. Many initiatives that addressed strategic information technology (IT) in construction have been explicitly issued by the government to challenge the industry to take advantage of IT utilisation and to strengthen the industry development. This is in line with Ofori (2000) that suggested construction industry would benefit from the strategic application of information technology. IT has been recognized as a driver for many construction organisations in the Malaysian Construction Industry (MCI) in moving them towards a new information technology (IT) era (Mastura Jaafar et al., 2007). Consequently, an IT strategy was purposely developed for the construction industry in the Construction Industry Master Plan (CIMP) Strategic Thrust 6 (CIDB, 2007) and the Construction Industry Transformation Plan 2016-2020 (CIDB Malaysia, 2015) to achieve Vision

2020. In 2009, early effort on BIM implementation began by conducting awareness programs and workshops with the industry. In 2012, CIDB was also working closely with Unit Kerjasama Awam Swasta (UKAS) to deploy BIM in the Public Private Partnership (PPP) projects through a concept of 'Affordable BIM' where UKAS contractors and sub-contractors can use BIM through a periodical licensing arrangement. At the same time, the CIDB established a Committee of Building Information Modelling (BIM) in Construction Industry to coordinate the progress of BIM in this country. In the near term, Malaysia is taking vigorous action in the development of Malaysia's Building Information Modelling (BIM) Roadmap (2014-2020) to encourage the construction industry stakeholders towards a wide adoption of BIM by 2020 (CIDB, 2012). The main roadmap focus was on motivating the stakeholders to implement BIM in alignment with the national agenda. Researchers on BIM have also been encouraged to devise new practices and new tools to develop the industry stakeholders' capability in understanding and taking full benefit of this new technology. Thus, the impact and research on such technology can contribute to new knowledge in the related country, industry as well as organisation for continuous improvement.

Meanwhile, BIM adoption encompasses significant challenges such as the users' operational skills and knowledge. It also requires conceptual and processes knowledge to confirm and create organisational and inter-organisational quality and requirements, which are likely to be a mixture of both organisation and project driven needs (Arayici & Coates, 2013). Furthermore, the different types of buildings and uses may add another difficulty in understanding the required process and standard. As global construction is moving towards higher quality and efficiency, and a construction organisation needs to face the challenges, it is crucial for BIM adoption to be managed efficiently by the construction organisation to speed up the implementation. BIM can be seen as an innovation that will allow organisations to remain competitive. Achieving an efficient innovation involves innovation management, which requires the organisation to employ knowledge management practices for executing the innovation management processes as well as a business

strategy that would bring about a higher level of innovation performance (Goh, 2005a). Knowledge sharing is one of the primary knowledge management processes, and it is a people-to-people process (Ryu, Ho, & Han, 2003). If the organisations can manage innovative knowledge, they can then create value-added and secure long-term sustainable business growth (Goh, 2005a). Thus, this research intends to explore knowledge sharing as a tool and how it can be utilised to develop the people element of BIM such as skills and processability for effective technology adoption in automating the project life cycle in a construction organisation. Knowledge sharing practices (in this context of research) are the processes through which an organisation disseminates BIM implementation related knowledge to its members with continuous interactions through various approaches. In other words, knowledge sharing has become a practice or mechanism to assist the organisation in implementing BIM. This research aims to develop an intra-organisational knowledge sharing framework for an effective implementation of Building Information Modelling (BIM) in Malaysia, which can guide the construction stakeholders in reaping the potential benefits of BIM implementation that includes socio-technical and socio-cultural aspects.

1.3 Problem Statement and Justification

1.3.1 The importance of knowledge sharing

Knowledge sharing is concerned with organisational and ‘cultural’ changes, which are needed to encourage people to share knowledge using IT tools or techniques or both. There is growing realisation that knowledge sharing is critical to knowledge creation, organisational learning, and performance achievement (Ipe, 2003). Knowledge sharing is also critical to an organisation’s success (Davenport & Prusak, 1998) as it leads to faster knowledge distribution to portions of the organisation that can significantly benefit from it (Syed-Ikhsan & Rowland, 2004).

From a technical innovation standpoint, knowledge sharing and practical application are the essence of technological capability development (Gilbert & Cordey-Hayes,

1996) to start the dissemination process (Larsen & Ballal, 2005; Sexton & Barrett, 2004), to prevent loss of knowledge and lessons learnt, and also to increase operational efficiencies (Liang, Saraf, Hu, & Xue, 2007). Furthermore, knowledge without use in applications can quickly become obsolete and forgotten. This information and knowledge should be shared and grown through applications (Arayici & Coates, 2013). Recent reports highlight the importance of collaborative working both now and in the future. It is argued that in the constantly changing global economy the ability to communicate and share knowledge over time and space, within and between organisations or communities, is essential to achieve this flexibility by making the best use of the knowledge and competencies available. Successful knowledge management implementation or initiatives and the enormous potential of using BIM to engage the construction industry clients and practitioners in overcoming the fragmentation is not being realised in practice. Moreover, collaborative environments are necessary to increase productivity as well as creativity by enabling new forms of work in production and knowledge-intensive businesses (European Commission Information Society and Media, 2006).

1.3.2 The Importance of the Malaysian Construction Industry

Malaysia started to develop its construction industry since independence. It has broadened its industrial base from only the production of raw materials to a broader range of assets and manufactured products. The focus of its economy has moved from a mainly agriculture and mining based country in the 1960s to an industrialised nation after the launch of Vision 2020 in the early 1990s, which stimulated high technology, knowledge-based and value-added industries. In 2012, Malaysia's economic performance ranking improved to seventh place out of 59 compared with being ranked 12th in 2007. It has become one of the 20 largest exporting nations worldwide (The German Chamber Network, 2012).

The Malaysian construction industry has two-time multiplier effect, with more than 120 other industries relying on construction for their growth and sustainability. It creates a multiplier effect for industries such as manufacturing, financial services, and professional services. For instance, construction consumes 15 percent of the country's total manufacturing output (CIDB, 2007). It is important to note that the results from the quantitative analysis for the Malaysian construction sector data series from 1991 to 2010 by Khan, Liew & Ghazali (2014) exhibit a strong correlation between the construction sector and Malaysia's economic growth.

The Construction Industry Master Plan (CIMP) is a comprehensive plan for the strategic position and future direction of the Malaysian construction industry over the next ten years. There are seven strategic thrusts in CIMP 2006-2015 with knowledge sharing initiatives being one of the themes under the strategic thrusts, which are in line with the Malaysian government's vision to create a knowledge-based economy (CIDB, 2007). These initiatives will also strengthen Malaysia's capability to innovate; adapt and create indigenous technology; and design, develop and market new products, thereby providing the foundation for indigenously driven growth. This commitment requires a high level of capability at economic and social standards. Knowledge management, amongst other business practices, has to be implemented in some Malaysian organisations to help achieve this significant goal (Mohamed, 2014). Therefore, the sharing of knowledge among the construction players will benefit the construction industry, organisations, and individuals when the improvement significantly takes place.

1.3.3 The need for research in BIM and knowledge sharing

A lot of research into BIM implementation has been conducted in other countries like the United States, United Kingdom, Finland, German, China, and Singapore. The Associated General Contractors of America 2005 has stated that there is no clear consensus on how to implement or use BIM (Azhar, Khalfan, & Maqsood, 2012) and

the issue needs clarification (Gu & London, 2010). However, there are many signs that the use of BIM tools and processes is growing in some markets among the construction players (McGraw Hill Construction, 2014; McGraw Hill Construction, 2008). For instance, in every country, more than 90% of industry stakeholders expect to be using BIM within three years (RIBA, 2014). A survey conducted in early 2007 found that 28 percent of the U.S. AEC industry was using BIM tools; that number had grown to 49 percent by 2009 (Eastman, Teicholz, Sacks, & Liston, 2011).

Meanwhile, Hong Kong has established the Hong Kong Institute of Building Information Modelling (HKIBIM) to promote and create awareness of BIM, to enhance the utilisation of BIM, to develop and establish the standard for BIM practices, to conduct research for improvement, and to establish BIM Guidelines for Hong Kong. Singapore was promoting the usage of BIM under the submission system for building plan approval (Zakaria, Mohamed Ali, Marshall-Ponting, Haron, & Abd Hamid, 2012). The UK Government published a construction strategy article that requires the submission of a fully collaborative 3D BIM (with all project and asset information, documentation and data being in an electronic format) as a minimum by 2016 (NBS, 2015). Nevertheless, BIM development in the UK construction industry is facing challenges. For instance, while there are general knowledge and understanding of Level 2 BIM, it appears that industry participants' capacity and ability to deliver Level 2 BIM such as using the Construction Operations Building Information Exchange (COBie) and PAS 1192-2 appears to be lacking. This challenge implies that the industry requires education and training in Level 2 BIM tools, techniques and processes (Royal Institution of Chartered Surveyors, 2015). Although BIM development in the UK is facing challenges, it continues to grow. A survey reported that the industry had seen the most rapid BIM growth since 2014; it showed awareness is near universal and adoption is up to 62 percent of practices using BIM on some projects, up by 8 percent year on year. More than 55 percent describe themselves as confident in BIM compared to 35% back in 2012, but 90% said BIM adoption requires changes in workflow, practices, and procedures. Learning from colleagues (75%) and fellow professionals (62%) were cited as key ways by which

people keep their skills sharp. Professional bodies and expert organisations, such as the NBS, the BIM Task Group, BSI, and RIBA, were also deemed significant (NBS, 2017). As BIM is well accepted globally and the demand is growing, the Malaysian construction industry has learned from the initiatives of other countries to improve current practices. The involvement from the government, for instance by forming a BIM working group like in Hong Kong is one way to set the direction of BIM in Malaysia. Thus, the Malaysian government calls for the construction industry players to increase ICT adoption that includes BIM adoption and mechanisation in the industry, and innovations in building research through the Construction Industry Transformation Plan 2016-2020 (CIDB Malaysia, 2015). Besides, Ofori (2000) confirmed that research in the construction industry must differ in every country because of the uniqueness of culture in particular groups of people, and its influence on societies and organisations.

In the Malaysian context, BIM adoption is progressing well, driven primarily by a private sector which is already aware of the significant benefits to be derived from the strategic adoption of BIM (Ismail, 2015). However, not much research has been completed in BIM because it is relatively new, but there is pressure from the government for more research to overcome the construction industry's problems (CIDB, 2014). Despite the well-documented benefits and strong support from the Malaysian government, the take-up for BIM adoption is still at a low level and needs to consider essential aspects such as management, education and technology strategies (Mohd Nor & Grant, 2014; Zahrizan et al., 2013; Won et al., 2013). A preliminary work on the perceptions of industry professionals was undertaken to develop a research model base on perception towards better BIM usage incorporating strategic IT implementation and technology acceptance theories (Enegbuma, Dodo, & Ali, 2014). Omar, Nasrun, Nawati, and Nursal (2014) highlighted the importance of BIM software selection based on a precise analysis of a company's demands instead of choosing based on marketing promotion as it can influence the project execution throughout the building process. Some researchers investigated BIM implementation but limited themselves to benefits and challenges (Mohd Nor & P. Grant, 2014;

Zahrizan, Ali, Haron, & Marshall-Ponting, 2014; Salleh & Fung, 2014) while others focused on prioritising initiatives (Harris, Irfan, et al., 2014) and the culture aspect (Ghafar, Ibrahim, Shari, Rahimian, & Putra, 2010). Earlier research on organisational readiness has been explicitly conducted for preparedness from the perspective of designers' organisations (Haron, 2013). Meanwhile, some studies showed that the implementation of BIM is still at a low level and needs to consider essential aspects such as management, education and technology strategies (Mohd Nor & Grant, 2014; Zahrizan, Ali, Haron, Marshall-Ponting, & Abd Hamid, 2013; Won, Lee, & Dossick, 2013). Some suggested the technical aspect needed to be improved, nevertheless the technology itself is unique to be blamed. According to Rezgui, Hopfe, and Vorakulpipat (2010), it is the reality of the models themselves, the way they are developed, and the working instrument that supports their use which specified the differentiation.

Challenges in implementing BIM are divided into technical and non-technical aspects. From the non-technical or managerial aspect, the leadership of the top management, the empowerment of the executive management team and employee dedication are vital to ensure the full benefits of BIM adoption are realised. Eastman et al. (2011) mentioned that BIM technologies and evolving work processes must be supported by a team, a management, and a cooperative owner. Team members need appropriate training and information to be able to contribute and participate in the changing work environment. In contrast, a lack of understanding and knowledge (Zahrizan et al., 2014; Won et al., 2013; Salleh & Fung, 2014; Owen et al., 2010) remains a significant barrier to BIM adoption, forcing many companies to retrain experienced workforce in the new tools (Eastman et al., 2011). Meanwhile, a study by Haron (2013) showed that more than 50% of respondents agreed that every skill that the staff possesses during the BIM implementation process must be shared with other related colleagues. For BIM optimum performance, Azhar et al. (2012), Smith (2014), and Salleh and Fung (2014) urged organisations to find strategies to lessen the learning curve of BIM trainees. Moreover, Rezgui, Boddy, Wetherill, and Cooper (2011) and Ravinchandran & Lertwongsatien (2005) stressed the need for supporting processes through

organisational approaches and for improving the human interaction aspects for successful integration in construction through IT. The willingness of the participants to share knowledge is critical (Won et al., 2013) to ensure the exchange of knowledge, which very often is tacit and personalised (Lindner & Wald, 2011).

Overall, in this new era, with the complexity and volumes of information related to the construction industry, it is impossible for knowledge workers to keep up with the knowledge being created. Davenport and Glaser (2002) stressed that failure to be updated with current information might result in patient deaths for medical practitioners. In other industries this can lead to failure in products, projects, businesses and wastage of resources. Furthermore, there is a danger in assuming that the type of knowledge that made an organisation successful in the past will be the type of knowledge that will make it successful in the future (Arayici & Coates, 2013).

In the Malaysian construction industry context, Building Information Modelling (BIM) is one of the innovative technologies that need to be deployed in the planning, design, construction, and facility management. The important features of BIM are that it provides an object-oriented database that is made up of intelligent objects, a 3D representation of integrated information, and a relational database that is interconnected. The adoption of BIM as a technological innovation can be seen as one of the potential solutions to the current problems in the construction industry. It can make the industry more efficient, effective, flexible, and innovative while improving productivity towards contributing to the national economic growth. To ensure BIM is successfully implemented, the government and other sectors must collaborate in an integrated, coordinated, and cooperative effort. This effort can be conducted through human capital development, training and education, and research and development as continued efforts to improve and expand knowledge and technology.

Predicting that the adoption of BIM continues to progress, "just-in-time knowledge" seems related to this situation whereby the right knowledge in implementing BIM needs to be shared at the right time by the construction players who have to acquire the knowledge and experience in applying BIM within the organisation and expand beyond that later. As the conceptual knowledge in implementing BIM is crucial to its adoption, it is important for a construction organisation to manage it effectively to speed up the implementation. BIM is an innovation that will allow organisations to remain competitive. Achieving efficient innovation involves innovation management that requires the organisation to employ knowledge management practices for executing the innovation management processes as well as a business strategy that would bring about a higher level of innovation performance (Goh, 2005). Knowledge sharing is one of the primary knowledge management processes, and it is a people-to-people process (Ryu, Ho, & Han, 2003). The question then is how knowledge sharing practices could be used by the construction organisation to expedite the adoption of BIM in construction practice. If the organisation can manage innovative knowledge, it can then create a value-added and secure long-term sustainable business growth (Goh, 2005). Knowledge sharing practices (in this context of research) are the processes of transferring, disseminating, and exchanging knowledge, experience, skills, and valuable information of BIM implementation, which includes explicit and tacit knowledge from one individual to other members within an organisation with continuous interactions through various approaches. In other words, knowledge sharing becomes a practice or mechanism to assist the organisation in implementing BIM. Therefore, this research aims to develop a framework of intra-organisational knowledge sharing practices in implementing BIM within the Malaysian construction industry, which can guide the construction stakeholders to reap the potential benefits of BIM implementation that includes socio-technical and socio-cultural aspects from a real practice context and improve workflow in implementing BIM with sufficient knowledge sharing practices. Although it will be seen from a construction organisation's perspective, it is still valuable to enhance awareness, understanding and guide others through their amount and quality of experience, that map the framework to possibly improve performance in implementing BIM.

1.4 Research Questions

The following research questions will form the focus of this research.

- i) How are knowledge sharing practices in implementing BIM used by the construction organisation to improve the BIM adoption and implementation?
- ii) What are the factors influenced by knowledge sharing for the success of BIM implementation?

1.5 Research Aims and Objectives

This research aims to develop a framework of intra-organisational knowledge sharing practices in implementing BIM within the Malaysian construction industry. By having the framework, the construction organisations can understand and choose knowledge sharing practices, align with their organisations' need for implementing BIM for future use and continuous improvement. This research embarks on the following objectives to achieve the aim,

- i) To explore and review relevant literature related to the challenges in the local context (Malaysia) construction industry, the needs towards change; innovation, knowledge-based economy and the use of ICT. Also, to review and examine relevant literature related knowledge management concept in general and particularly knowledge sharing. To further explore and review BIM concepts, uses, benefits, and challenges.
- ii) To explore the current implementation of BIM within the business process by the construction organisations in Malaysia.
- iii) To ascertain the current status, practices, policies of knowledge sharing, and organisational culture in implementing BIM in Malaysia.
- iv) To identify the factors which are perceived to be barriers and enabling factors to improve knowledge sharing in implementing BIM in Malaysia.
- v) To develop a framework of organisational knowledge sharing for effectively implementing BIM, which encompasses the key factors of knowledge sharing by utilising the emerging findings in objective iii) and objective iv) and then to cross-reference the outcome with the literature review.
- vi) To validate and refine the framework of knowledge sharing in implementing BIM.

1.6 The Scope of the Research

The rationale to have a research scope is to focus on the research area and to set limits to what should be investigated. This also helps the researcher to get to the relevant case and actual participants within the industry who have engaged in BIM implementation and are familiar with the process of BIM particularly in the area of knowledge sharing. The boundaries of scope are considered based on some criteria as follows:

The context of Research: *Malaysian construction organisation*

This research will focus on construction organisations, which employed BIM in their business. According to Won, Lee, & Dossick (2013), when adopting BIM, companies do not implement it immediately in every project; instead, they use it in several selected projects until they gain sufficient knowledge and confidence. BIM is encouraged to start with a small investment (Hardin, 2009) and expected to achieve measurable financial return after several projects implementation, thus requires organisation's effort for long-term investment. Smith & Tardif (2009) mention that long-term investment often remains unseen in education and training that will allow an entire organisation to change its business culture, and in the resulting reform of core business processes to achieve higher productivity. The construction organisation can be a client, a designer, an integrated design consultant or contractor.

Respondent: *Top management, Middle management*

This research requires a respondent who has capacity and capability of understanding BIM application. The potential respondent was referred to Construction Industry Development Board (CIDB) Malaysia as a gatekeeper who currently takes part as a training centre for BIM seminars, workshop, etc. Top or middle management who are involve in implementing BIM to facilitate exploration.

Technology Application: *Consist of Parametric BIM objects*

Within the context of technology used in Building Information Modelling, this research focuses on the application of BIM tools in which the technologies allow users to produce building models that consist of parametric objects. Either it is engaged as BIM 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 visualisation only, which carries no attribute to the element. Parametric BIM objects is referred to (Sacks, Eastman, Lee, & Teicholz, 2019) as follows: 1) consist of geometric definitions and associated data and rules, 2) geometry is integrated non-redundantly, and allows for no inconsistencies, 3) parametric rules for objects automatically modify associated geometries when a new object is inserted into a building model or when changes are made to associated objects, 4) objects can be defined at different levels of aggregation, so we can define a wall as well as its related components, 5) objects can be defined and managed at any number of relevant levels of a hierarchy, 6) objects' rules can identify when a particular change violates object feasibility regarding size, manufacturability, and so forth, 7) objects have the ability to link to or receive, broadcast, or export sets of attributes.

Area of Exploration: *Knowledge sharing practices, People, Process, Technology*

This research explores and investigates knowledge sharing practices, which encapsulate the key factors of knowledge sharing in implementing BIM. Then, issues regarding people, process, and technology factors were considered to develop the framework as many pieces of literature mentioned those factors are important in implementing BIM.

1.7 Contribution to Knowledge

The contribution to the knowledge of this research can be divided into two categories that are theoretical and practical. In the academic context, the primary outcome of this study which is the organisational knowledge sharing's framework will contribute to the current body of knowledge. As the approach taken is qualitative in nature, the framework is expected to guide the construction stakeholders to ease the flow of learning with appropriate knowledge sharing practice and potentially tackle some of the organisation's problems such as lack of knowledge, lack of skills, and resistance to change in implementing BIM within their community of practice for continuous improvement and competitive advantage for better adoption in BIM. Also, the framework will guide the organisations towards a more practical target for the systematic BIM implementation and speed up the successful implementation process of BIM in Malaysia.

1.7.1 Contribution to the Body of Knowledge

This study determines that Malaysian construction organisations do execute formal and informal knowledge sharing approaches (technology element) and practices (people, process, and technology elements) inside the organisation, but in an unstructured way. Unfortunately, it seems that Malaysian construction organisations are unable to utilise the benefit of knowledge sharing in their organisations. However, it is hoped that Malaysian construction organisations, which have interest in adopting or implementing BIM, can apply the key factors that impact upon the successful practice of knowledge sharing as a guideline in supporting the successful BIM adoption and implementation with the help of this study. It is foreseen that the factors proposed in this study could help businesses, especially construction organisations, to better organise their knowledge management initiatives, as well as to establish Malaysian country in producing a knowledgeable society and at the same time creating extraordinary wealth. Hence, the findings of the present study have deepened the understanding of knowledge in the field of knowledge management and knowledge sharing, especially among construction organisations, which implement

BIM in Malaysia. Besides, the empirical studies of knowledge sharing in construction have concentrated mainly on developed countries, while a few reviews of knowledge sharing in construction focused on the developing countries. This study, in addition to partially filling the research gap, provides a practical approach to how construction organisations could understand the knowledge-sharing initiatives in their organisations.

1.7.2 Contribution to the Construction Organisation

Meanwhile, the research has also contributed to the industry, simplified as follows:

- a) The proposed knowledge-sharing practices in implementing BIM together with the key factors that are most likely to affect the successful implementation of knowledge sharing will enable managerial levels to adopt a proactive approach in accelerating BIM adoption and implementation in an organisation. The framework may serve as a guide for organisations intending to improve their knowledge sharing practices in implementing BIM to improve performance.
- b) The result of the study will have implications for policymakers in general and construction organisations in particular, to inform decisions on the need for and effective adoption of knowledge sharing practices focusing on BIM implementation.
- c) Policymakers, training providers and those who are associated with the formulation of knowledge sharing practices for construction organisations, may wish to incorporate some of the findings of the results in their national or organisation provisions.
- d) Construction organisations which are interested in adopting or implementing BIM could be supported by receiving relevant education and training, and by the development of knowledge sharing practices that are suited to their specific knowledge sharing needs.

1.8 Structure of Thesis

The thesis write-up is divided into seven chapters. A brief breakdown of the chapters and what the researcher seeks to address in each chapter are as follows:

Chapter 1 Introduction

This chapter provides the background of the research, the research problems, aims and objectives as well as the relevant research questions which will be the foundation for all discussions in the following chapters. Accordingly, the achievements of this research are also briefly mentioned besides the scope of this research. Finally, the structure of the thesis is presented at the end of the chapter.

Chapter 2 Literature Review

This chapter describes the literature review that was conducted on the challenges facing the construction industry related to the difficulties within the global and local (Malaysia) construction industry, the Malaysian construction industry needs towards changes, innovation and the use of ICT, knowledge management concept in general and particularly knowledge sharing, BIM concept, uses, development, evolution and implementation requirements to provide a better understanding of the research context.

Chapter 3 Research Methodology

This chapter 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 strategy for the data collection and member's checking for framework validation. Also, the chapter explains the technique used in the analysis and issues related to data collection.

Chapter 4 Findings

This chapter concentrates on the qualitative data analysis; precisely the result of the case study findings with the BIM practitioner's organisations. The data was analysed by using a content analysis through NVivo11 software.

Chapter 5 Discussion and Framework Development

This chapter includes the discussion of organisation findings in a cross-examination between the organisations and is supported by a theoretical review for validation. This leads to the development and formulation of the preliminary framework.

Chapter 6 Framework Validation

Accordingly, this chapter reports the results of framework validation via the peers' interviews. This is to validate the draft framework for cross triangulation of methodologies. The final framework is developed and discussed in this chapter.

Chapter 7 Conclusion and Recommendations

This chapter presents the main conclusion and recommendations of this research and the research journey. There is a discussion as to how the objectives and the aim have been achieved, and the implications of this study. Also, suggestions for further research are given. References and appendices are shown at the end of the thesis.

1.9 Chapter Summary

This chapter has provided the basis for the development of the thesis. Furthermore, this chapter highlighted the importance of knowledge sharing, the importance of the Malaysian construction industry and the need for the adoption of knowledge sharing practices in implementing BIM as an initiative for the future development of Malaysian construction organisations. From this discussion, the need for the research, the research questions and the aim and objectives of the research (sections 1.3, 1.4 and 1.5) emerged, forming the development of a novel contribution to knowledge, that is a framework of intra-organisational knowledge sharing practices in implementing BIM within the Malaysian construction industry. It also highlighted the scope of the research, the research contributions, and finally the structure of the thesis. The rationale for the research is to identify the key factors of knowledge sharing practices in construction that support BIM processes to accelerate and improve BIM implementation in the Malaysian construction industry. The next chapter will review and examine the development of the Malaysian construction industry, knowledge sharing practices and Building Information Modelling, which provides the theoretical background for this research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The previous chapter introduced the background of the thesis. The rationale for the research was justified and the research questions, aim and objectives were established. Accordingly, it presented the scope of the research, the contribution of the study, and the structure of the thesis. This chapter will present a review of the literature on the Malaysian construction industry, the challenges it faces and initiatives for the challenges. This is followed by a review of the literature on knowledge management and knowledge sharing with its association in improving organisational performance. Subsequently, the chapter continues with a review of the literature concerning the Building Information Modelling concept.

2.2 The Malaysian Construction Industry

Malaysia is a dynamic developing country in Southeast Asia, which comprises approximately 330,000 square km and consisting of two regions, the Malaysian Peninsula and part of the island of Borneo. Malaysia is a multi-ethnic, multicultural and multilingual society with 32.30 million members (Department of Statistics Malaysia, 2017).

The construction industry is one of the biggest industries worldwide. It makes significant contributions towards social and economic development at national and international levels. It provides communities with places for housing, education, culture, health care, business, leisure and entertainment. In addition, it constructs the infrastructure projects that are essential for these facilities to perform their intended functions. Furthermore, it increases the gross domestic product (GDP), motivates the

development of other industries that support the construction process such as building materials and construction equipment as well as offers employment opportunities (UKCG, 2009). Malaysia started to develop its construction industry since independence. It has broadened its production base from only raw materials to a wider range of assets and manufactured products. The focus of its economy has moved from a widely agriculture and mining based country since the 1960s towards an industrialised country after the launch of Vision 2020 in the early 1990s. This was stimulated by high technology, knowledge-based and value-added industries. Malaysia's economic performance ranking improved from 12th in 2007 to 7th place out of 59 in 2012. It has become one of the 20 largest exporting nations worldwide (The German Chamber Network, 2012).

Construction as defined in the Yearbook of Statistics 2003 (page 14) by the Department of Statistics, Malaysia includes “new construction, alteration, repairs, and demolition. Installation of any machinery or equipment which is built-in at the time of the original construction is included, as well as installation of machinery or equipment after the original construction but which requires structural alteration in order to install”. In other words, construction is the steps in which the plans, specifications, materials, and equipment are transformed by the construction players. Generally, the industry is made up of several players. The construction players include clients (public and private), developers, consultants (management, architectural, engineering, and cost), manufacturers, contractors, workers, material suppliers, and equipment hirers. The Malaysian construction industry is generally separated into two areas. One area is general construction, which comprises residential construction, non-residential construction and civil engineering construction. The second area is special trade works, which comprises activities of metal works, electrical works, plumbing, sewerage and sanitary works, refrigeration and air conditioning works, painting works, carpentry, tiling and flooring works, and glass works (Ibrahim, Roy, Ahmed, & Imtiaz, 2010).

2.2.1 Role of the Construction Industry

The construction industry is a highly important and productive sector that constantly contributes to the Malaysian economy. For instance, output for the construction sector hovered around RM 34,880 million, RM 38,646 million and RM 43,190 million in 2012, 2013 and 2014 respectively (Department of Statistics Malaysia & Central Bank of Malaysia, 2015). This sector is crucial for the development of the nation although its contribution is relatively small in comparison with other economic sectors such as services, manufacturing, and agriculture. For example, the average contribution of services, manufacturing and agricultural sectors to the Gross Domestic Product (GDP) during the last two decades from 1990 to 2010 was 48.3, 28.2, and 9.3 percent respectively, while the average contribution of the construction sector in the same period was only 4.1 percent. Its contribution to the GDP is 12 times smaller than the services sector, 7 times smaller than the manufacturing sector and 2.2 times smaller than the agricultural sector of Malaysia (Department of Statistics Malaysia & Central Bank of Malaysia, 2016). Besides, the construction industry generates one of the highest multiplier effects through its extensive backward and forward linkages with other sectors of the economy regardless of the different stages of industrialisation in different countries (Abdullah, 2004; Khan, Liew, & Ghazali, 2014). The Malaysian construction industry has a two-time multiplier effect, with more than 120 other industries relying on construction for their growth and sustainability. It creates a multiplier effect for other industries including manufacturing, financial services, and professional services. For instance, construction consumes 15 per cent of the total manufacturing output (CIDB, 2007). Importantly, the result from the quantitative analysis of the Malaysian construction sector data series from 1991 to 2010 by Khan, Liew & Ghazali (2014) exhibit a strong correlation between the construction sector and Malaysia's economic growth. The findings reveal that construction activities in Malaysia are heavily dependent on the volume and size of the nation's economy while at the same time the aggregate economy and its growth also depends on heavy investment in the construction sector with a correlation coefficient of 0.82 in the first decade (1991-2000) and 0.78 in the second decade (2001-2010) towards achieving Vision 2020. The results indicate that construction activities are highly associated and have a direct relationship with Malaysia's GDP. Thus, the construction industry is

crucial because of the role that it plays as a major indicator of domestic performance in the economy.

As Malaysia is in the process of industrialisation, the construction industry plays an important role in generating wealth within the sector as well as in other growing sectors. The industry also helps in improving the quality of life for Malaysians through the translation of the government’s socio-economic policies into necessary amenities and infrastructure such as residential areas, roads, railways, electricity, communication services and many others. The Malaysian Government has realised the importance of developing the construction industry while at the same time benefitting other industries. This has resulted in the initiation of several mega projects such as the Kuala Lumpur International Airport, the federal administrative centre of Putrajaya, the Multimedia Super Corridor and the Sepang Formula One Circuit. These projects were built using highly mechanised techniques between 1998 to 2001 and cost more than 15 billion US Dollars as shown in Table 2.1. The development continues to grow and a major contribution to Malaysian construction projects came from the implementation of several mega projects as shown in Table 2.1.

Table 2.1: Major construction projects in Malaysia

Major project	Year	Costing (RM billion)	Source
Kuala Lumpur International Airport, Sepang	1998	8.70	Ibrahim et al. (2010)
Federal Government Administration Centre, Putrajaya	1999	30.80	Ibrahim et al. (2010)
Multimedia Super Corridor, Cyberjaya	1999	20.10	Ibrahim et al. (2010)
Formula one circuit	2001	0.43	Ibrahim et al. (2010)
Double Tracking Project, Ipoh – Padang Besar	2007	12.49	CIDB Malaysia (2008)
South Klang Valley Expressway	2007	1.10	CIDB Malaysia (2008)
7 Tolled Highways	2011- 2015	19.0	Abu Mansor (2010)
2 Coal Electricity Generation Plants	2011- 2015	7.0	Abu Mansor (2010)
Petronas LNG Melaka Plant	2011- 2015	10.0	Abu Mansor (2010)
Liquefied natural gas (LNG) plant, Sarawak	2013	5.70	CIDB Malaysia (2014)
Onshore Gas Terminal, Terengganu	2013	2.30	CIDB Malaysia (2014)
Gas Fired Independent Power Plant, Pulau Pinang	2013	2.20	CIDB Malaysia (2014)
Duta Ulu Kelang Expressway (DUKE) Phase 2, Kuala Lumpur	2013	1.40	CIDB Malaysia (2014)

2.2.2 Type of Construction Organisations

The industry provides significant employment opportunities with a registered workforce of 1.2 million, representing 9.5 per cent of Malaysia’s total workforce. Employees in the industry include competent personnel such as engineers, architects, planners, and surveyors, in addition to skilled and non-skilled construction workers (CIDB Malaysia, 2015). As the application of BIM in Malaysia is still progressing at a relatively low level, there aren’t many construction organisations that have implemented BIM. Thus, construction organisations in this study refer to any construction organisations in Malaysia whether they are client organisations, consultants or contractors, small, medium or large organisations, with at least two years’ experience in BIM and covered under the scope of study as explained in 1.5. A general definition of Small Medium Enterprises (SMEs) before the establishment of the Malaysia National SME Development Council (NSDC) in June, 2004, is according to annual sales turnover, or the number of full-time employees (Central Bank of Malaysia, 2005). The working definition for SMEs in the ICT, mining and quarrying, and construction sectors is based under the service sector as shown in Tables 2.2 and 2.3.

Table 2.2: Summary of the SME definitions in Malaysia based on the number of full-time employees (Central Bank of Malaysia, 2005)

Sector / Size	Primary agriculture	Manufacturing (including manufacturing agro-based & manufacturing related services)	Service sector (including ICT, mining and quarrying construction sector), and
Micro	Less than 5 employees	Less than 5 employees	Less than 5 employees
Small	Between 5 & 19 employees	Between 5 & 50 employees	Between 5 & 19 employees
Medium	Between 20 & 50 employees	Between 51 & 150 employees	Between 20 & 50 employees

Table 2.3: Summary of the SME definitions in Malaysia based on annual sales turnover (National SME Development Council, 2005)

Sector / Size	Primary agriculture	Manufacturing (including manufacturing agro-based & manufacturing related services)	Service sector (including ICT, mining and quarrying, and construction sector)
Micro	Less than 200,000	Less than 250,000	Less than 200,000
Small	Between 200,000 & less than 1 million	Between 250,000 & less than 10 million	Between 200,000 & less than 1 million
Medium	Between 1 million & 5 million	Between 10 million & 25 million	Between 1 million & 5 million

The Construction Industry Development Board of Malaysia (CIDB) recommends the definition for SMEs in the construction sector to be based on paid-up capital or tendering capacity as shown in Table 2.4 to reflect the true size of the construction companies in Malaysia. Construction organisations in the Malaysian construction industry have clients from both public and private sectors. The contractors are either Bumiputra (A Malaysian of indigenous Malay origin) or non-Bumiputra (A Malaysian of non-Malay origin) and the consultants from different professional backgrounds like architects, quantity surveyors and engineers. It is compulsory for all contractors whether they are Bumiputra or non-Bumiputra, local or foreign to register with the Construction Industry Development Board before they could take up any projects or bid in any tender depending on their tendering capacity and paid-up capital as shown in Table 2.5. The contractors are classified under three categories of large, medium and small enterprise.

According to Malaysia Country Report 2017 (CIDB Malaysia, 2017), a total of 71,799 contractors were registered in 2016, an increase of 5.5% from 2015 as shown in Table 2.5. G1, G2 and G3 grades form the largest portion of registrations with a total of 55,850 contractors. Grades G4 and G5 contractors accounted for a total of 8,154 contractors, while G6 and G7 contractors numbered 7,795 of the total registered. The number of registered foreign contractors did not show any significant change, accounting for only 447 contractors.

Consultancy organisations, however, must be registered under their own professional bodies. The engineers should register with the Board of Engineers Malaysia, quantity surveyors with the Board of Quantity Surveyors Malaysia, and architects with the Board of Architects Malaysia.

Table 2.4: Registration Grade for contractors by CIDB (CIDB Malaysia, 2016)

Contractor Grades of Registration	Limit of tender/ Value of work (MYR)	Paid-up Capital (MYR)	Size of Company
G7	No limit	RM 750,000	Large
G6	Not exceeding 10 million (USD 2.45 million)	RM 500,000	
G5	Not exceeding 5 million (USD 1.22 million)	RM 250,000	Medium
G4	Not exceeding 3 million (USD 730,000 million)	RM 150,000	
G3	Not exceeding 1 million (USD 240,000 million)	RM 50,000	Small
G2	Not exceeding 500,000 (USD 122,680 million)	RM 25,000	Small
G1	Not exceeding 200,000 (USD 49,050 million)	RM 5,000/ 10,000	Small

Table 2.5: Number of Contractors by Grade (CIDB Malaysia, 2017)

Contractor Grades of Registration	Limit of tender/ Value of work (MYR)	2014	2015	2016	Size of Company
G7	No limit	5,332	5,618	6,206	Large
G6	Not exceeding 10 million	1,594	1,528	1,589	
G5	Not exceeding 5 million	4,130	4,287	4,746	Medium
G4	Not exceeding 3 million	3,038	3,093	3,408	
G3	Not exceeding 1 million	8,825	8,875	9,375	Small
G2	Not exceeding 500,000	9,268	10,441	12,407	Small
G1	Not exceeding 200,000	34,485	33,991	34,068	Small
	TOTAL	66,672	67,833	71,799	

Meanwhile, overall registered professional consultants are 3,574 firms with respective number of Consulting architect, quantity surveying and engineering firms were 1,424, 313 and 1,837, respectively. This resulted in a total of 3,574 registered professional consultancy firms.

Table 2.6: Registered consultant organisations (CIDB Malaysia, 2010)

Type of professional consultant organisation	August, 2010
Architect	1,424
Quantity Surveyor	313
Engineer	1,837
Total	3,574

2.2.3 Challenges Facing the Malaysian Construction Industry

The construction industry has been challenged by many conflicts of sustainability that cause waste and inefficiencies that require improvements. For instance, the building sector contributes up to 30% of global annual greenhouse gas (GHG) emissions that can cause climate change and consumes up to 40% of energy production. If the massive growth in construction continues unabated, the effect of greenhouse gas (GHG) emissions from buildings will double in the next 20 years (UNEP, 2009). An Economist article from the year 2000 identified a 30% wastage in the U.S. construction industry while a National Institute Standards and Technology (NIST) study from 2004 determined a lack of interoperability was costing the industry \$15.8 billion annually. A U.S. Bureau of Labor Statistics study shows construction alone, out of all non-farm industry, as decreasing in productivity since 1964, while all other industry has increased productivity by over 200 percent (The American Institute of Architects, 2007). Pressures from the business world and global economy have pushed the industry to take initiatives in embracing sustainable construction. Pitt, Tucker, Riley, and Longden (2009) posited the need to bridge the gap between client demand and awareness in order to push their financial budgets towards incorporating environmental consideration to achieve sustainable construction. This issue is not only important for the building sector but also relevant to facilities management. Rice, Pitt, and Tucker (2011) stressed the requirements for a sustainability policy mainly for big facilities management organisations in terms of achieving environmental targets whereas a different approach may be needed in targeting small and medium-sized organisations.

In the Malaysian context, the issue of inefficiency in the construction industry is well addressed in the Construction Industry Master Plan (CIDB, 2007). Conflicts in efficiency are contributed by many linking factors that worsen project outcomes. The industry has faced conflict due to the inefficiencies of project outcomes including time and cost overrun, low productivity, and poor quality that lead to customer's dissatisfaction (Chan et al. 2003). Project delays beyond contract time are mainly caused by a contractor's financial aspects (Shehu, Endut, & Akintoye, 2014), contractor's improper planning, contractor's poor site management, inadequate

contractor experience, inadequate client finances and payments for completed work, problems with sub-contractors, material shortage, labour supply, equipment availability and failure, lack of communication between parties, and mistakes during the construction stage (Sambasivan & Soon, 2007). Meanwhile, the availability of cheap foreign worker has encouraged the industry to use labour-intensive construction methods rather than productive technology-intensive methods, thus leading to low productivity (CIDB, 2007). Conflict related to low quality end products are always caused by buildability problems. The study by Mydin, Zin, Zaimi, Majid, and Zahidi (2011) identified eight root causes of buildability problems that contribute to poor quality end product. They are misunderstanding a client's requirements, discrepancies in design, design changes, inadequate design team experience, time constraint in design, lack of design review, no early involvement of construction personnel, unrealistic design specifications, lack of construction knowledge and poor design information supplied to designer. In addition, Jaffar, Tharim, and Shuib (2011) found behaviour and communication conflict have a negative impact on buildability.

The fragmented nature of the construction industry is a major source of the aforementioned problems. Many researchers have acknowledged the construction industry as a fragmented industry (Griffith & Sidwell, 1998; Holroyd, 2003; Elmualim & Gilder, 2013; Nawi, Lee, Azman, & Mohamad Kamar, 2014). Fragmentation is caused by project players conducting the design and construction process in a linear sequence throughout a project's life cycle in the traditional procurement method. Evbuomwan and Anumba (1998) pointed out that this method caused the 'over the wall' syndrome that leads to the separation of the various parties and information in the construction project, increased cost due to design changes and unnecessary liability claims, poor actual project life-cycle analysis, and poor communication of design rationale and intent. Marshall-Ponting and Aouad (2005) also identified that fragmentation would allow information wastage, lots of repetition and long lead time, together with redundant and replicated work at different interfaces between departments and slow product development and process improvement. Furthermore, Ezzat Othman (2011) conceded that a fragmented and adversarial relationship created between project participants eventually obstructed contractors

from providing designers with construction comments and feedback to improve the building design. The problems that have arisen show that there is a difficulty in terms of communication and transmitting the information between parties in a construction project in Malaysia. There is an urgent need to establish an innovative approach to ensure all the information can be distributed equally among different parties in the construction project through its life cycle. Consequently, each party needs a platform that can enhance communication and at the same time to share and disseminate the information and knowledge effectively and efficiently. Increasing the level of knowledge within the construction community will drive and strengthen change in the local market for long term sustainability and will ensure sustainable capabilities across the construction industry value chain. This will then enhance the ability to compete in the global market, which in turn will increase foreign exchange earnings (CIDB, 2007).

Accordingly, the AEC industry is encouraged to adopt and apply technologies in order to improve the quality and productivity of the industry (Ibrahim et al., 2010; Kassim, 2012). The call for improved performance had been made earlier to the construction industry through the Latham Report (1994) and the Egan Report (1998) concerning its efficiency, quality, and sustainability (Holroyd, 2003), thus urging the industry to innovate and adopt new technology and modern management methods. The indexes of labour productivity for construction and non-farm industries from 1964 to 2009 demonstrated that labour productivity within the construction industry is relatively unchanged and is now estimated to be about 10 percent less than what it was in 1964 (Eastman et al., 2011). Although many materials and technological improvements have been made, the decrease in construction productivity is real. Lessons learnt from efficiencies in the manufacturing industry through automation, the use of information systems, better supply chain management and enhanced collaboration tools have influenced the construction field to benefit from automation. The complexity of systems in the construction industry often prevents the project stakeholders from sharing and exchanging accurate information, and the NIST study has shown the incurred cost from the inadequate interoperability of data (Eastman et al., 2011). This has made the industry realise the full potential of BIM technology.

Meanwhile, the transition from conventional practices to new practices in the building industry requires firms to acquire new skills and knowledge to meet market demand for new technologies (McCoy, O'Brien, Novak, & Cavell, 2012). Hence, it is vital for the industry to take up the challenge and venture into innovation to remain competitive and survive. There are several definitions of innovation as in Table 2.7. Innovation is described in many ways in terms of ideas or concepts, product, process or system and management for a positive outcome. Atkin et al. (2003) argued that innovation does not necessarily have to be a dramatic change but is the process where a good idea or creation of new knowledge concerning a product or process begins to affect its context.

Table 2.7: Definition of innovation

Author	Definition
Badu, Holt, & Edwards (2015)	The invention and implementation of a management practice, process, structure, or technique that is new to the state of the art; is intended to further Organisational goals; and involves the introduction of novelty in an Organisation that brings with it positive Organisational change.
McCoy, Badineli, Koebel, & Thabet, (2010)	Product inventions are novel ideas or concepts that the institution has implemented to bring about real change (Inventions become innovations through the process of commercialization)
Rigby et al. (2012)	Innovative project delivery engages innovative processes, products, or systems to facilitate the successful collaboration of the relevant project stakeholders to fulfil the program requirements for a built facility (procurement).
Larsen & Ballal (2005)	An idea, practice or material artefact perceived to be new by the relevant units within the adoption process' social system.
Slaughter (2000)	An innovation is defined as a non-trivial improvement in a product, process, or system that is actually used and which is novel to the company developing or using it (a context of construction project).
OECD (1996) in Atkin et al. (2003)	<p>A technical innovation is a technological product innovation is the implementation or commercialisation of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer.</p> <p>A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these.</p>

Innovation can be influenced whether by the individual or actor, organisation and the industry field as in Figure 2.1. The potential performance improvement from innovation in the construction field is unlimited. It is a challenge in itself to bring about change. Atkin and Borgbrant (2010) suggested the three levels; strategic, tactical and operational levels for organisational changes. At the strategic level, improvements should consider the recent construction process situation through the actor's experience and perspectives on the needs of changes by investigating factors that promote or inhibit change. After the need for change has been understood, an organisation can progress by supporting changes through education, learning or research at the tactical level. An organisation can support its business through corporate education and let the individuals learn to improve while research can be carried out for developing new knowledge and support individual learning. Essentially, the results of the issue raised for research can be applied within the organisation in the industry.

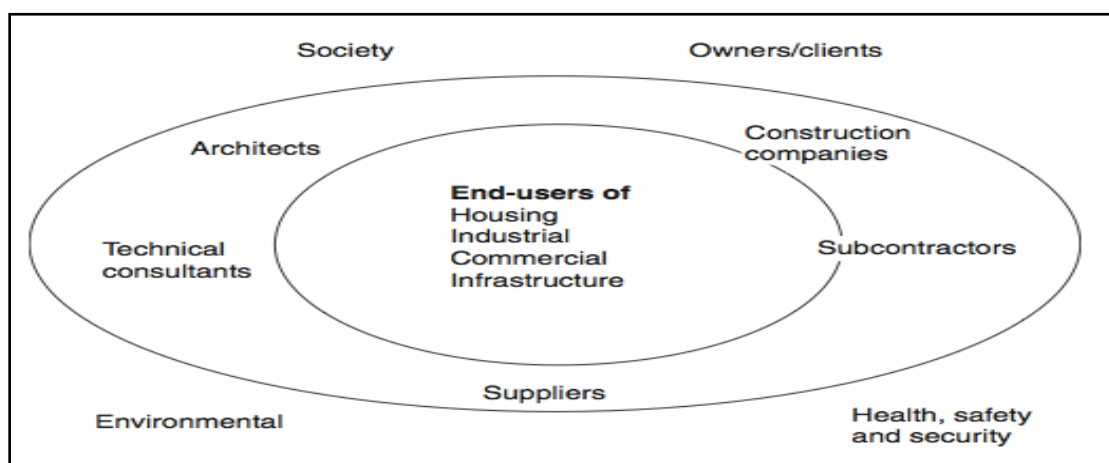


Figure 2.1: The construction field (Atkin & Borgbrant, 2010)

Meanwhile, several researchers have revealed important and significant relational factors on innovation. Atkin, Borgbrant, and Josephson (2003) mentioned the significant relationship between competence, knowledge, communication and learning which influenced innovation. New knowledge is acquired through information that is put into context by prior knowledge followed by transferring it via channels of communication; inter- and intra-organisation with openness and trust. The

creation of new knowledge will continuously take place in internal and external contexts that requires continuous learning where learning is the process when new knowledge is acquired to build competency, however competency is built on the knowledge of the people involved in the innovation. Sexton and Barrett (2004) also supported that organisational capability and an appropriate response to the interaction environment to absorb and use appropriate new technologies are important for construction organisations' innovation. It implies the flow of physical structure, knowledge, skills, organisation, values, and asset to benefit the construction stakeholders (Choi, 2009). The impact of innovation is not solely on the organisation itself, but closely to benefit business environment that the organisation owned. Hardie et al. (2014) found organisational innovations were closely linked to technological innovations, mainly depend on the business strategies for innovation successes, which include human resources, technology, marketing, knowledge and innovation. They highlighted the importance of management to guide and direct the organisation to achieve successful innovation (Gambatese & Hallowell, 2011; Hardie et al., 2014).

Referring to the definition by Atkin et al. (2003), BIM as one of the potential solutions for construction industry inefficiency can be linked to both technical and process innovation. It is a technological innovation that improves performance with changes related to the industry field. For instance, the massive size of the Chinese construction industry has resulted in many instances of improvements in the efficiency of construction processes stemming from the use of BIM and by extension BIM-enabled construction cost and project management (Royal Institution of Chartered Surveyors, 2015). In the US, built environment professionals typically collaborate with each other using BIM's construction cost and project management aspects to improve the efficiency of construction projects with respect to cost and time (Royal Institution of Chartered Surveyors, 2015). Considering BIM as a recent technological and process innovation in the construction industry and the benefits it offers, it is vital to study this kind of innovation since it has been widespread from the year 2000 to support BIM development towards change in organisations for performance improvement and long-term investment. BIM knowledge and implementation will foster learning and strengthen the organisation's capability;

bringing competitive advantages for the organisation's business. Hence, knowledge sharing practices in implementing BIM will improve the workflow and the organisation's internal business, thus creating potential value to stakeholders in the field.

2.3 Malaysian Government Initiatives

The construction sector is becoming more important due to higher demand for modern and efficient infrastructure in line with the aim of becoming a developed country. Further, there is a need to increase the adoption of technology and modern methods of construction, the quality of training to align the workforce supply and demand, the availability of high-quality information, and to address the low productivity and scale of Bumiputera companies. In addition, Malaysian companies are experiencing increasing competition from foreign players and constraints in going abroad, including financing and market intelligence to win in target overseas markets (CIDB Malaysia, 2015). Accelerating the development of the Malaysian construction industry and preparing it to meet the future demands of the economy will require an industry transformation. The Malaysian Government wants the country's construction industry to be a world class, innovative and knowledgeable solution provider in accordance with achieve Vision 2020 (CIDB, 2007). The construction sector is gearing itself for the transformation into a knowledge-based economy or K-Economy, which is an economy driven by knowledge and innovation. The government together with the CIDB has seriously planned and initiated many efforts to upgrade the level of knowledge and skills among the construction players to achieve the intended aim.

2.3.1 Towards a Knowledge-based Economy

The role of knowledge is crucial in the new economy as technology becomes more complex and economic growth is driven by knowledge-intensive industries. In Malaysia, the efforts to transform Malaysia into a knowledge-based economy (K-economy) from a predominantly mining and agricultural-based economy started in the early 1990s. Among the efforts is the launch of the National IT Agenda (NITA) to

foster the development of IT as a strategic enabler of dynamic economic growth. Also, the development of the Multimedia Super Corridor (MSC) was designed to be an engine of economic growth within an economy for the 21st century. Efforts have also been made to cultivate and secure the necessary human resources, increasing the capacity for the acquisition and application of science and technology, establishing research and development to drive the transition, ensuring the necessary infrastructure and financing, as well as ensuring that the development of the K-economy did not result in a knowledge divide. Having a K-economy will strengthen Malaysia's capability to innovate, adapt and create original technology, and design, develop and market new products, thereby providing the foundation for internally driven growth (Economic Planning Unit Malaysia, 2002).

The Construction Industry Master Plan (CIMP 2006-2015) was launched in December 2007 to guide the Malaysian construction industry's transformation into a more dynamic and robust sector. The plan was developed to rectify the weaknesses in the construction sector and to improve the industry's performance as well as its image, and includes seven strategic thrusts. The plan highlights knowledge, and encouragement of knowledge sharing for continuous improvement under the strategic thrusts 4, 5 and 6 of the CIMP, as described in Table 2.8.

Table 2.8: Seven strategic thrusts in Construction Industry Master Plan, 2006-2015 (CIDB, 2007)

Strategic Thrust (ST)	Recommendations
ST 1	Integrate the construction industry value chain to enhance productivity and efficiency
ST 2	Strengthen the construction industry's image
ST 3	Strive for the highest standard of quality, occupational safety and health, and environmental practices
ST 4	Develop human resource capabilities and capacities in the construction industry
ST 5	Innovate through research and development and adopt new construction methods.
ST 6	Leverage on information and communication technology in the construction industry
ST 7	Benefit from globalisation including the export of construction products and services

Three out of eight critical success factors identified in the CIMP were related to the establishment of K-economy and crucial to the successful implementation of the CIMP. They are creation of competent workers through skill-upgrading and knowledge enhancement for human resource development, sharing of the best

practices to upgrade the level of knowledge of the construction community for knowledge enhancement, and continuous research and development that is essential to introduce new and creative methods, materials, tooling and equipment for innovation adoption (Sundaraj, 2007).

Despite the Malaysian government's initiatives, encouragements and the fast growth of construction organisations, the importance of knowledge and enhancement in knowledge management practices in construction cannot be denied as they could help the industry to improve and establish the industry towards the K-economy. Due to the industrialisation push factor, some innovation or new techniques are being adopted and implemented by the construction sector, for instance green building management, knowledge management, Industrialised Building System, Building Information Modelling and other modern methods. Nevertheless, the take up of modern methods such as BIM is relatively low. Thus, this research investigates how the knowledge sharing practices used by the construction organisations could help to accelerate and improve the BIM implementation.

2.3.2 Research into Knowledge Sharing in Malaysia

Knowledge management has received major attention from diverse sectors in recent years (refer to Table 2.9), including construction, manufacturing, health, and the public sector ranging from small, medium to large firms, as evident in a number of recent publications and conferences. Several knowledge management research and project initiatives in Malaysia have been undertaken that focus on the various aspects of knowledge management. Some researchers have focused on the relationship between KM and growth performance, and critical success factors of KM strategies (Eze, Goh, Goh, & Tan, 2013; Mohamamed Fathi, Eze, & Goh, 2010; Mohd Zin, 2013; Othman, Ismail, Yahya, & Ahmad, 2018), organisational culture and KS (Jain, Sandhu, & Goh, 2015) and developing a framework or model for improved organisation performance (Abdul Karim, Mohammad, Abdullah, & Razi, 2011; Ismail & Yusof, 2008; Mohd Zin, 2013). Although knowledge management has been accepted in many sectors in Malaysia, awareness in the Malaysian construction

industry remains low and the relatively few studies of knowledge management in Malaysia tend to be conceptual (Mohd Zin, 2013). The studies of knowledge management in Malaysian organisations are limited, especially in construction organisations, which covers a broader background of the organisations and different players in the industries (for instance builders, consultants, and developers). The knowledge management strategies and knowledge sharing practices in Malaysian construction organisations seem to have implications for Malaysia as a developing country that is moving toward Vision 2020 as a knowledge-based society and developed country. It is a diverse and multi-ethnic community that is encouraged by its government to pursue innovation for efficiency. However, there is a limited number of research in relation to construction organisations in Malaysia, particularly those that combined the issue of knowledge sharing practices in construction organisations with Building Information Modelling (BIM) application. Thus, this study tried to explore these two issues of knowledge sharing practices in implementing BIM to improve the performance of construction organisations.

Table 2.9: Knowledge Management and Knowledge Sharing Research in Malaysia

Issue	Type of organisation/ Sector	Findings	Author
Understanding KM practice and exploring Critical success factors of KM in consultant firms for Malaysian construction industry	Consultant firms in Malaysian Construction Industry	Based on descriptive analysis, reliability and relative important index (RII) analysis, it is found that continuous organisation support, leadership demonstration by senior staff/management, knowledge and sharing culture, execution of plan, and continuous learning make the top five factors very vital to the effective execution of KM.	(Othman et al. (2018)
Knowledge management and growth performance in construction industry	Large construction companies (contractors) in Malaysia	Based on partial least squares structural equation modelling analysis from 110 questionnaires, the findings show a positive relationship between KM and growth performance in the Malaysian construction industry.	Yusof, Abu Bakar, Abd. Razak, & Tabassi (2015)
Knowledge sharing approaches in Malaysian construction organisations for improved performance	Large, small, medium-size construction organisations (contractors)	The research developed a model via the data collected from the web-based survey which provides the factors that impact upon the successful implementation of knowledge-sharing approaches. Several key factors that need to be addressed within knowledge-sharing initiatives are related to a knowledge sharing-based IT system, knowledge-sharing leaders and teams, a supportive environment for knowledge sharing, strategies for knowledge sharing, motivational aids for knowledge sharing, training for knowledge-sharing approaches, internal marketing for knowledge-sharing communication, knowledge-sharing performance measurement, a flexible organisational structure, and human resources.	Mohd Zin (2013)
Organisational climate, trust and knowledge sharing: insights from Malaysia	Multinational firms in Malaysia	Based on survey data collected from 231 participants from 25 multinational firms, it is found that organisational climate dimension, partnership is positively related to knowledge donating (KD) and knowledge collecting (KC). However, fairness dimension was not positively related to KD and KC.	Jain et al. (2015)
Perspectives of SMEs on knowledge sharing	Small, medium-size enterprises (SMEs) manufacturing firms	Based on factor analysis and reliability analysis with 250 responses from systematic sampling, the results indicate that knowledge technology, motivation, effective reward systems, trust and empowering leadership should be addressed to encourage KS within SMEs.	Eze et al. (2013)
Exploring knowledge sharing among medical and non-medical staff: A Case study of an Ophthalmology Hospital in Malaysia	Ophthalmology Hospital, Health Sector in Malaysia	The result collected via a survey data from a purposive sample of 54 staff showed that there was a good awareness about the importance of KS. However, organisational barriers identified include no system for identifying colleagues-sharers knowledge sharing, lack of reward and recognition. For individual barriers include less interaction between receiver-sharer, and lack of trust and communication.	Okoroji, Velu, & Sekaran (2013)
Proposed framework of organisational readiness for KM in the Malaysian Public Sector	Public Sector in Malaysia	Proposed a conceptual framework which includes KM process, KM enablers, and individual acceptance.	Abdul Karim et al. (2011)
Key determinants of KS in an electronics manufacturing firm in Malaysia	Manufacturing firm in Malaysia	Based on survey with 141 responses from electronic firms (private companies), it is indicating that collectivism, social network, social trust, shared goal, incentive systems, kiasuism and self-efficacy emerged significantly with a firm's ability to share knowledge except individualism.	Mohamamed Fathi et al. (2010)
Reviewing existing model of KS to develop KS Model for Public Organisations	Public Sector in Malaysia	Identified three dimensions of KS: technological, organisational and individual.	M. B. Ismail & Yusof (2008)

2.3.3 Towards ICT Application

In the construction industry, there are two categories of ICT. There are automation and information and communication technology (ICT). Construction automation is based on the use of IT products such as computers in most job site applications. These include surveying applications, equipment control, and the installation and fabrication of construction products. Information and Communication Technology (ICT) is the use of computer application systems for capturing, organising, storing, and analysing as defined by the Information Technology Association of America (ITTA). ICT is the study of the design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware. It deals with the use of electronic computers and computer software to convert, store, protect, process, transmit, and securely retrieve information. Information, Communication and Technology (ICT) would mean information infrastructure, which generally covers the hard infrastructure, regulatory and monitoring system. Increasingly though, ICT also covers broadcasting and multimedia in the era of convergence.

ICT investment has had a positive and significant impact on Malaysia's economic growth. The positive economic benefits stemming from ICT that Malaysia has experienced may be a useful lesson for other economies (Kuppusamy & Shanmugam, 2007). Many initiatives addressing strategic information technology (IT) in construction have been explicitly issued by the government to challenge the industry to take advantage of IT utilisation and to strengthen the industry development. This initiative is in line with Ofori (2000) that suggested the construction industry to benefit from the strategic application of information technology. IT has been recognised as a driver for many construction organisations in the Malaysian Construction Industry (MCI), and moving towards the new information technology (IT) era (Mastura Jaafar, Ramayah, Abdul-Aziz, & Saad, 2007).

The role of ICT in the construction industry in Malaysia has become more crucial. The Government of Malaysia has brought the awareness of Information and

Communication Technology to the public during the 6th Malaysia Plan (1991-1995). The government started to develop and implement various software for the public to utilise. With just a click of the mouse from the comfort of their living rooms, the public can interact with the government or pay utility bills at anytime, anywhere. However, ICT has only been slowly adopted by key players in construction industry in operating day-to-day affairs. Somehow, the cost constraint of implementing ICT in daily operations has been a challenge for small companies. The Seventh Malaysia Plan (1996-2000), which guides and charts the policy direction of ICT saw the Malaysian Government providing various incentives to facilitate a greater adoption of ICT to improve capacity in the business sector, industry and life in general. The related incentives covered areas such as computerisation and automation, the creation of venture capital funds, enhancement of education and training programmes and a conducive legal environment to facilitate the development of ICT. Furthermore, an IT strategy plan was purposely developed for the construction industry in the Construction Industry Master Plan's (CIMP) Strategic Thrust 6 (CIDB, 2007) and the Construction Industry Transformation Plan 2016-2020 (CIDB Malaysia, 2015) to achieve Vision 2020. In 2009, early effort in BIM implementation began by providing awareness programs and workshops with the industry. In 2012, CIDB was also working closely with Unit Kerjasama Awam Swasta (UKAS) to deploy BIM in the Public Private Partnership (PPP) projects through a concept of 'Affordable BIM' where UKAS contractors and sub-contractors can use BIM through a periodical licensing arrangement. At the same time, the CIDB established a Committee of Building Information Modelling (BIM) in the Construction Industry to coordinate the progress of BIM in this country. In the near term, Malaysia is taking vigorous action on the development of Malaysia's Building Information Modelling (BIM) Roadmap (2014-2020) to encourage the construction industry stakeholders towards the wide adoption of BIM by 2020 (CIDB, 2012). The main roadmap focus was given to the motivations of the stakeholders to implement BIM aligned with the national agenda. Researchers on BIM have also been encouraged to focus on the development of new practices and new tools to develop the industry stakeholders' capability in understanding and taking full benefit of this new technology. Thus, the impact and research on such technology can contribute to new knowledge in the related country, industry as well as organisation for continuous improvement.

Building Information Modelling (BIM) can be traced back to the parametric modelling research conducted in the USA and Europe in the late 1970s and early 1980s. The Architecture-practically Engineering-Construction (AEC) industry started to implement it in projects from the mid-2000s (Eastman et al., 2011). BIM has brought new momentum to the transformation of the global construction industry's landscape. Outlining the global footprint, the diffusion of BIM can be verified through the growing number of early adopter countries, such as the United States, United Kingdom, China and Singapore. These countries have made BIM their strategic agenda. This has further gained attention from many other countries. BIM has become essential in the global digital economics due to its evolution that brings about market competition. While other early adopter countries have already positioned themselves by mandating BIM, the embracement of BIM in Malaysia is still at an infant stage.

In Malaysia, the idea to bring BIM into practice was highlighted by the Director of the Public Works Department (PWD) in 2009; who urged construction companies to adopt ICT to enhance productivity and efficiency. The Malaysian government then announced BIM adoption in 2010 with the first infrastructure construction project to use it being the National Cancer Institute in Sepang (mybuildingsmart.org.my). Currently, the private and public sector are in the positive adoption of BIM. According to the CIDB, there are over 20 projects utilising the BIM concept at different levels of maturity (mybuildingsmart.org.my). Meanwhile, the PWD's BIM pilot projects are the Healthcare Centre Type 5 at Sri Jaya Maran, Pahang, the Administration Complex Project of Suruhanjaya Pencegah Rasuah Malaysia (SPRM) at Shah Alam, Selangor, a primary school in Meru Raya Ipoh, Perak and a primary school in Tanjung Minyak 2, Melaka Tengah, Melaka (Latiffi, Mohd, Kasim, & Fathi, 2013). These pilot projects are part of the Malaysian government's initiative in exposing government officers to BIM (JKR, 2013).

Further, the government is seriously strengthening the BIM initiatives under the Construction Industry Transformation Plan (2016-2020). The Construction Industry Transformation Plan (CITP) recommends the establishment of a referral centre to

support BIM adoption in Malaysia. The centre will house BIM technologies, showcase its benefits, provide training and raise awareness of BIM and other cutting-edge IT and modern methods that are transforming construction globally. Graduates of Akademi Binaan Malaysia (ABM) will be trained and groomed as ‘BIM experts’, and will provide training and hands-on guidance for BIM adoption at the referral centre. CITP also recommends the introduction of a certification and accreditation programme for BIM personnel endorsed by international bodies and acknowledged by Malaysia’s professional boards. This is to ensure that the quality of BIM personnel in construction meets desired and required standards. The referral centre will also launch BIM as a service, which will adopt the software as a service (SaaS) model, where consumers only need to pay for the software when they need it or to develop a home-grown BIM-enabled solution with a lower cost of ownership. This model will make BIM adoption much more affordable. Also, a defined BIM guide with clear implementation stages, methodologies and standards is critical to increase adoption rates, as evidenced by the UK BIM benchmark. Learning from the United Kingdom that showed an increase in BIM adoption rates by having detailed guidelines provided by the British Standards Institution (BSI) and the BIM Task Group, a Malaysian-specific BIM guide has been recommended in the CITP to be developed in collaboration with worldwide BIM experts such as buildingSMART (CIDB Malaysia, 2015).

The government set up several key performance indicators for BIM adoption which are to be achieved by 2020. The indicators are 40% of public projects above RM100 million must use BIM level 2 by the first quarter of 2019, BIM Object Library to be developed by the first quarter of 2017, 1000 BIM personnel are trained and certified by the fourth quarter of 2018, BIM submission using 4 pilot projects by the first quarter of 2020 and 5 public pilot projects use BIM level 3 by the third quarter of 2020.

Nevertheless, BIM adoption encompasses significant challenges such as the operational skills and knowledge for the users. In addition, it requires conceptual and

process knowledge to confirm and create organisational and inter-organisational quality and requirements, which are likely to be a mixture of both organisation and project driven needs (Arayici & Coates, 2013). Furthermore, the different types of buildings and uses may add another difficulty in understanding the required process and standard. As global construction is moving towards higher quality and efficiency, and construction organisations need to face the challenges, it is crucial for BIM adoption to be managed efficiently by construction organisations to speed up the implementation. BIM is an innovation that will allow organisations to remain competitive. The necessity to adopt more organised knowledge sharing practices, which encompass the key factors in implementing BIM are in demand. Therefore, this research investigates how the knowledge sharing practices in construction that support the BIM process used by the construction organisations could help to accelerate and improve the BIM implementation. This study also identifies the key factors to knowledge sharing practices in implementing BIM to develop a framework of knowledge sharing practices in implementing BIM, which will serve to guide the construction organisations particularly in improving BIM implementation.

2.4 Knowledge Management and Knowledge Sharing

2.4.1 Knowledge within Organisations

The importance of knowledge has been discussed for a long time, but it has received growing attention in the economy and businesses since the 1960s (Nonaka & Takeuchi, 1995). Knowledge is seen as a valuable resource in organisations, and the management of this knowledge is critical to the success of any organisation. Knowledge exists at numerous levels within organisations (Ipe, 2003). Some authors categorised it broadly into human (individual), social (group) and structured (organisational) levels (Alavi & Leidner, 2001; DeLong & Fahey, 2000). Individual knowledge is knowledge kept in an individual's mind, while group knowledge exists via relationships between individuals or within groups. Organisational knowledge is commonly said to be a dynamic symbiosis of individual, group, organisational and inter-organisational experiences, values, information, and expert insights.

The term ‘knowledge’ is one of the confusing aspects of knowledge management. The terms ‘information’ and ‘data’ are commonly used interchangeably with the term knowledge. In fact, each means differently. Any organisation intending to practice knowledge management must differentiate between data, information and knowledge. DeLong and Fahey (2000) and Baporikar (2014) advocate that it is important to distinguish between the interrelated concepts of data, information, knowledge and wisdom in order to gain a better understanding of managing knowledge. Otherwise, the organisation will treat data, information and knowledge in the same way, and knowledge will become undervalued (Nianti, Zin, & Egbu, 2009), which makes the understanding of knowledge management difficult to comprehend.

2.4.2 Distinguishing Data, Information and Knowledge

To grasp what knowledge management entails, there is a necessity to understand what knowledge is and how it is derived. It is also important to distinguish between data, information and knowledge as a starting point. Table 2.10 provides the different definitions of data, information and knowledge by various authors in literature, and some authors describe data, information and knowledge in a hierarchical view illustrated in Figure 2.2. The figure shows the different levels of knowledge hierarchy; data is at the lowest point and it is regarded as a collection of facts and figures; followed by information which is seen as structured data and finally knowledge at the top of the hierarchy is regarded as information transformed when an individual’s personal experience, beliefs and values are included. Some literature includes wisdom in the hierarchy. However, the knowledge pyramid will be sufficient for this study as its aim is to explore knowledge sharing.

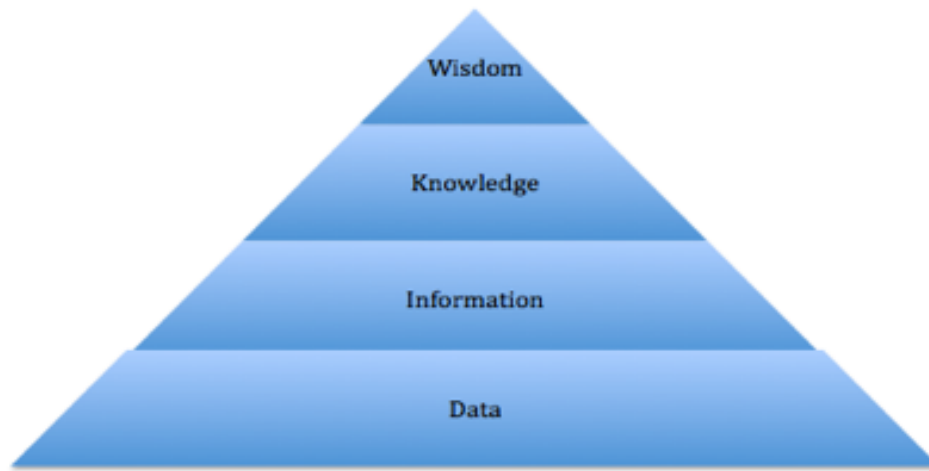


Figure 2.2: Knowledge hierarchy adapted from (Baporikar, 2014)

There are various definitions of data, information and knowledge by different researchers. Nonaka and Takeuchi (1995) view data, information and knowledge as a sequence in order; data is declared as the raw material for information, and information is the raw material for knowledge. According to Davenport and Prusak (1998), data is a set of discrete, objective facts about events such as structured records of transactions. Information is a message meant to change the receiver's perception and have an impact on the receiver's judgment and behaviour. The common working definition of knowledge is,

“A fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices, and norms.”

Source: Davenport and Prusak (1998)

Data can be described as a series of meaningless outputs from any operation and represent symbols such as numbers, letters, facts or magnitudes and is the means through which information and knowledge is stored and transferred. Information is structured data, which is placed in a context that makes a valuable output (Ahmed,

Lim, & Loh, 2002). In simple terms, Rezgui et al. (2010) described data as raw numbers and fact, information is processed data, and knowledge is authorised information. However, Khalil (2000) argued that knowledge is not just about information. It is based on the collection of information available and held by the mind from the range of information available. Knowledge involves combining the individual experience, skills, intuition, ideas, judgements, context, motivations and interpretation (Ahmed et al., 2002). All knowledge is rooted in tacit knowledge, and even the most explicit knowledge includes some tacit parts or aspects. Knowledge is information in context and once we add context, we add tacitness (Nonaka, Kodama, Hirose, & Kohlbacher, 2014).

Table 2.10: Data, Information and Knowledge Definition

Author(s)	Data	Information	Knowledge
Nonaka and Takeuchi (1995)	Raw material for information	A flow of meaningful messages	Commitments and beliefs created from these messages
Davenport and Prusak (1998)	A set of discrete facts	A message meant to change the receiver's perception	Experiences, values, insights, and contextual information
Ahmad, Lim and Loh (2002)	Meaningless outputs such as numbers, letters and facts	Data structured placed in a context that makes a valuable output	Combining the individual experience, skills, intuition, ideas, judgements, context, motivations and interpretation
Yacine Rezgui et al. (2010)	Raw numbers and fact	Processed data	Authorized information

Davenport & Davenport and Prusak (1998) further stress that knowledge becomes meaningful when it is seen in a broader context, through the perception and reflection of someone's culture, which expand from someone's beliefs. As found in literature, it is clarified that data itself is meaningless without explanation. While information requires purpose, clarification and meaningful explanation, knowledge requires real human contribution in order for it to be used.

For the purpose of this research, it is important to distinguish these concepts from the start so that information is not taken entirely to mean knowledge, but seen as a very fundamental component of knowledge. This research does not lose sight of the reality that when knowledge is mentioned to BIM practitioners, what comes to mind is information. As a result of this, information is presented alongside knowledge especially at the data collection (interview) and data validation (survey questionnaire) stage. The rationale for this is that information is very close in meaning to knowledge and this enables the BIM practitioners to understand the meaning of knowledge sharing within the context of BIM implementation in the Malaysian construction industry.

2.4.3 Knowledge Taxonomies

Knowledge can also be defined according to its taxonomy and its classification as shown in Table 2.11. An understanding of the concept of knowledge and knowledge classification is important because theoretical developments in the knowledge management area are influenced by the distinction between the different types of knowledge (Alavi & Leidner, 2001). Nevertheless, this section will not discuss all the classifications in Table 2.11 below but briefly describe the most common ones.

Despite the various classifications of knowledge, scholars have some common understanding of parts of these viewpoints. The classification of tacit and explicit knowledge remains the most common and practical. Knowledge could be categorised into two types, explicit and tacit knowledge as shown in Table 2.12, which are usually defined within knowledge management literature. The former refers to non-codified knowledge, which is subjective and often the personal experiences of an individual and, therefore, is difficult to transmit. On the other hand, explicit knowledge is codified, is objective and easy to communicate. Tacit knowledge of individuals is the basis of organisational knowledge creation. Organisational knowledge creation, therefore, should be understood as a process that “organisationally” amplifies the knowledge created by individuals and crystallises it as a part of the knowledge network of the organisation (Nonaka, 2008). Tacit knowledge is personal, context

specific and hard to formalise and communicate, that includes concrete know-how, crafts and skills (Nonaka & Takeuchi, 1995; Nonaka, 2008). Whereas explicit knowledge or codified knowledge refers to knowledge that could be transmitted in a formal and systematic language, for example procedures, methods and rules. A study done by Thuc Anh, Baughn, Minh Hang, and Neupert (2006) suggests that tacit knowledge is the most important strategic resource and the ability to acquire, integrate, store, share and apply the knowledge is important for building and sustaining competitive advantage. Egbu (2005) asserts that the tacit knowledge of the individual is an essential component of organisational success.

Table 2.11: Different types of knowledge adapted from Alavi and Leidner (2001)

Authors	Knowledge classifications	Definitions
Alavi & Leidner (2001); DeLong & Fahey (2000)	Individual	Created by and inherent in the individual
	Social	Created by and inherent in collective actions of a group
Hislop (2005); McKenzie & Van WinKelen (2004); Alavi & Leidner (2001); Nonaka & Takeuchi (1995)	Tacit	Knowledge is rooted in actions, experience, and involvement in specific context
	Cognitive tacit	Mental models
	Technical tacit	Know-how applicable to specific work
	Explicit	Articulated, generalised knowledge
Hansen et al (1999)	Codified	Available in written documents and manuals, procedures
	Non-codified	Acquired through experience
McKenzie & Van WinKelen (2004); Alavi & Leidner (2001);	Declarative	Know-about
	Procedural	Know-how
	Causal	Know-why
	Conditional	Know-when
	Relational	Know-with
McKenzie & Van WinKelen (2004);	Endbrain	Conceptual skills and abilities
	Embodied	Acquired by doing
	Encultured	Acquired through socialisation
	Embedded	Organisational routine
	Encoded	Sign and symbols

Table 2.12: Typologies of Knowledge (Nonaka & Takeuchi, 1995)

Tacit Knowledge (Subjective)	Explicit Knowledge (Objective)
Knowledge of experience (body)	Knowledge of rationality (mind)
Simultaneous knowledge (here and now)	Sequential knowledge (there and then)
Analog knowledge (practice)	Digital knowledge (theory)

Tacit and explicit knowledge are not totally separated, but exclusively complementary entities. The organisational knowledge can be created through a continuous communication between tacit and explicit knowledge as suggested by Nonaka and Takeuchi (1995) that knowledge is the product of the interaction of both explicit and tacit knowledge. However, this research is not making distinctions between the many different types of knowledge. The research is concentrated mainly on tacit and explicit knowledge, especially the individual tacit knowledge of construction organisation workers shared within their team or unit in the organisations in particular related to BIM adoption or implementation. It will associate knowing how with tacit knowledge and knowing about facts and concepts with explicit knowledge.

Nonaka and Takeuchi (1995) identified four modes of knowledge conversion or known as the SECI process (see Figure 2.3). The model is based on the two types of knowledge outlined above. The mechanisms for conversion and transfer include socialisation, externalisation, combination and internalisation.

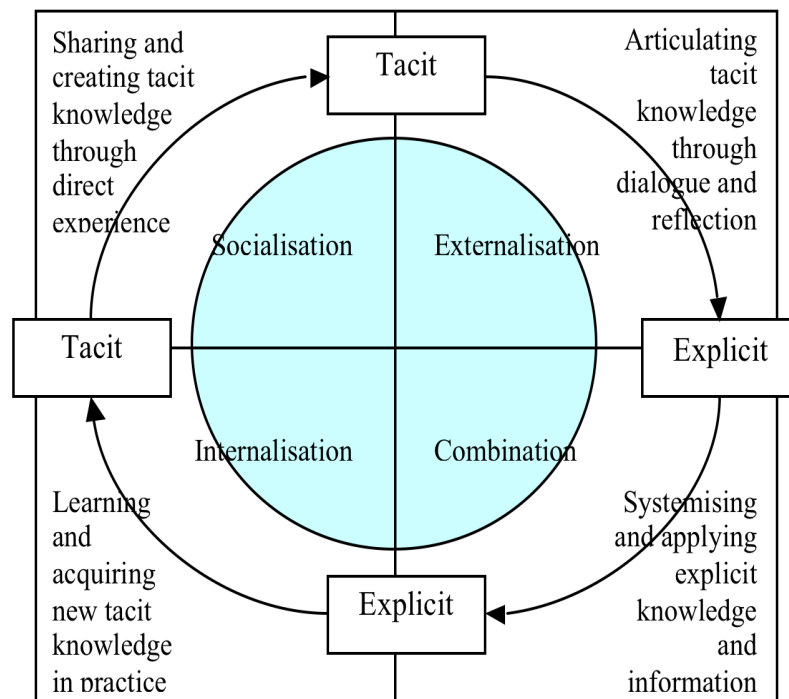


Figure 2.3: SECI Process in the Modes of knowledge conversion by Nonaka and Takeuchi (1995)

Socialisation (tacit to tacit) comes from just being around other people usually through mentorships, apprenticeships and includes rules of behaviour, codes of conduct. The person who is learning learns without ever thinking about its meaning. Externalisation (tacit to explicit) is done by formulating concepts and creating models to be able to explain how something works. Combination (explicit to explicit) is for example how the organisations learn from conversations, meetings and written documents. Internalisation (explicit to tacit) occurs when something is learned and then repeated over and over again for a long period of time. People stop thinking about their actions and do them automatically, often referred to as learning by doing (Berg, Legnerot, Nilsson, & Gluch, 2012).

2.4.4 Knowledge Perspectives

There are two different perceptions of the nature and status of knowledge in organisations: Knowledge as an asset or knowing as a process (Quintas, 2005). The knowledge as an asset perspective is concentrated on the identification of valuable knowledge within organisations and how to develop mechanisms for managing it effectively. In the knowing as a process perspective, knowledge is viewed as a social construct that is developed, transferred and maintained in social conditions, and the focus is to support relations and interactions where knowledge expands.

While traditional economies used to rely on tangible assets such as land and capital, today's economy has evolved to treat knowledge as the primary production factor on which competitive advantage rests (Beijerse, 1999). The most important characteristics of knowledge are uniqueness and originality. The first knowledge is created from the resources and organisations' controlled capabilities; knowledge cannot be imitated or substituted, which makes it a key strategic asset resource to all businesses (Cabrera & Cabrera, 2002) for sustainable competitive advantage (Barney, Wright, & Ketchen Jr., 2001). In a resource-based view of the firm, knowledge is seen as key assets and claims that knowledge is the strategic productive resource of the firm (Grant, 1996). These resources and capabilities can be viewed as vast amounts of tangible and intangible assets, including organisational management skills, its

organisational processes and routines, and the information and knowledge it controls (Barney et al., 2001). Resources can be physical, human and organisational in nature and can be used to implement value-creating strategies (Grant, 1996).

The second knowledge emphasizes knowing as a process rather than an asset. It is on the basis of a social creation (Sveiby, 2001), a process that is culturally situated, technologically mediated and socially distributed. Furthermore, knowing is not a stagnant capability or stable action of actors but rather a continuous social accomplishment as actors engage in the world of practice (Xiaomi An, Deng, Wang, & Chao, 2013). This perspective of knowledge focuses on the processes of creating new knowledge via an active ongoing process from different cultural perceptions of knowledge and how it might be managed (Quintas, 2005).

2.4.5 Knowledge Management within Organisations

The importance of knowledge may have been discussed for a long time, but it has received growing attention in the economy and businesses since the 1960s (Nonaka & Takeuchi, 1995). Knowledge management was developed out of a number of disciplines including computer science (Farenhorst & Izaks, 2008), human resource management (Dainty, Qin, & Carrillo, 2005), innovation (Egbu, 2005) and education (Agarwal, Kiran, & Verma, 2012). As a result, there is no one accepted definition of knowledge management but most of the definitions include some form of knowledge sharing. Knowledge is central to many management research traditions (Grant, 1996), and consequently, managing knowledge in organisations is important for organisational success.

Knowledge management (KM) is emerging as an important concept for organisations to effectively preserve and manage valuable knowledge in order to improve productivity and competitiveness. According to Davenport and Prusak (2000), KM "is managing the corporation's knowledge through a systematically and organisationally

specified process for acquiring, organising, sustaining, applying, sharing and renewing both the tacit and explicit knowledge of employees to enhance organisational performance and create value". This definition is supported by Alavi and Leidner (2001) and X An, Deng, Chao, and Bai (2014) who noted that KM is the systematic process of managing knowledge assets, processes, and organisational environments to facilitate their creation, sharing, utilisation, and maintenance for achieving the strategic objective of an organisation. Four processes characterise knowledge management: generation, codification, transfer (also known as knowledge sharing), and application (Alavi & Leidner, 2001). Shajera and Al-Bastaki (2014) viewed KM as a strategy that can be developed within a firm to ensure that knowledge reaches the right people at the right time, and further, these people should share and use information and knowledge to improve organisational functions. As a result, there is no one accepted definition of knowledge management but nearly all of the many definitions mention some form of knowledge sharing and the resource being managed in the case of knowledge management is always knowledge.

Knowledge, as discussed in section 2.5.3, is categorised into different types i.e. tacit (know-how) and explicit (know-that), hence, the subject of how they are managed is to a certain extent more complex. As already mentioned, knowledge is essential to many management research traditions (Grant, 1996), and consequently, managing knowledge in organisations is important for organisational success. Knowledge management is not only about transferring tacit knowledge into explicit knowledge, it also involves creating repositories of knowledge and best practice, which can be shared, applied and used to resolve problems and challenges. Knowledge sharing has been used to communicate, exchange and transmit knowledge both internally and externally, in the process of improving business and services. Organisations are now realising that their true value and strength lies in the intellectual capital of their employees. There is a general consensus in literature that KM is about making the right knowledge available to the right people. It is about making sure that an organisation can learn and be able to retrieve and use its knowledge assets when they are needed.

Knowledge sharing is particularly relevant to this study, since it captures the process of disseminating knowledge from one individual or group to another within the organisation. Knowledge sharing assists in organisational learning; in its absence, the gap between individual and organisational knowledge enlarges. Knowledge sharing is one of the most challenging processes for a knowledge-based enterprise due to employees' possible reluctance to share what they know. Furthermore, knowledge sharing plays an important role as discussed in section 2.6 especially when the country is moving towards knowledge-based industry.

2.4.6 Knowledge Management Tools/Approaches

Knowledge management tools are used to support KM processes and sub-processes. Various researchers used different terms for knowledge management tools such as approaches (Nianti, Zin, & Egbu, 2009) and mechanisms (Boh, 2007; J. U. Egbu, 2013). By focusing on a project-based organisation, Boh (2007) defined knowledge-sharing mechanisms as the formal and informal mechanisms for sharing, integrating, interpreting and applying know-what, know-how, and know-why embedded in individuals and groups that will aid in the performance of project tasks. Al-Ghassani, Anumba, Carillo and Robinson (2005) used the term 'KM techniques' for non-IT tools and 'KM technologies' as IT tools to differentiate between KM tools. Table 2.13 shows the characteristics of KM tools in comparison between KM technique and KM technologies.

Table 2.13: KM tool- Comparison between KM techniques and technologies (Al-Ghassani et al., 2005)

KM tools	
KM techniques	KM technologies
- Require strategies for learning	- Require IT infrastructure
- More involvement of people	- Require IT skills
- Affordable to most organisations	- Expensive to acquire/ maintain
- Easy to implement and maintain	- Difficult to implement/ maintain
- More focus on tacit knowledge	- More focus on explicit knowledge

Hence, knowledge sharing tool is any medium and practice which individuals or teams in an organisation or organisations use to encourage the knowledge flow. It encompasses different techniques and technology either in a formal or informal way, based on information technology or non-information technology.

There are various ways to promote knowledge sharing, through IT or non-IT approaches. These can facilitate knowledge sharing in implementing BIM. Some of the suggested approaches are shown in Table 2.14. Studies by various researchers below highlighted some differences in the approach used for knowledge sharing both between SMEs and large construction organisations. Also, some of the authors (Arayici & Coates, 2013; Hardin, 2009; Salleh & Fung, 2014; Zakaria, Mohamed Ali, Marshall-Ponting, Haron, & Abd Hamid, 2012) focused their research explicitly on BIM implementation or adoption. The studies provide good examples of knowledge sharing approaches used in the context-specific.

Table 2.14: The Knowledge Sharing Approaches in the Construction Organisations.

Reference	Approaches/ Initiatives
Salleh & Fung (2014); Arayici & Coates (2013); Hardin (2009); Dave & Koskela, (2009); Yang (2004); Eastman et al. (2011)	Proper training session and techniques includes (Organisation, workshops, brainstorming sessions, seminars, role plays, video presentations)
López, Carrillo, & Bustamante (2013)	Knowledge Management System: Intranet Based Program, Content Administration Program, Work Group Program, Work Flow Program, Artificial Intelligence Based Program, Business Intelligence Program, Knowledge Mapping Program, Innovation Support Tool Program, Competitive Intelligence Tool Program, Knowledge Portals.
Arayici & Coates (2013)	Knowledge Transfer Partnership Program
Zakaria, Mohamed Ali, Marshall-Ponting, Haron, & Abd Hamid, (2012)	Forming BIM working group, documented lesson learnt
Berg et al., (2012)	Documented lesson learnt
Albino, Garavelli, & Schiuma (1999)	The media characteristiCase depend on the combination of codes and channels. These media rely on rules, forms, procedures and databases, and use basically impersonal media sources, such as written and numeric documents, e-mail, telephone, fax and EDI.
Arayici & Coates (2013)	BIM manual
Hardin (2009), Dave & Koskela, (2009), Yang (2004)	BIM manual, documented tutorials, articles, materials, and standard
Arayici & Coates (2013)	Learning by doing, individual and group learning
Love et al. (2004)	Individual and group learning
Berg et al., (2012)	Using a central knowledge platform such as website and blog, 3D-models to inform future development
Hardin (2009); Dave & Koskela (2009)	Technical support.
Love et al. (2004)	TQM technique
Yang (2004); Berg et al., (2012)	Meetings, conversation, dialogues and social activities. Regular meetings, informal meetings, face-to-face communication.

2.4.7 The Importance of Knowledge Sharing

The importance of knowledge has been discussed for a long time, but it has received growing attention in the economy and businesses since the 1960s (Nonaka & Takeuchi, 1995). Knowledge management involves some activities and the most frequently discussed activity in the process of knowledge management is knowledge

sharing (Ford & Chan, 2003). Various authors have discussed knowledge sharing in different settings. (Xiaomi An, Deng, Wang, & Chao (2013) and Ryu, Ho, & Han (2003) state that knowledge sharing is the process of disseminating knowledge from one individual, continue to expand into a group, and to another within an organisation. While in traditional knowledge management the emphasis was placed on technology or the ability to build systems that efficiently process and leverage knowledge, the new model of knowledge management involves human and actions. It aims to create an environment where power equals sharing knowledge rather than keeping it (Al-Alawi, Al-Marzooqi, & Mohammed, 2007).

Knowledge sharing is concerned with the organisational and ‘cultural’ changes, which needs to encourage people to share knowledge. Across the different parts of an organisation, which has different culture, leadership and processes in each part, managing what the “organisational knows” becomes critical for achieving collaboration and effective processing of knowledge. Knowledge sharing is therefore a key knowledge management activity to focus on (Søndergaard, Kerr, & Clegg, 2007). There is growing realisation that knowledge sharing is critical to knowledge creation, organisational learning, and performance achievement (Ipe, 2003; Nonaka, 2008). Further, it should be a norm and cultured as a routine in the organisation, and begins with every employee as Nonaka (2008) stressed that every knowledge worker should consistently and continuously create new knowledge and disseminate it widely throughout the organisation as a way to success. Knowledge sharing is also critical to an organisation’s success (Davenport & Prusak, 1998; Nonaka, 2008) as it leads to faster knowledge distribution to portions of the organisation that can significantly benefit from it (Syed-Ikhsan & Rowland, 2004). Generally, when something is being transferred, someone will acquire it and someone else will lose it. However, knowledge, which is an intangible asset, is in contrast with tangible assets. Tangible assets tend to decrease in value when they are used, but knowledge flourishes when used and depreciates when not used (Sveiby, 2001). By this means, knowledge will keep on increasing whenever a person shares the knowledge that he/she has; when someone transfers and shares their knowledge, they do not lose it (Syed-Ikhsan & Rowland, 2004). From a technical innovation standpoint, knowledge sharing and

practical application is the essence of technological capability development (Gilbert & Cordey-Hayes, 1996) to start the dissemination process (Larsen & Ballal, 2005; Sexton & Barrett, 2004), to prevent loss of knowledge and lessons learnt, and also to increase operational efficiencies (Liang, Saraf, Hu, & Xue, 2007). Furthermore, knowledge without use in applications can quickly become obsolete and forgotten. This information and knowledge should be shared and grown through applications (Arayici & Coates, 2013).

There is no clear-cut definition of knowledge sharing. It is interchangeably used as knowledge transfer, knowledge dissemination or knowledge exchange. Knowledge transfer is the process where unclear and diverse habits are rearranged and kept in a way that they can be familiarised and utilised in future usage (Liu, 2009). In most cases, the transfer is between sender and receiver. However, at different times each party can be either the source of knowledge or its receiver. When the exchange takes place; it can be characterized as knowledge-sharing. In literature, knowledge exchange has also been used interchangeably with knowledge sharing (Cabrera et al., 2006). Knowledge exchange is the two-way communication from sender to receiver and vice-versa. It has to do with the mutual sharing of knowledge and it is also technology (IT) based. Some of the knowledge sharing definitions can be referred to in Table 2.15. By taking into account the nature of BIM application that requires collaborative context and involves BIM innovative technology (IT innovation) for its implementation, and referring to the definition in Table 2.15 by Ravinchandran and Lertwongsatien (2005), Yacine Rezgui et al. (2010) and Šajeva (2014), thus, for this study, knowledge sharing in implementing BIM is defined as the process of transferring, disseminating, and exchanging of knowledge, experience, skills, and valuable information of BIM implementation, which includes explicit and tacit knowledge from one individual to other members within an organisation with continuous interactions through various approaches. In other words, knowledge sharing practices has become a tool or mechanism that support the BIM process and assist organisations in implementing BIM.

Table 2.15: The knowledge sharing definition

Authors	Definition
Ravinchandran & Lertwongsatien (2005)	Knowledge sharing as the process that organisation diffuses innovative technologies related knowledge to the members through various media and modes of communication.
Yacine Rezgui et al. (2010)	Knowledge sharing as an organisational, social, collaborative, and dynamic process involving fostering and continuous interactions between tacit and explicit knowledge.
Šajeva (2014)	Knowledge sharing means transfer, dissemination, and exchange of knowledge, experience, skills, and valuable information from one individual to other members within an organisation.
Yang (2004)	Knowledge sharing is the dissemination of information and knowledge through the entire department and/ or organisation.
Ipe (2003)	Knowledge sharing is the act of making knowledge available to others within the organisation.

Recent reports highlight the importance of collaborative working both now and in the future. One of the examples of collaborative working could be realised through the application of BIM in construction organisations. The application of BIM in this research involves the Architecture, Engineering and Construction (AEC) industry, where projects are delivered by temporary project organisations, put together from different groupings such as design and construction teams working in collaboration. This means that the knowledge in construction organisations tends to be dependent on something else, is situational, bound to individual and local practices (Styhre & Gluch, 2010), involves experience-based and tacit knowledge (Woo, Clayton, Johnson, Flores, & Ellis, 2004; Nesan, 2012), yet has a unique and short-term orientation which creates obstacles that may hinder the development of routines and organisational memory (Berg et al., 2012). Accordingly, much of the valuable construction knowledge is in the minds of project players which will involve tacit knowledge. Heavy fragmentation in the industry might cause valuable knowledge to be lost after the project finishes. Also, knowledge and expertise leaves when the employees leave the organisation. Therefore, it is crucial to ensure that knowledge is retained within the organisation (Bender & Fish, 2000).

Meanwhile, it is argued that in the constantly changing global economy, the ability to communicate and share knowledge over time and space, within and between organisations or communities, is essential to achieve this flexibility by making the best use of the knowledge and competencies available. However, successful knowledge management implementation or initiatives and the enormous potential of using BIM to engage the construction industry clients and practitioners in overcoming the fragmentation is not being realised in practice. Moreover, collaborative environments that should be in the nature of BIM implementation are necessary to increase the productivity as well as the creativity by enabling new forms of work in production and knowledge-intensive businesses (European Commission Information Society and Media 2006). Importantly, technological change for the 21st century must employ the processes of knowledge sharing throughout the organisation in order for the industry to remain competitive and survive. Nonaka and Takeuchi (1995) point out that individuals generate new knowledge and that an organisation needs to learn to mobilise knowledge accumulating at the level of the individual. Accordingly, the performance indicator for each individual organisation is embodied in its ability depending on the amount and quality of experience it can apply and manage rather than its size or the number of assets it has (Love, Huang, Edwards, & Irani, 2004). Knowledge sharing is to prevent loss of knowledge and lessons learnt, and to increase operational efficiencies (Liang et al., 2007). Thus, if the KS framework is in place, the knowledge which may have been lost with the leaving employee can be transferred to the existing employees. Moreover, in implementing new technology such as BIM, knowledge sharing which occurs within the organisation will enable learning, continuous development and change, and reacting to internal and external environment to achieve competitive success. For a technology like BIM that related to IT, the organisations that were able to defeat knowledge barriers were more likely to promote the absorption of information technology than other organisations. In addition, the technology providers should share their knowledge with potential adopters, improving the knowledge stock of organisational units to promote technology assimilation (Ravinchandran & Lertwongsatien, 2005; Ming-ming et al., 2010). The value of knowledge will depend on detailed knowledge disseminated in the sharing and the organisation's ability to solve practical problems effectively (Ming-ming et al., 2010).

A review of the literature revealed that there are no definite theories on knowledge sharing. Most of the views on knowledge sharing are nested in knowledge management theories. By referring to Table 2.15, this study has defined knowledge sharing in implementing BIM as the process to transfer, disseminate, and exchange knowledge, experience, skills, and valuable information of BIM implementation, which includes explicit and tacit knowledge from one individual to other members within an organisation with continuous interactions through various approaches.

2.4.8 Knowledge Sharing Theoretical Frameworks/ Knowledge Sharing Models and Frameworks

The different knowledge sharing frameworks, models and concepts found in literature will be considered as part of the theoretical framework for this research, which facilitates the development of the framework in this research. This theoretical understanding is vital to understand which view has the better theoretical support, thus supporting this research with a strong theoretical underpinning. Yin (2011) suggested to assemble even a small collection or some number of concepts, from abstract concepts or ideas in representing a logical theory related to the researcher's focus of study for the establishment of a theoretical framework, which then guides the development of concepts and theories in the researcher's study as well as data collection activities. Instead, like in this study, a case study employed cannot be defined through its research methods but it has to be defined in terms of its theoretical orientation. This places emphasis on understanding processes alongside their (organisational and other) contexts. The value of the theory is key. Although a case study may begin with only a simple theory or a primitive framework, the researcher needs to develop theoretical frameworks during the course of the research which inform and make sense of the data and which can be systematically examined during the case study for plausibility (Hartley, 2004). Essentially, the formulation of a theoretical framework serves to consolidate the different perspectives from other scholars studying a particular research area of interest in order to develop a specific research focus and approach (Kumar, 2011). Thus, four theoretical frameworks were employed to develop the framework for this research. The four theoretical frameworks are (a) A Receiver-Based Model of Knowledge Sharing (Lichtenstein &

Hunter, 2006) (b) Foundation of Knowledge Management System Model (Gorelick & Tantawy-Monsou, 2005) (c) The Four Organisational Elements of IT success (Alshawi, 2007a) and (d) A Framework of Knowledge Sharing Research (Wang & Noe, 2010).

It is important to mention that the approach of the research is not on developing the knowledge sharing practices framework, which encapsulates the key factors 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 key factors of knowledge sharing practices 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 dependent on the responses captured during the interview. As far as the research outcome is concerned, the key factors of knowledge sharing practices in implementing BIM which is explored and identified through the case studies, become the main contribution of the research. The identified key factors would be fed into the theoretical framework for developing the conceptual framework, which is discussed further in Chapter 5.

Several studies (Alshawi, 2007a; Lichtenstein & Hunter, 2006; Walker, Maqsood, & Finegan, 2005; Wang & Noe, 2010) in different study contexts have put forward different models and frameworks for knowledge sharing factors and their implementation in organisations. In knowledge sharing, the process must involve the actors, who are an individual, a group of people or an organisation. The sharing process must focus on the ways different individuals deal with knowledge (Albino, Garavelli, & Schiuma, 1999). The model developed by Hunter and Lichtenstein (2008) illustrates a process-oriented model of knowledge sharing that studied the potential role of receivers in sharer choices as shown in Figure 2.4. The model assumes that a person who possesses knowledge (donor/sharer) becomes conscious of the value of their own knowledge to a potential receiver, the sharer would then provide support by bringing the knowledge of team members to the attention for potential receivers through any mechanism. The receiver is able to understand the

knowledge, comprehend it effectively and provides further feedback about the receiver's knowledge needs, making a loop and continuous process of sharing. Furthermore, it is assumed that no essential parts of this explicit knowledge are lost in the transfer process and that both sender and receiver achieve the same meaning from the knowledge.

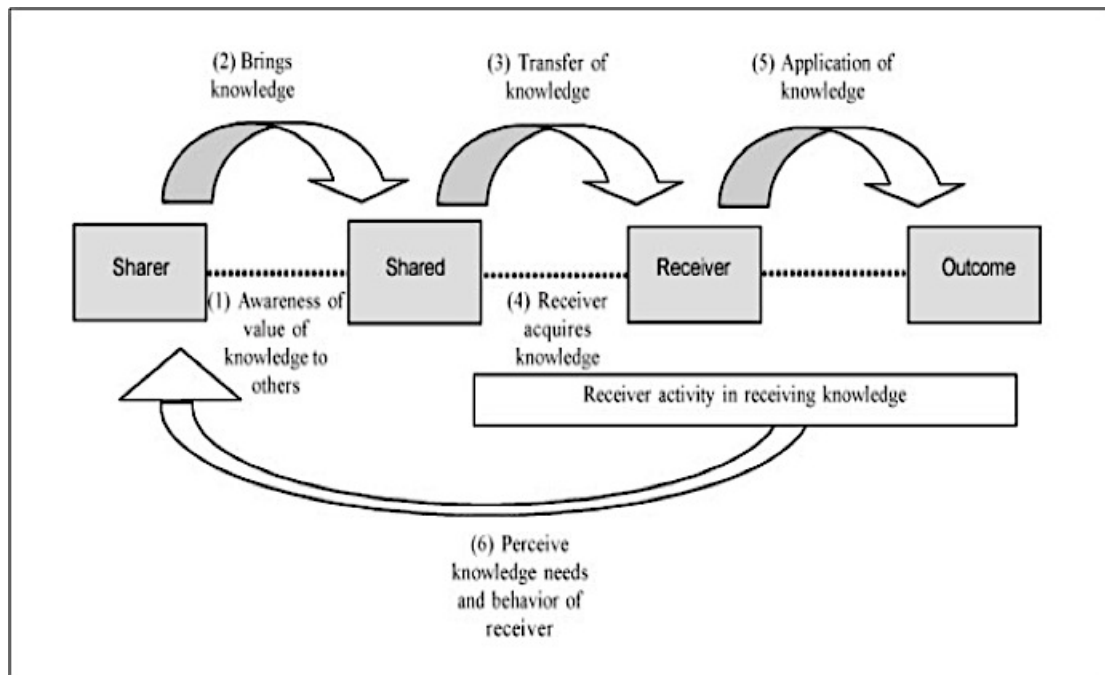


Figure 2.4: A receiver-based model of knowledge sharing (Lichtenstein & Hunter, 2006)

Walker, Maqsood, and Finegan (2005) established the framework of organisational transition depicted in Figure 2.5 with three stages of transformation process. The framework illustrates what is happening within the organisation at each stage where there is a transition from inaccessible thick boundaries isolating the organisation from its external knowledge environment with people, process, and technology similarly segregated and isolated within inaccessible boundaries with integrated people, process, and technology. However, this research only considered and adopted people, process and technology as the core elements to study the key factors in knowledge sharing practices in construction organisations, particularly during BIM implementation.

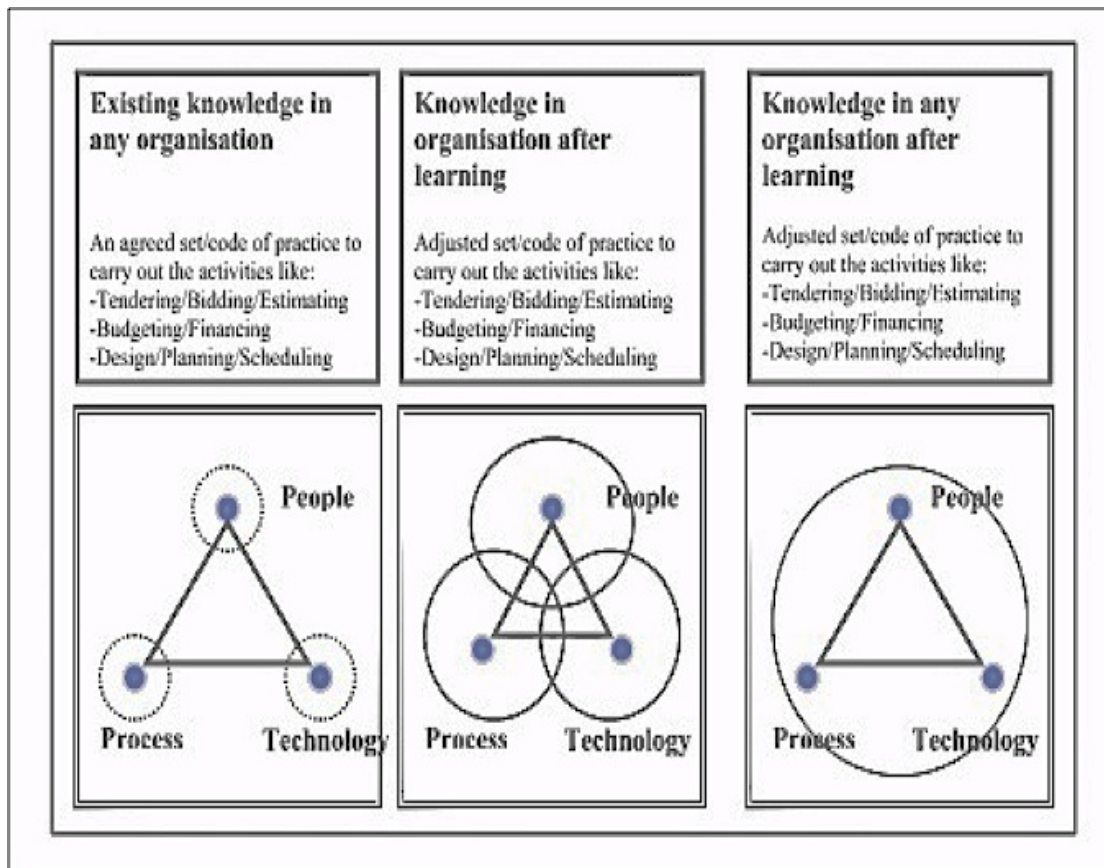


Figure 2.5: Three stages of organisational transition extended from organisational learning and interaction with external sources of innovation model (Walker et al., 2005)

This research looked at the model developed by Gorelick and Tantawy-Monsou (2005) which forms the basis of the knowledge sharing framework developed for this research, as shown in Figure 2.6. The foundation of the framework shows the interrelation of people, processes and technology embedded within a given culture, with people and processes seen as the major factors in knowledge management to ensure performance and learning for sustainability. Culture has an influence on all three elements; on people when it comes to the awareness of cultural differences, on processes when it comes to following processes strictly and on technology when it comes to accepting new technologies. As noted in the literature, knowledge sharing has become a vital element in knowledge management.

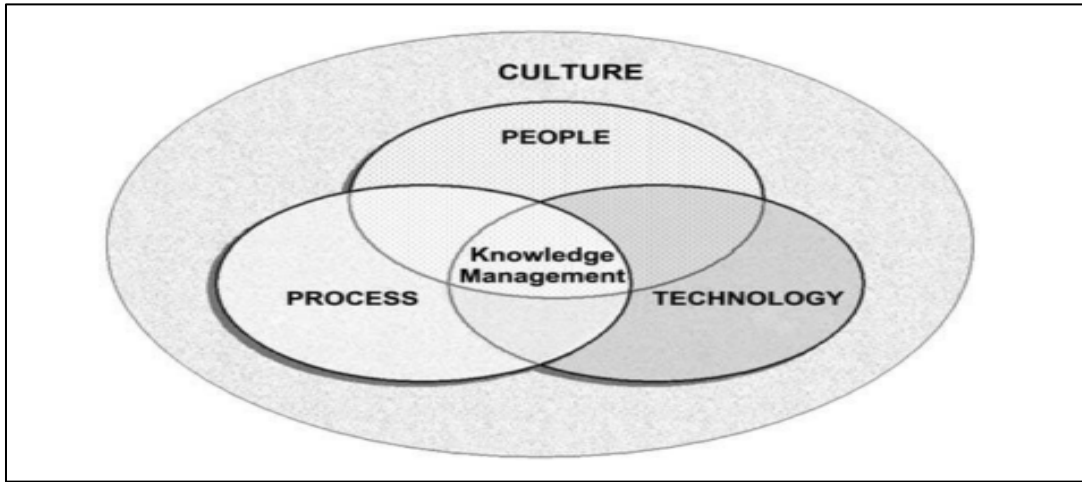


Figure 2.6: Foundation of Knowledge Management system (Gorelick & Tantawy-Monsou, 2005)

Due to the element of IT in BIM implementation, which is involved in this research, this study considered the four main elements of people, process, work environment and IT infrastructure guided by Alshawi (2007) as shown in Figure 2.7. The elements are highly interdependent with each other to benefit from information system or information technology. Process improvement is shown as the core competency that an organisation needs to develop to achieve the IT capability. This element needs people with the necessary skills and power to implement process improvement with the management’s consent and the creation of an environment that facilitates the proposed change. Moreover, a high level of integration between the three elements can be enabled by a flexible IT infrastructure.

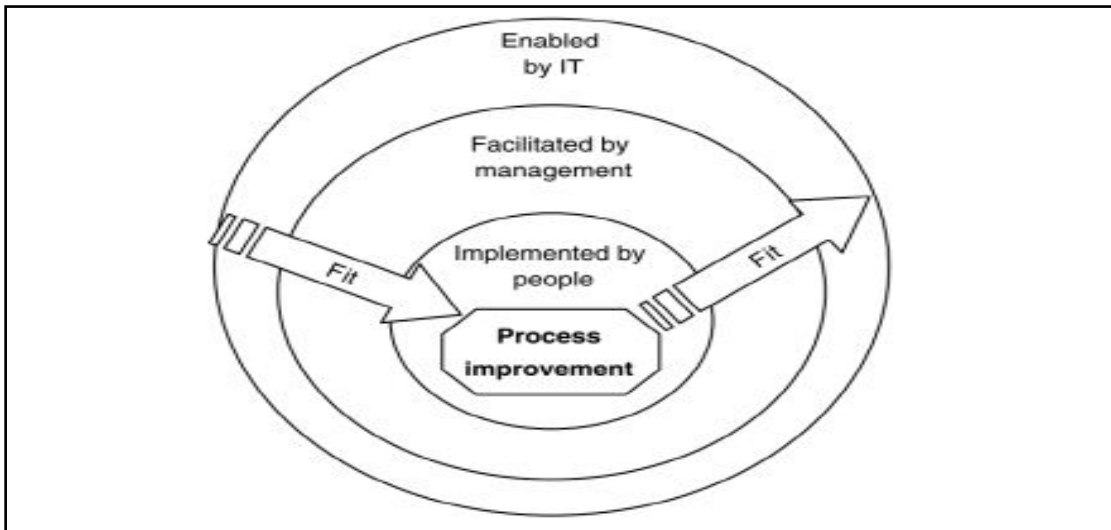


Figure 2.7: The four organisational elements of IT success (Alshawi, 2007)

In addition, the framework in Figure 2.8 puts emphasis on areas of knowledge sharing within the context of this research; the issues within each area of emphasis are shown to directly or indirectly influence knowledge sharing through environmental and motivational factors. This framework shows a clear process orientation aimed at describing factors for the knowledge sharing processes as well as knowledge-related processes. It has been organised on different levels (individual, cultural, team and organisational) and by knowledge types which are connected by generic knowledge sharing activities. Thus, by focusing on the four examples the framework provides a better understanding of the key factors, which influences knowledge sharing. Hence, for this research the focus is to improve the organisation's performance in implementing BIM through effective knowledge sharing practises. Therefore, this review uses an organising framework from previous knowledge sharing research and identifies emerging theoretical issues, which lays a foundation to the development of the framework for knowledge sharing practices in implementing BIM to improve the organisation's performance.

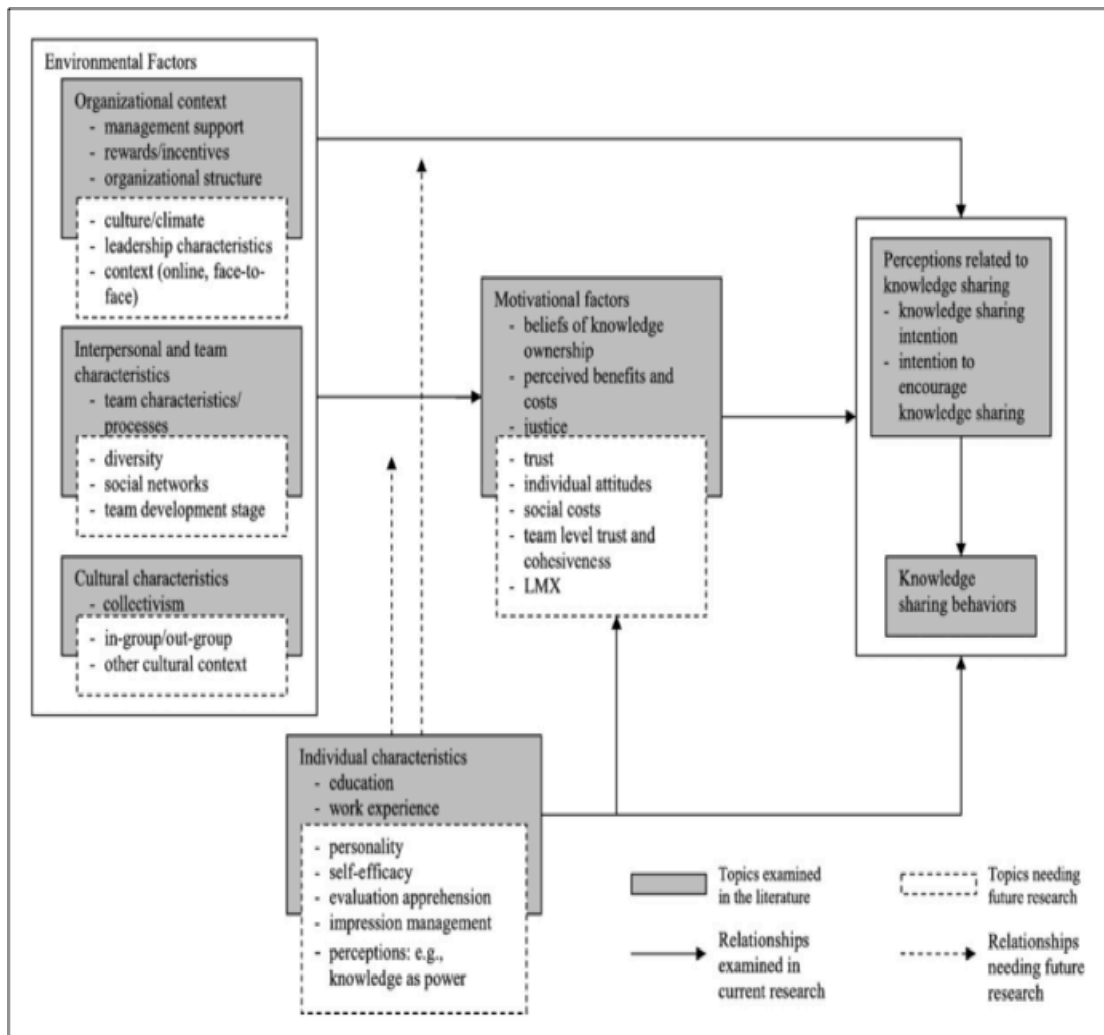


Figure 2.8: A Framework of knowledge sharing research

2.4.9 Key Factors for Knowledge Sharing Practices

Practice as defined in The Oxford Study Dictionary (1991) is repeated action. In this research, the knowledge sharing practices are habitual actions by the organisation considering people, process and technology elements to support the actions. Key factors are viewed as those activities and practices that should be brought forward to ensure the successful implementation of knowledge sharing in an organisation. Identifying the key factors is useful to provide researchers and practitioners with the basic requirements for developing a successful knowledge sharing practice among employees and teams within the organisation.

Knowledge sharing can take place at individual, group and organisational level. According to Lindner and Wald (2011) and Egbu and Coates (2012), the process of knowledge sharing involves a few steps that begin with the knowledge creation, followed by the use, transferring and sharing, and finally the storage of knowledge in a way that it is easy to retrieve for further use. Many authors have studied a comprehensive list of key factors for successful implementation of knowledge sharing in a different context, and some explain it through their model or framework development. For instance, during the 1990s Gilbert and Cordey-Hayes (1996) described a few key factors of knowledge sharing through the process of knowledge sharing in their developed model of a large management practice in Sweden. Some of the key factors are shown in Table 2.5. According to them, the process of knowledge sharing is dynamic which needs continuous learning and involves four steps. Beginning with the knowledge acquisition i.e. the knowledge that must be obtained before it can be transferred through lesson learnt, by doing, by 'borrowing', by acquiring individuals with new knowledge and by a continuous process of searching or scanning. This is followed by the communication of knowledge acquired through written or verbal means. However, if the aim of the organisation is to encourage knowledge transfer, it must be aware of the key factors that inhibit the distribution of information. The communication channels must be developed to provide an opportunity for the transfer of knowledge to occur and encouraged effectively. Then, the application of knowledge obtained and communicated must be carried out for it to be maintained to enable the organisation to learn. Assimilation is the result and effect of applying the knowledge gained and key to the process of knowledge sharing which requires the transfer of the results of history into the routines of the organisation. The researcher suggested the importance of a climate of learning in an organisation which means that the organisation must be adaptive and be able to respond to both internal and external environment, thus it must be open and be able to communicate (Gilbert & Cordey-Hayes, 1996).

Despite the learning environment, the communication for knowledge sharing stated by Ahmed et al. (2002) refer to the TOTS model that ties trust, openness and teamwork to describe the key factors for sharing knowledge. Trust involves both

managers' and employees' responsibility to practise their own initiatives. Workers need the management's trust to act in their personal capacity to make effective decisions in a group or as individuals. Also, openness makes employees feel more comfortable and will establish communication between all levels of the organisation, and further encourages the sharing of knowledge. For managers to gain trust, they can be part of a team by offering help when needed but not seen as a dictator who just gives the orders. Thus, having an environment of trust, openness and teamwork will increase the chance of creating a sharing environment (Ahmed et al., 2002) and knowledge sharing happens more efficiently if there is a level of trust existing between employees (Dave & Koskela, 2009). Meanwhile, Singh et al. (2011) believed that BIM integration will succeed with trust between different project participants.

Table 2.16: Analysis of the key factors of knowledge sharing (Adapted from Gilbert and Cordey-Hayes (1996) and Albino, Garavelli, and Schiuma (1999))

Reference	Component	Description
Gilbert & Cordey-Hayes (1996) Albino, Garavelli, & Schiuma (1999)	The actors	The individual or an organisation. The transfer process must focus on the ways different individuals deal with knowledge.
Gilbert & Cordey-Hayes (1996) Nonaka and Takeuchi (2004)	Process	Knowledge acquisition, communication, application, assimilation. SECI Process (Refer Figure 2).
Cordey-Hayes, 1996; Cohen and Levinthal, (1990) Albino, Garavelli, & Schiuma (1999).	Internal environment/ Organisational factor - culture	Place of the interaction takes place; internal or external environment. Internal context: corresponds to the organisational culture and is basically represented by a set of behaviours, technical skills and technology assets, attitudes and values belonging to and shared by the members of an organisation. It is characterized, on one hand, by the receptive and absorbing capability of the learning organisation and, on the other hand, by the transmission capability of the organisation, that is the ability of both making the tacit knowledge (individual know-how and organisation routines) explicit and codifying all the informal knowledge present in the organisation.
Gilbert & Cordey-Hayes (1996)	External	External context: The external context can be defined as a set of variables representing the conditions in which inter-organisational relationships take place. It influences the nature of the knowledge exchanged such as the market structure, its national/international scale, the connected technology path, firm cooperation, closeness, expectations and socio-cultural aspects.
Gilbert & Cordey-Hayes (1996) Ahmed et al. (2002); Dave & Koskela (2009) Eastman et al. (2011) Liu (2009)	Communication Organisational factor Leadership Organisational structure	Written or verbal Trust, openness and teamwork (TOTS model). A significant impact to accelerate the pace of BIM implementation also requires a leadership of senior management who has strong internal knowledge. Organizational structure refers to the way people and jobs in an organization are arranged so that the work of the organization can be performed

There are other authors who attempted to highlight the key factors for successful implementation of knowledge sharing. In a research on 400 firms of knowledge-intensive business services in Poland, Zieba and Zieba (2014) found that firms with leadership and support by the management, which employ motivational practices are more innovative than their competitors. Furthermore, Alawi et al. (2007), in their study of organisational culture identified trust, communication between staff, information systems, reward systems and organisational structure as critical success factors for the effective knowledge sharing in the organisation. In a case study of a construction project, the researchers discussed human resource strategies to encourage a knowledge sharing culture and suggested that the organisation recognises and rewards knowledge sharing, develop effective training and development systems and changing its organisational structures and work content to overcome the challenges of the construction industry (Dainty et al., 2005). Based on a research into the Jordanian construction industry, Arif, Mohammed, and Gupta (2015) found that trust was at the heart of control of knowledge within the organisation. The second important factor was the environment created by the management through motivation, demonstration of its commitment and appropriate organisational structure, climate and form. The third factor was the communication factor, which includes technologies, platforms and avenues created to facilitate KS before technology can be implemented. The current literature indicates that certain preconditions should be available in an organisation to enable the successful implementation of KM initiatives including knowledge sharing. Three main and critical factors were identified for organisational KM; organisational culture, structure and IT infrastructure (Shajera & Al-Bastaki, 2014).

It is important to mention that the approach of the research is not on developing the knowledge sharing practices 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 key factors of knowledge sharing practices 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 key factors are not rigid and are dependent on the responses captured during the interview. As far as the

research outcome is concerned, the key factors of knowledge sharing practices in implementing BIM which were explored and identified through the case studies will become the main contribution of the research. The identified key factors would be fed into the theoretical framework for developing the conceptual framework, which is discussed further in chapter 5. The identified key factors from the emerging case studies' findings are then validated and discussed in chapter 6. However, this section discusses some of the key factors identified during the literature review stage.

2.4.9.1 Leadership and management support

Many authors (Akhavan, Jafari, & Fathian, 2006; Al-Adaileh & Al-Atawi, 2011; Moshari, 2013; Zieba & Zieba, 2014), have identified the critical importance of leadership and management support to the successful implementation of knowledge sharing in an organisation. For successful knowledge management implementation, the visible leadership and commitment of top management must be sustained throughout a knowledge management effort (Moshari, 2013). Also, the organisations' management should encourage employees to give feedback to improve KS efforts. This will encourage them to contribute positively, raise creativity, encourage them to invent innovative ideas, and improve their performance (Alrawi & Hamdan, 2011). Nevertheless, Sandhu, Jain, and Ahmad (2011) argue that knowledge sharing is influenced by top management who do not clearly explain the approach of knowledge sharing, hence affecting employees' willingness to share knowledge. Two case studies by Gorry (2008) on knowledge sharing in the USA found that one of the main barriers to knowledge sharing is lack of management and leadership support. In a BIM implementation plan, Deutsch (2011a) and Smith and Tardif (2009) suggested that leadership requires senior management's support with a vision that aligns with the way the organisation works.

2.4.9.2 Human resource practices

Selecting the right people for the right jobs and training them to adapt to the organisation's vision while improving performance is a challenge for human resource

departments. It is argued that human resource practices should be aligned to strengthen knowledge sharing by focusing on team development training programmes, recognising and rewarding knowledge sharing as well as changing organisational structures and work content to suit the needs of knowledge workers (Dainty et al., 2005). In order to retain knowledge workers in an organisation, human resource management must also ensure conducive working environment as the desired working environment by using a variety of human resource mechanisms and techniques to encourage a knowledge-sharing culture such as teamwork, a shared vision, and promoting trust.

2.4.9.3 Organisational factor

2.4.9.3.1 Culture

Organisational culture is an important factor frequently mentioned to promote the sharing of knowledge. Maintaining an effective organisational culture is arguably the most significant determinant in the success of KM initiatives. Organisational culture can be defined as the shared, basic assumptions that an organisation learnt while coping with the environment and solving problems of external adaptation and internal integration that are taught to new members as the correct way to solve those problems (Park, Ribière, & Schulte, 2004). Each organisation has its unique culture, which develops over time to reflect the organisation's identity in two dimensions: visible and invisible. The visible dimension of culture is reflected in the espoused values, philosophy and mission of the firm while the invisible dimension lies in the unspoken set of values that guide employees' actions and perceptions in the organisation (McDermott & O'Dell, 2001). Organisations must encourage individuals and teams as a whole into believing that knowledge sharing is a healthy and normal way to do business. Having an appropriate and adaptable culture is not optional. If the culture is not KM friendly, "no amount of technology, knowledge content or good project management will make the effort successful" (Davenport & Prusak, 1998). Moreover, the success of a company at shaping its culture will help enhance its ability to manage knowledge more effectively (Davenport & Prusak, 1998).

2.4.9.3.2 Trust

Trust refers to a belief in people's capability (Szulanski, 2000) or to 'competence trust', which is a belief in people's competence (Fong, 2005). Trust also refers to trust within the organisation among the employees and between employees and the leadership (Arif et al., 2015). Commitment is the physical and mental expression of the concept of trust. It is the proof of trust. Commitment means that another party will take this trust on board and "live up to" the spirit of the bargain by probably committing more personal pride and obligation to "do the right thing" than would otherwise be the case (Bakri, Ingirige, & Amaratunga, 2010). Arif et al. (2015) found that trust is the main factor to control knowledge flows within the construction industry in Jordan. Trust is perceived to be positive in relation to knowledge donating and knowledge collecting. According to the research by Jain et al. (2015), cognitive trust is positively related to one's own willingness to share knowledge within the organisation (knowledge donating), while affective trust is positively related to one's ability to get colleagues to share knowledge (knowledge collecting).

2.4.9.3.3 Structure

Traditional organisational structures are usually characterised by complex layers and lines of responsibility with certain details of information reporting procedures. Currently, most managers realise the disadvantages of bureaucratic structures in slowing the processes and raising constraints on information flow. In addition, such procedures often consume a great amount of time in order for knowledge to filter through every level (Al-Alawi et al., 2007). While the centralisation of an organisation's structure can create a stable medium of control for making a decision, a more informal and flexible structure is needed for knowledge creation and knowledge sharing. Flexible structures lead to better internal communication and more openly shared ideas and knowledge (Egbu, 2005). Accordingly, Syed-Ikhsan and Rowland (2004) argued that knowledge sharing prospers with structures that support ease of information flow with fewer boundaries between divisions.

2.4.9.4 Technology

Technology may improve the efficiency of knowledge management processes. Knowledge Management (KM) techniques and technologies could be used to improve and enable the implementation of the sub-processes of KM, for instance, knowledge creation, codification, and transfer (Ruikar et al., 2007). Knowledge sharing, for example, is a sub-process of KM. Thus, technology is a fundamental element to the implementation of knowledge sharing. Alshawi (2007b) posits that technology is one of the key enablers to knowledge management as it allows the process of storing, organising and diffusing codified knowledge as well as externalising and socialising tacit knowledge. From the knowledge management perspective, the technology element is related to the knowledge management tools or also known as information technology (IT) tools (Al-Ghassani et al., 2005) as discussed earlier in 2.5.5.2. The level of IT support a company needs depends on its choice of knowledge management strategy (Hansen, Nohria, & Tierney, 1999).

2.5 Building Information Modelling

2.5.1 The Concept of Building Information Modelling (BIM)

The term BIM (Building Information Modelling) has gained much attention. The different definitions can be referred to in Table 2.17. While the model is an important component of BIM, many now view BIM as more of a process change than new technology. The model may serve as a knowledge resource for all project participants, but BIM is a process that enhances collaboration resulting in improved information management and an overall leaner process. Although at the beginning BIM was perceived as a new technology, in reality it is an emerging technology coupled with process and human interactions.

Table 2.17: Building Information Modelling (BIM) definition

No.	Author	Process	Technology/ Tool/ Software	Definition
1.	Construction Industry Development Board Malaysia (2014)	X	X	BIM is a modelling technology and associated set of processes to produce, communicate and analyse digital information for construction life cycle.
2.	Zahrizan, Ali, Haron, & Marshall-Ponting (2014)	X	X	BIM can be viewed as a combination of advanced process and technology that offers a platform for collaboration between different parties in the construction project by exploiting the uses of Information Technology (IT).
3.	Penn State Computer Intergrated (2013)	X	X	Building Information Modelling is the act of creating an electronic model of a facility for the purpose of visualization, engineering analysis, conflict analysis, code criteria checking, cost engineering, as-built product, budgeting and many other purposes.
4.	C. Egbu & Coates, (2012)	X	X	BIM is the utilization of a database infrastructure to encapsulate built facilities with specific viewpoints of stakeholders.
5.	Hardin (2009)	X	X	BIM is a process and software.
6.	McGraw Hill (2008)	X	X	BIM is the process of creating and using digital models for design, construction and/or operations of projects.
7.	AGC (2006)	X	X	Building Information Modelling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and improve the process of delivering the facility.

However, the definition of BIM technology is still subject to variation. Thus, Eastman et al. (2011) describe modelling solutions that **do not** utilise BIM design technology to avoid misunderstanding (refer to Table 2.18). BIM brought the industry forward from 3D CAD, animation, linked databases, spread-sheets, and 2D CAD drawings toward an integrated and interoperable workflow where these tasks are collapsed into an organised and collaborative process that maximizes computing capabilities, web communication, and data collection into information and knowledge capture (Eastman et al., 2011).

Table 2.18: Not BIM Technology (Eastman et al., 2011)

	Type of Model (Not BIM technology)	Description
a)	Contain 3D data only and no (or few) object attributes	<ul style="list-style-type: none"> - Only for visualizations. - No intelligence support for data integration and design analysis. - Limited use of analysis (only provide geometry and appearance for visualization).
b)	No support of behaviour	<ul style="list-style-type: none"> - Do not utilize parametric intelligence. - Creating inconsistency views of model.
c)	Composed of multiple 2D CAD reference files that must be combined to define the building	- No 3D model that is feasible, consistent, countable, and display intelligence regarding the objects contained within it.
d)	Allow changes to dimensions in one view that are not automatically reflected in other views	<ul style="list-style-type: none"> - Allowance for errors. - Difficult to detect.

BIM emerged from three dimensions and used components for design toward an integrated workflow where these tasks are collapsed into a systematic and collaborative process that maximises computing capabilities, communication features, and data aggregation into information and knowledge retrieval (Weygant, 2011; Eastman et al., 2011). According to Hardin (2009), BIM is a revolutionary technology and process that changed the way buildings are designed, analysed, constructed, and managed. BIM is also a digital representation of the physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder (Azhar, Khalfan, & Maqsood, 2012). BIM can be understood as a technology (software) and process that brings together multidisciplinary stakeholders in a facility's lifecycle by using three-dimensional intelligent models (Hardin, 2009).

Within the context of this research, and because it is related to the Malaysian context, BIM is defined based on the Malaysian BIM roadmap guideline. BIM is a modelling

technology and associated set of processes to produce, communicate and analyse digital information for a construction life-cycle (Construction Industry Development Board Malaysia, 2014). Modelling technology within this context of research is referred to as a 3D parametric authoring tool and some examples are BoCAD, Tekla Structures, Revit Architectures and Structures, Bentley Systems.

2.5.2 The Use of BIM in Construction Lifecycle

BIM covers assessment of IT use in the development, management and legal compliance within the facility lifecycle for the entire construction community (Eastman et al., 2011). Also, BIM can be applied in various stages of the project, from inception through project delivery as shown in Figure 2.9 below. The BIM uses are provided to familiarise project team members who are new to BIM. The guide suggested considering implementing BIM not in a full range. However, it stressed to the user concerning the main reason for using BIM in the project and to set objectives of adoption. Only then, the use of specific BIM application can be selected.

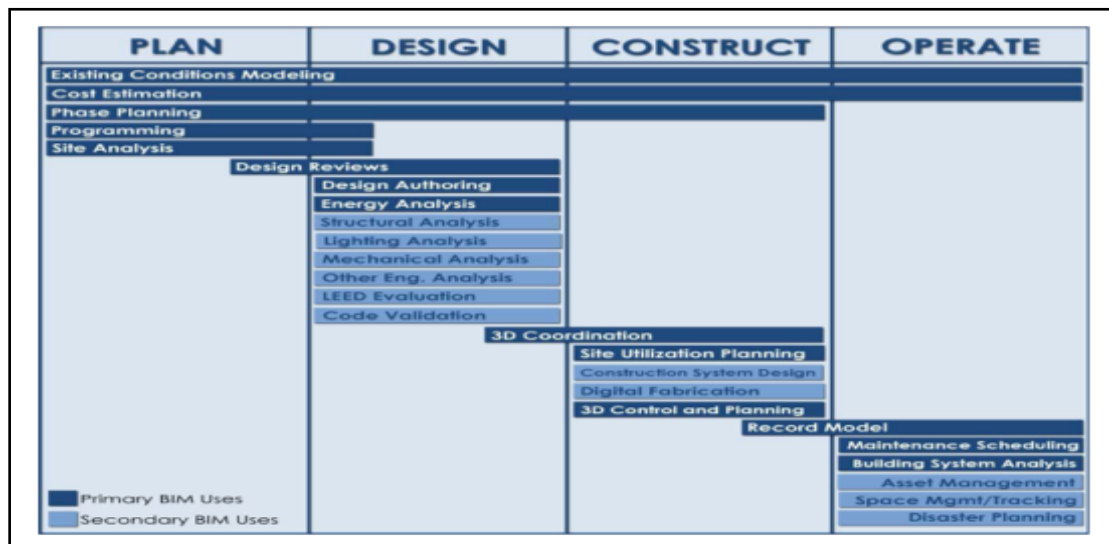


Figure 2.9: BIM use/ application in project life cycles (BIM Project Execution Guide, 2009)

BIM is used for model analysis, clash detection, product selection, and whole project conceptualisation (Weygant, 2011) to improve the performance and quality of construction projects. Importantly, BIM also supports the concept of Integrated Project Delivery (IPD) which is a novel project delivery approach to integrate people,

systems, business structures and practices into a collaborative process to reduce waste and optimise efficiency through all phases of the project life cycle (Glick & Guggemos, 2009; Latiffi, Mohd, Kasim, & Fathi, 2013; Nawi, 2012b) as shown in Table 2.19.

In addition, a building information model can be used for the following purposes (Azhar, 2011):

- a) Visualisation: 3D renderings can be easily generated in-house with little additional effort.
- b) Fabrication/shop drawings: It is easy to generate as-built drawings for various building systems.
- c) Code reviews: Fire departments and other officials can be quickly included once the model is complete. They may use these models for their review of building projects.
- d) Cost estimating: BIM software has built-in cost estimating features. Material quantities are automatically extracted and updated when any changes are made in the model.
- e) Construction sequencing: A building information model can be effectively used to coordinate material ordering, fabrication, and delivery schedules for all building components.
- f) Conflict, interference, and collision detection: All major systems can be instantly and automatically checked for interferences in 3D space.
- g) Forensic analysis: A building information model can be easily adapted to graphically illustrate potential failures, leaks, evacuation plans, and so forth.
- h) Facilities management: Facilities management departments can use forensic analysis for renovations, space planning, and maintenance operations.

Table 2.19: BIM applications and benefits in a construction life cycle (Latiffi et al., 2013)

Phase	Stage	BIM benefits
Pre-construction	Existing conditions modelling	Enhances accuracy of existing conditions documentation.
	Planning	Identifies schedule sequencing or phasing issues.
	Design	Facilitates better communication and faster design decision.
		Perform clash detection and clash analysis.
		Increases design effectiveness.
	Scheduling	Enables project manager and contractor to see construction work sequence, equipment, materials and track progress against logistics and timelines established.
	Estimate	Enables generation of takeoff, counts and measurements directly from a 3-Dimensional (3D) project model.
Site analysis	Decreases costs of utility demand and demolition.	
Construction	Construction	Enables demonstration of construction process, including access and exit roads, traffic flows, site materials and machineries.
		Provides better tracking of cost control and cash flow.
		Enables tracking of work in real time, faster flow of resources and better site management.
Post-construction	Operation/ Facilities management	Keeps track of built asset.
		Manages facilities proactively.
		Enables scheduled maintenance and provides review of maintenance history.

2.5.3 The Level of BIM

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 (2011) 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 that 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. 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.

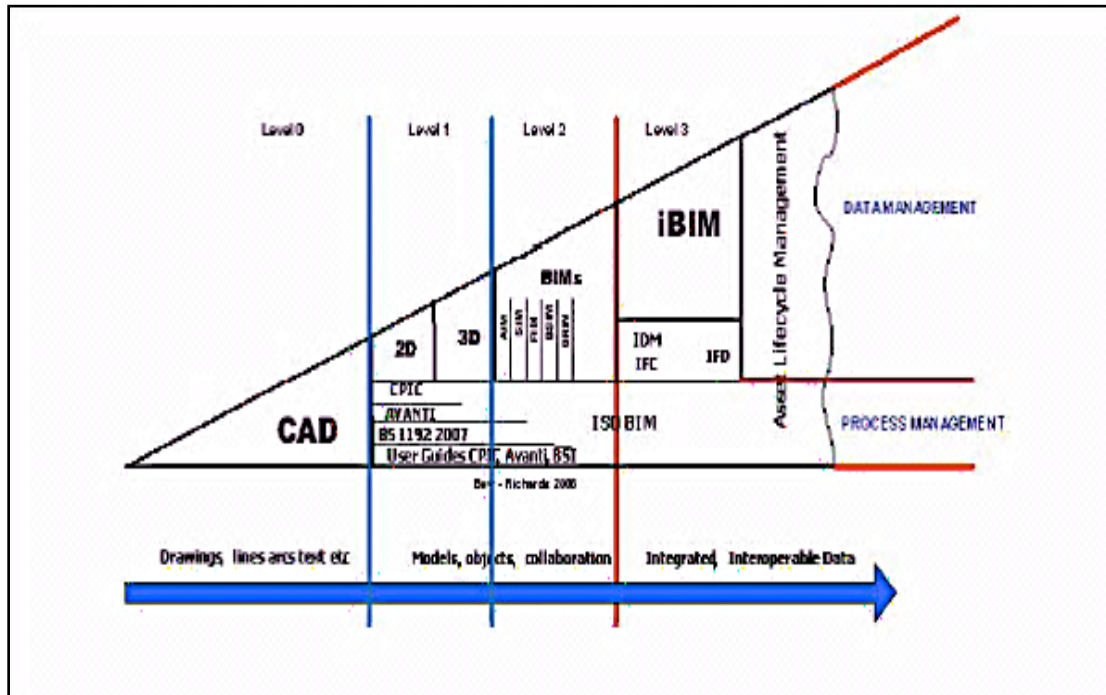


Figure 2.10: BIM Evolutionary ramp - construction perspective by Bew and Richard (2008) in Bew and Underwood (2010)

Referring to Figure 2.10, Bew and Richard (2008) in Bew and Underwood (2010) 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 managed by a stand-alone finance and 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.

Fully interoperable models in later stages will need new technologies to deliver the concept, maybe using Atomic or Federated BIM, to enable effective large data model sharing. This may need advanced Identity Lifecycle Management systems controlling the access and security.

2.5.4 Level of Detail/Development - Progression of BIM Model

Both the United States (US) and United Kingdom (UK) use Level of Definition to describe the level of model detail that could be used by the BIM users with different terms and numbers. The users could understand when referring to its descriptions guided by the given standard as shown in Tables 2.20 and 2.21.

BIM Standards and Execution Plans provide guidance on the process whereby collaborative teams can produce BIM models. The Level of Development (LOD) descriptions, included in Table 2.20 identify the specific minimum content requirements and associated authorised uses for each model element at five progressively detailed levels of completeness (AIA, 2013). For the United Kingdom BIM Strategy, the Construction Industry Council (CIC) first commissioned the BIM Protocol in 2013. The protocol was drafted for use with all common construction contracts (i.e. contracts for design and construction in respect of an asset) and supports BIM working at Level 2 (Construction Industry Council, 2018). In this BIM Protocol, Level of Definition means the Level of Model Detail and Level of Information. It uses APM Project Stages and references to Data Drops described in the UK Government BIM Strategy. The detailed description about Level of Definition that applies in the UK is given in Table 2.21.

Table 2.20: Level of detail/ development (AIA, 2013)

Level of detail/ development	Description
LOD100	LOD 100 is described as the development of model at a conceptual phase, where the model elements are in the form of narratives, information, non-geometric or line work or symbol. The party involved during this development is solely from architect background on the client's requirement.
LOD200	LOD 200 is the lowest level at which a geometric representation of a Model Element will appear. At LOD 200, the model will consist of generic elements of size, shape, location, orientation, any data associated with model element shown in approximate geometry with an estimated value. LOD 200 elements are useful both early in the design process when specifics have not yet been determined. In addition to the geometric representation, the LOD 200 Model Element may also include non-graphic information. The most common type of non-graphic information attached to Model Elements is cost information. The party involved during this development is solely from architect background on the client's requirement.
LOD300	LOD 300 Model Elements are specific assemblies, such as specific wall types, engineered structural members, system components, etc. The design of the Model Element is developed in terms of composition, size, shape, location and orientation. Constructability and coordination of other building components may require changes to some model elements after they are designated LOD 300, but such changes should be minimized as much as possible. The development involves other consultants such as structural and MEP engineers begin to populate the model with details of dimensions, capacities and assemblies. At this stage, the model is suitable for tender documentation and procurement.
LOD400	LOD 400 will provide a model with specific assemblies that are accurate in terms of size, shape, quantity and detailing information. A designation of LOD 400 indicates that detail beyond that included in LOD 300 is to be provided. A Model Element qualifies as LOD 400 once all information necessary for fabrication and installation has been resolved. The model at LOD 400 is suitable for construction where the development of shop drawings, construction method statements, fabrication, installation, material purchasing and others, begin to take place.
LOD500	LOD 500 is the final development level of BIM. When an as-built Model is required, obviously not every aspect of the Project is field verified. LOD 500 provides for specific indication of which elements will be field verified. This allows the owner to be clear on what is and is not verified, and allows whoever is responsible for producing the as-built Model to determine and price the effort involved. It is the development of as-built model and utilisation of model for maintaining and altering the building throughout its lifecycle. Model Elements do not necessarily need to be brought up to LOD 400 before going to LOD 500. Likewise, not all Model Elements will be developed to be LOD 500 in order to be appropriate for the as-built Model. A Model Element representing paint might never be developed beyond LOD 100, but the owner may want the colour field verified in certain areas.

Table 2.21: Level of detail/ development (British Standards Institution, 2013; Construction Industry Council, 2013)

Level of detail/ development	Description
Level 1 Brief	The graphical model will either not exist or will inherit information from the aim (for work on existing buildings and structures)
Level 2 Concept	The graphical design may only show a massing diagram or specify a symbol in 2D to represent a generic element.
Level 3 Develop Design	The object shall be based on a generic representation of the element. The specification properties and attributes from design allow selection of a manufacturer's product, unless the product is nominated, free issue or already selected.
Level 4 Production	The objects shall be represented in 3D with the specification attached. The level of detail should as a minimum represent the space allocation for the product's access space for maintenance, installation and replacement space in addition to its operational space.
Level 5 Installation	At build and commission stage any generic object shall be replaced with the object procured from the manufacturer. Any essential information to be retained shall be reattached or relinked to the replacement object. Inheritance of information is a complex issue and should be well understood and the solution tested at mobilisation. The selection of the product should give further detail about flanges and connections so that final positioning of pipework and ductwork can be defined. Although minimum levels of graphical detail can be specified at each design stage, care should be taken that adequate detail is provided to convey design intent and installation requirements.
Level 6 As constructed	All necessary information about the product shall be included in the handover document and attached to the commissioning and handover documentation. The as-constructed model shall represent the as-constructed project in content and dimensional accuracy. NOTE: In addition is all the manufacturer's maintenance and operation documentation, commissioning records, health and safety requirements, the final COBie information exchange, as-built models in native format and all relevant documentation.
Level 7 In Use	At the operation stage, the performance of the project shall be verified against the EIR and the brief. If the specification is not met and changes are necessary, then objects that have been changed or replaced with different equipment shall be updated accordingly. At the in-use stage, the object's information shall be updated with any supplementary information such as maintenance records or replacement dates, and objects that have been changed or replaced with different equipment shall be updated accordingly.

2.5.5 BIM Benefits

BIM advantages vary either for short-term or long-term investment and for project or business improvement. Several benefits of BIM has been discussed on improvement in sustainability for integrated data environment (Kivits & Furneaux, 2013), design management and knowledge (Elmualim & Gilder, 2013; H. Li & Wong, 2014), and facilitates design analysis, improves safety, productivity and monitoring the equipment in real time in different project phases (Li & Wong, 2014). It offers various benefits that are acknowledged by the researchers as shown in Table 2.21.

According to Li et al. (2014), BIM is a process involving the creation and management of objective data with property, unique identity and relationship. BIM is now being increasingly used as an emerging technology (Elmualim & Gilder, 2013; Wong et. al., 2009) to assist in conceiving, designing, construction and operating the building in many countries (Wong et. al., 2009). Besides, Mohd Nor and P.Grant (2014) posited BIM as a solution for communication and information barriers in AEC industry. The BIM technology helps building in a virtual environment prior to physical construction (Shujaa, Gardezi, Shafiq, & Khamidi, 2013; Takim, Harris, & Nawawi, 2013; McGraw Hill Construction, 2014). Despite traditional practice, BIM technology and associated processes allow responses by the building design and construction process to the increasing pressures of greater complexity, faster development, improved sustainability while reducing the cost of the building and its subsequent use (Eastman, Teicholz, Sacks, & Liston, 2011; Li et al., 2014; McGraw Hill Construction, 2014).

Table 2.22: Benefits of BIM

Author	Financial	Better information & communication	Better coordination	Improved sustainability	Respond to complexity	Improved visual	Create/improved services/business	Improved safety
(Azhar, 2011)	x							
(McGraw Hill Construction, 2008)		x	x					
Mohd Nor & P.Grant (2014)		x						
(Shujaa, Gardezi, Shafiq, & Khamidi, 2013; Takim, Harris, & Nawawi, 2013)		x				x		
(Eastman, Teicholz, Sacks, & Liston, 2011; Li et al., 2014).	x		x	x	x			
(McGraw Hill Construction, 2014)	x	x	x		x		x	
(Kivits & Furneaux, 2013)				x				
(Li & Wong, 2014)		x	x		x			x

According to findings from Stanford University’s Centre for Integrated Facilities Engineering (CIFE), based on 32 major projects, using BIM allows the following benefits to be realised (Azhar et al., 2008):

- a) Compared to traditional methods project time can be reduced by 7%;
- b) A good visualisation tool can be used to detect clashes enabling the owner to save up to 10% of the contract value via clash detection activities;
- c) Compared to traditional methods used to generate a cost estimate, utilisation of BIM can save up to 80% of time to generate a cost estimate.

Eastman et al. (2011) simplified BIM benefits at the design stage as follows:

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

BIM provides earlier 3D visualisations and quantifies the area of spaces and other material quantities, allowing for earlier and more accurate cost estimates. For technical buildings (labs, hospital, 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 can also support automatic evaluations.

b) Extraction of cost estimates during the design stage.

At any stage of the design, BIM technology can extract a 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 disciplines.

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.

2.5.6 BIM Future Challenges

BIM implementation is growing in many countries; however, some issues have been raised regarding culture, technology, process and policy (refer to Table 2.23) for the construction stakeholders, organisations and policy makers to take up the challenges for effective BIM implementation. Referring to analysis done by Won et al. (2013), there is an urgent need to tackle the managerial aspects rather than the technical aspects for effective implementation of BIM. They found the factors such as willingness to share and exchange information, knowledge and education as critical to motivate managers and project participants in implementing BIM. As suggested by Taylor and Levitt (2007), the organisation should first aligns BIM technology with their work process to realise the benefits and dissemination of the technological innovation. Thus, based on the many future challenges for BIM, and concerning the lack of awareness, knowledge, and competency, this research attempts to look into the tactical organisation's initiatives to promote and ease the organisational learning of implementing BIM by transferring and sharing knowledge related to BIM within the organisation for organisation improvement and competitiveness.

Table 2.23: BIM challenges

No.	BIM Challenges	Reference
Organisation Culture		
1	Learning curve of BIM trainees	Azhar (2011); Mohd Nor & P.Grant (2014); Azhar et al., (2012); Smith, (2014); Salleh & Fung (2014) ; Gu & London (2010); Singh, Gu, & Wang (2011); Hardin (2009); Arayici & Coates, 2013)
2	Inadequate commitment from top management, leadership issue and need for executive support	Chien, Wu, & Huang (2014); Mahamadu, Mahdjoubi, & Booth (2014); Eastman et al. (2011); Zahrizan et al. (2014); Arayici & Coates (2012)
3	Difficulty in process change management	Chien, Wu, & Huang, (2014); Zahrizan et al. (2014)
4	Lack of collaboration, need for information sharing and communication	Smith (2014); Dossick & Neff (2010); Azhar (2011); Shang & Shen, (2014); Kassem, Kelly, Serginson, & Lockley (2015)
5	Trust	Singh et al., (2011); Gu & London (2010); Mahamadu, Mahdjoubi, & Booth (2014)
Technology		
6	Cost of software and hardware	Mahamadu, Mahdjoubi, & Booth (2014); Won et al. (2013)
7	Selection of suitable software	Omar, Nasrun, Nawi, & Nursal (2014); Haron (2013); Chien, Wu, & Huang (2014)
8	Lack of interoperability, need for well-developed practical strategies for the purposeful exchange and integration of meaningful information	Chien et al. (2014); (Azhar, 2011); Azhar, Khalfan, & Maqsood (2012); Mahamadu, Mahdjoubi, & Booth (2014); Mat Ya'acob, Mohd Rahim, & Zainon, (2018)
9	Security	Shang & Shen (2014)
10	Inadequate skills and competency, need for technical support	Chien et al., (2014); Salleh & Fung (2014); Harris, Che Ani, Haron, & Husain (2014); Mahamadu, Mahdjoubi, & Booth, 2014)
Process		
11	No clear guidelines to implement, need for standardization	Azhar (2011); Salleh & Fung (2014); Zahrizan et al. (2013); Haron (2013); Gu & London, 2010); Mahamadu, Mahdjoubi, & Booth (2014); Mat Ya'acob, Mohd Rahim, & Zainon, (2018)
Policy		
12	Legal and data ownership	Azhar (2011); Mahamadu, Mahdjoubi, & Booth (2014); Shang & Shen (2014); Mat Ya'acob, Mohd Rahim, & Zainon, (2018)
13	Resistance to change, need for government strategy	Harris, Che Ani, et al. (2014)

2.5.6.1 Organisational Culture

As an emerging technology that integrates different backgrounds, experiences and multiple stakeholders, the team should realise their degree of inputs throughout the project lifecycle when implementing BIM. Recently, Smith (2014) explored the potential of quantity surveyor professionals becoming major players with vast advantages to improve the value of the services in the BIM environment. Meanwhile, new roles such as BIM manager, and the organisation structure of project teams arise in BIM-enabled projects (Singh et al. 2011). By this means, BIM in the near future will involve other career prospects. Therefore, defining the rights and responsibilities are critical between team members and model users (Hardin, 2009). Moreover, BIM is a cross-boundary system. Within organisations, roles can be redefined based on individuals' backgrounds. However, among organisations, project teams need to re-establish new communication channels and redefine the working pattern based on the new organisational structure and role of their partners, which has a direct impact on the BIM collaboration (Shang & Shen, 2014).

In order to learn new technological innovation, the ability of receivers to absorb, adapt and modify new technology through education and training has a huge impact on the receiver to become a sender of technology (Choi, 2009). Similarly, it is possible for BIM adopters to disseminate their knowledge on BIM to other industry players or within the project team after knowledge acquisition through education or training. Formal or informal education and training are crucial for staff to acquire BIM operational knowledge that does not only involve the application of technology but also the management of process and information. In the implementation of BIM, education and training should be a continuous effort as the adopters might start with small-scale projects before becoming champions. Interestingly, the result revealed that the decision to adopt new technology is influenced by education investment when respondents were concerned about the types of skills graduate acquire rather than commercial value (Mohd Nor & Grant, 2014). Moreover, action research undertaken by Arayici and Coates (2013) showed different areas of knowledge that should be acquired by people who are working within the BIM context depending on company

change processes and needs that will impact the business systems (refer to Figure 2.9).

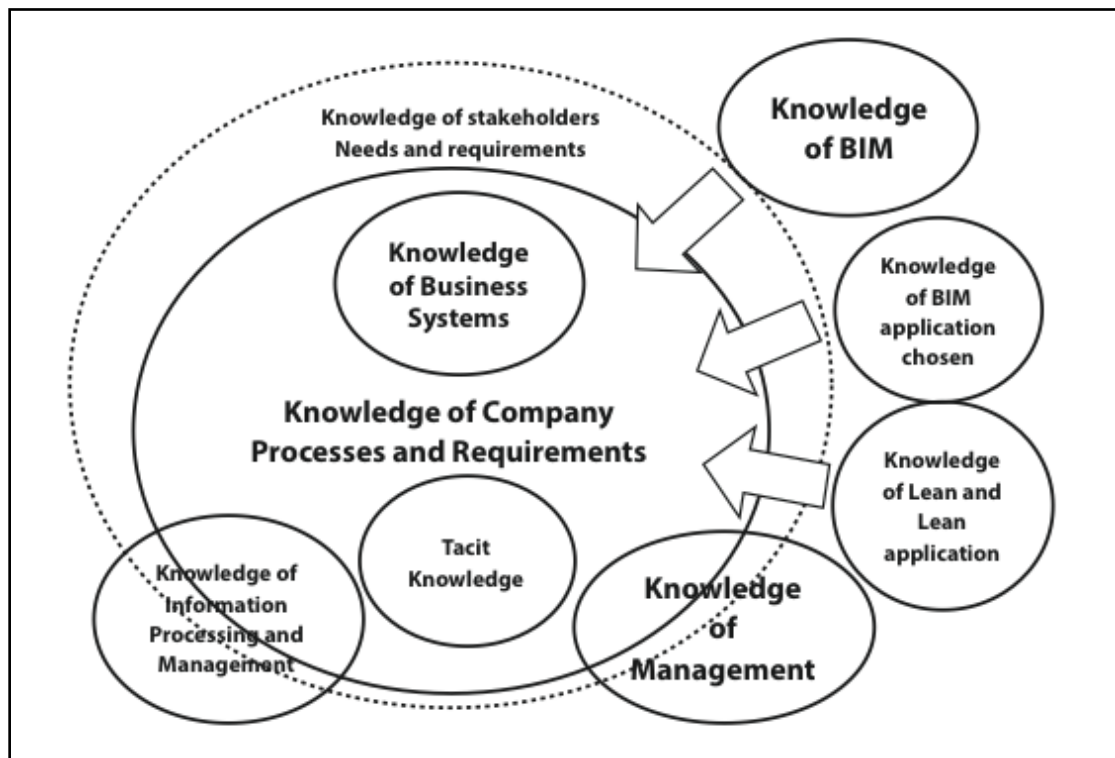


Figure 2.11:: The knowledge required to implement BIM (Arayici & Coates, 2013)

For BIM optimum performance, Azhar et al. (2012), Smith (2014), and Salleh and Fung (2014) urged organisations whether companies or vendors, or both, to find strategies to lessen the learning curve of BIM trainees while Gu and London (2010) pointed out the need for better training materials and technical support. In addition, staff ability and the effectiveness of the training should be examined (Singh, Gu, & Wang, 2011; Hardin, 2009; Arayici & Coates, 2013) to align an appropriate training strategy that will lead to an enhanced productivity payback (Hardin, 2009; Arayici & Coates, 2013). However, providing the staff with inappropriate training can also result in negative consequences. Importantly, it should encourage active participation of BIM learning and development within the organisation and provide learning mechanisms for new staff in the organisation (Arayici & Coates (2013).

The leadership of top management, the empowerment of the executive management team and the dedication of employees are also important to ensure the full benefits of BIM adoption are realised. A significant impact to accelerate the pace of BIM implementation also requires the leadership of senior management who has strong internal knowledge (Eastman et al., 2011) to motivate individuals in the organisation that are still lacking in knowledge to use new technology and to reduce the people's resistance to change (Zahrizan et al., 2014). Also, Zahrizan et al. (2014) claimed that initiatives of superior management personnel in the industry are needed to influence the staff and support the readiness of process change that is related to the culture within the organisation. Smith (2014) and Dossick and Neff (2010) argued that BIM projects are still facing organisational challenges that limit the collaboration between project stakeholders (Kassem et al., 2015) for modelling and model utilisation. Without the motivation by an individual leadership to hold team members for effective communication, the collaboration only exists for information exchanges rather than integrated problem solving and optimisation. In terms of training, Arayici & Coates (2012) also stated that visible support and leadership by the senior management is paramount to encourage BIM implementation and improve the staff skill.

Furthermore, BIM should enable visualisation and has a capacity to allow knowledge flows in a complicated working environment throughout a project lifecycle. Smith (2014) and Azhar (2011) pointed out the necessity of integration among various stakeholders. This reflects the importance of willingness to share information among project stakeholders (Won et al. , 2013). BIM broadens the work scope of stakeholders who require active information sharing and exchange, however, in reality, BIM only retrieves the information and resources (Shang & Shen, 2014). Thus, effective communication still depends on the human aspect and organisational culture that needs to be managed.

Meanwhile, Singh et al. (2011) believed that BIM integration will achieve success with trust between different project participants. Nevertheless, mutual trust on the

completeness and accuracy of 3D models has remained a major issue for industry players, resulting in information exchange on 2D drawings only (Gu & London, 2010). Trust is a main factor for strong collaborative relationships within the inter-organisational level.

2.5.6.2 Technology

Technology has been described as an appropriate medium or tool for improving team integration to support and synchronise all the project information and activities as a whole (Nawi, 2012b). Current BIM technologies available are varied and may provide different organisational capabilities, hence the stakeholders are required to assess currently available technologies on the market with necessary concern (Arayici & Coates, 2012). The selection of the most appropriate software solutions for individual firms is extremely important. Software should be chosen to improve the potential of the organisation after the investment has been made. In all cases, the software should enhance the ability of individual firms to communicate with other firms and exchange information reliably (Smith & Tardif, 2009). Omar, Nasrun, Nawi, and Nursal (2014) and Haron (2013) highlighted the importance of BIM software selection based on the correct analysis of company demand instead of choosing based on marketing promotion as it can influence the project execution throughout the building process. Furthermore, the demand for appropriate technological capability in project players was highlighted (Smith, 2014; Zahrizan et al., 2013), as well as software compatibility to exchange data for effective use of BIM (Chien, Wu, & Huang, 2014; Mat Ya'acob et al., 2018). Information cannot be transferred effectively with poor interoperability. The software also requires a powerful processor to run smoothly (Haron, 2013). Therefore, organisations need to carefully plan when upgrading or changing workstations. At the same time, organisations must be careful in terms of security to allow smooth communication. Low security always reduces the efficiency of remote communication, information sharing and harms trust between stakeholders (Shang & Shen, 2014). Furthermore, having technical support for early adopters may ease the process of using BIM. Inadequate experience and skills in BIM implementation (Chien et al., 2014; Salleh & Fung, 2014; Harris, Che Ani, Haron, & Husain, 2014) reflects the importance of having technical support particularly for new adopters.

2.5.6.3 Process

To date, many have claimed that there is a lack of standard documents and guidelines that can provide a clear direction and instructions for BIM implementation (Gu & London, 2010; Haron, 2013; Mat Ya'acob et al., 2018; Salleh & Fung, 2014; Zahrizan et al., 2013). Stakeholders tend to use BIM according to their own understanding and definition that may result in less collaboration. A standardised BIM process and defined guidelines will be necessary (Azhar et al., 2012), and also will clarify how BIM can be integrated in the current business practices. Gu and London (2010) reports that stakeholders should also understand the flexibility scope of BIM that can be accessed for only parts of the project's lifecycle.

2.5.6.4 Legal Issue and Government Strategy

BIM ownership needs to be protected through copyright laws and other legal channels to ensure data security and owner benefits. The American Institute of Architects (AIA) have formalised and documented legal regulation for digital design systems, and argued that ownership of the final output should belong to the client. The passive impact of this regulation is that designers no longer want to bear the risk of design errors and would rather use this as an excuse to transfer commitment to the ultimate owners. Thus, model ownership combined with a security system may in turn restrict users' access and hinder communication (Shang & Shen, 2014). Moreover, Mat Ya'acob et al. (2018) argued that there is no clear standard and policy on BIM process and procedure, no legal provision for intellectual property, cyber security, and ownership of the data model. In terms of procurement methods, BIM-based work processes require significant contractual changes. According to Eastman et al. (2011), several 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. Research by Owen et al. (2010) and Nawi (2012b) supported the implementation of BIM coupled with an integrated project delivery for successful collaboration in the construction industry. Government strategy will also help to boost the implementation for early adopters of BIM. Research suggested that government incentives and enforcement of regulations and policies are crucial to utilise BIM in projects

particularly to reduce the people's reluctance to change their attitude (Harris et al., 2014).

2.6 Research into knowledge sharing and BIM in Malaysian construction organisations

The term “knowledge” has been described as authorised information (Rezgui et al., 2010). It is based on the collection of information available and held by the mind from the range of information available (Khalil, 2000). Knowledge involves combining individual experience, skills, intuition, ideas, judgements, context, motivations and interpretation (Ahmed et al., 2002). Knowledge is not just made up of explicit knowledge which could easily be documented and stored, but instead involves tacit knowledge, which exists without being declared. The organisational knowledge can be created through a continuous communication between tacit and explicit knowledge as suggested by Nonaka and Takeuchi (1995) that knowledge is the product of the interaction of both explicit and tacit knowledge. Importantly, individuals within an organisation possess the essential knowledge, skills, and competencies from past experiences, which could benefit their new projects. Knowledge sharing is critical to knowledge creation, organisational learning, and performance achievement (Ipe, 2003; Nonaka, 2008). It is essential for the success of any organisation as effective knowledge sharing practices allow an individual and organisation to reuse and reproduce their knowledge to perform their role better. Knowledge sharing is also critical to an organisation's success (Davenport & Prusak, 1998; Nonaka, 2008) as it leads to faster knowledge distribution to portions of the organisation that can significantly benefit from it (Syed-Ikhsan & Rowland, 2004). Knowledge sharing is a vital process to retain competitive advantage and for the success of an organisation.

In the context of this study, knowledge sharing in implementing BIM is defined as the process where an organisation disseminates knowledge related to BIM implementation, which includes explicit and tacit knowledge to the members with continuous interactions through various approaches. In other words, knowledge sharing has become a tool or mechanism to assist the organisation in implementing

BIM. The knowledge sharing in implementing BIM among the employees or team members within the organisation could improve each employee's access and use of internal information and knowledge gained through various mechanisms such as different techniques, technical tools, the routines as well as practices used by the organisation.

Studies on knowledge management in Malaysian organisations are limited, especially in construction organisations, which covers the broader background of the organisations and different players in the industries (for instance builders, consultants, and developers) as discussed in Section 2.3.2. The knowledge management strategies and knowledge sharing practices in Malaysian construction organisations seem to have implications for Malaysia as a developing country that is moving towards Vision 2020 as a knowledge-based industry and developed country. The government of Malaysia has also urged construction organisations to adopt ICT to enhance productivity and efficiency. Accordingly, the Malaysian government set up some key performance indicators to facilitate BIM adoption to be achieved by 2020. Nevertheless, BIM adoption encompasses significant challenges such as the operational skills and knowledge for the users. Besides, it requires conceptual and process knowledge to confirm and create organisational, inter-organisational quality and requirements, which are likely to be a mixture of both organisation and project driven needs (Arayici & Coates, 2013). As global construction is moving towards higher quality and efficiency, and construction organisations need to face the challenges, it is crucial for BIM adoption to be managed efficiently by construction organisations to speed up the implementation. BIM can be seen as an innovation that will allow organisations to remain competitive. However, the study showed the implementation of BIM is still at a low level and needs to consider essential aspects such as management, education, and technology strategies (Mohd Nor & Grant, 2014; Zahrizan, Ali, Haron, Marshall-Ponting, & Abd Hamid, 2013; Won, Lee, & Dossick, 2013).

Malaysia is a diverse and multi-ethnic community that is encouraged by its government to pursue innovations in efficiency. However, there is limited research on construction organisations in Malaysia, particularly those that combined the issue of knowledge sharing practices in construction organisations with Building Information Modelling (BIM) application. Thus, this study tried to explore these two issues i.e. the knowledge sharing practices in implementing BIM to improve the performance of construction organisations.

The development of knowledge sharing by Malaysian construction organisations is therefore vital to the implementation of BIM within the construction industry. The necessity to adopt more organised knowledge sharing practices, which encompass the key factors in implementing BIM is crucial. Therefore, this research investigates how the knowledge sharing practices used by the construction organisations could help to accelerate and improve the BIM implementation. Also, this study identifies the key factors to knowledge sharing practices in implementing BIM to develop a framework of knowledge sharing practices in implementing BIM, which will serve to guide the construction organisations particularly in improving BIM implementation.

2.7 Theoretical Framework for Knowledge Sharing Practices in Implementing BIM

As mentioned earlier, four theoretical frameworks were employed to develop the framework for this research. The four theoretical frameworks are (a) A Receiver-Based Model of Knowledge Sharing (Lichtenstein & Hunter, 2006), (b) Foundation of knowledge management system model (Gorelick & Tantawy-Monsou, 2005), (c) The four organisational elements of IT success (Mustafa Alshawi, 2007a), and (d) A Framework of Knowledge Sharing Research (Wang & Noe, 2010). A theoretical framework as shown in Table 2.23 is then proposed to guide the line of research inquiry, and the development of the key factors of knowledge sharing practices for the framework is based on the emergence of the exploratory data that is captured in the case studies. The selection and adaptation of each element were made based on the

suitability of the element to be used within the context of the organisation and within the context of BIM implementation.

Table 2.24: Theoretical framework to explore key factors of knowledge sharing practices in implementing BIM

ELEMENTS	PRACTICES OF KNOWLEDGE SHARING
PEOPLE	Leadership and management support
	Human resource practice - teamwork
	Organisational factor – culture, trust, openness, structure
PROCESS	Communication
	Organisational factor – culture, trust, structure
TECHNOLOGY	KM techniques and technologies
	IT Infrastructure

The proposed elements of assessments are used to guide the line of research inquiry, and the development of the key factors of knowledge sharing practices 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 dependent on the responses captured during the interview. As far as the research outcome is concerned, the key factors of knowledge sharing practices in implementing BIM, which is explored and identified through the case studies has become the main contribution of the research. The identified key factors would be fed into the theoretical framework for developing the preliminary framework, which is discussed further in Chapter 5. The synthesis and justification of each knowledge sharing practice element are further discussed in Chapter 5 instead of this chapter to connect the logic and reflect upon the data that were collected with literature validation and also to eliminate any overlapping in the discussion.

2.8 Chapter Summary

The primary objective of this research is to develop and validate a framework of an organisational knowledge sharing practices in implementing BIM in Malaysian construction organisations. A theoretical framework is proposed as shown in Table 2.23 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. This chapter contributes to the research objectives by satisfying the following objectives:

1. To explore and review relevant literature related to the challenges in the local context (Malaysia) construction industry, the needs towards change, innovation, knowledge-based economy (K-economy) and the use of ICT.

Another objective is to review and examine relevant literature related knowledge management concept in general and particularly knowledge sharing and to further explore and review BIM concepts, uses, benefits, and challenges. The next chapter (Chapter 3) discusses the research design and methodology adopted for this research.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

It is critical that an appropriate research methodology is adopted to achieve the aim of this research. Research methodology refers to the principles and procedures of logical thought processes which are applied to a scientific investigation (Fellows & Liu, 2008). In this study, the research methodology will refer to the ‘research onion’ model in Figure 3.1 (Saunders, Lewis, & Thornhill, 2011).

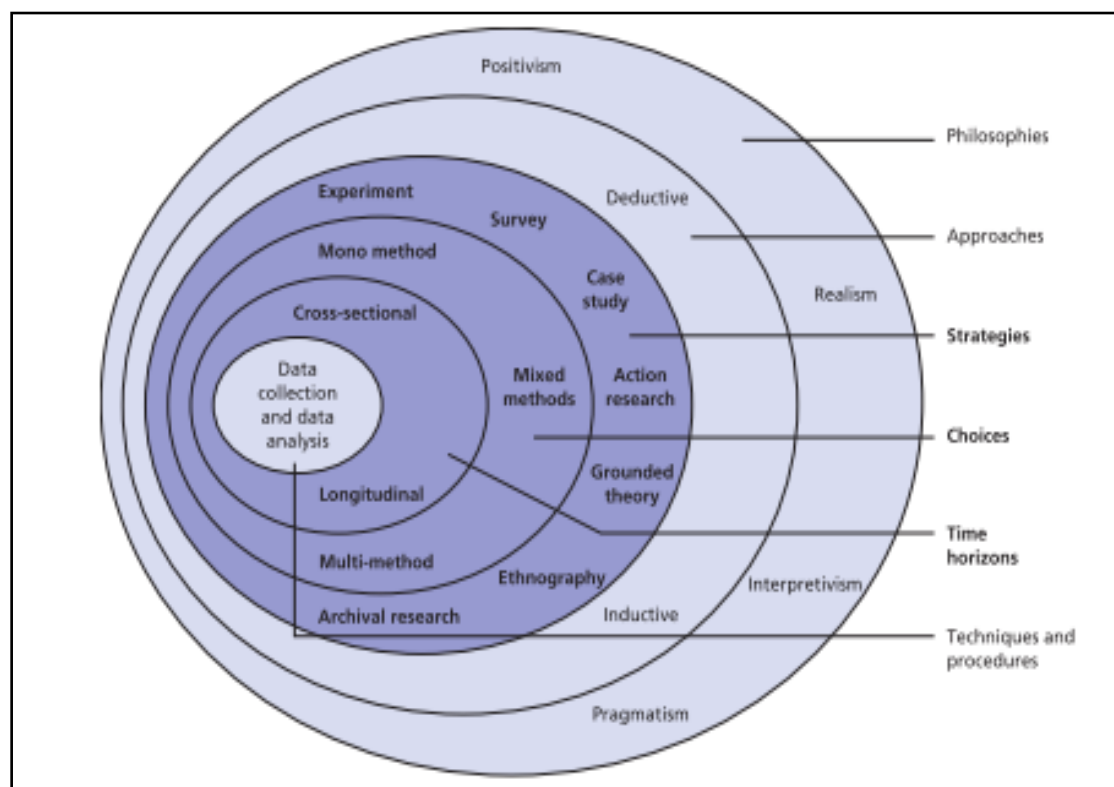


Figure 3.1: Research Onion (Saunders et al., 2011)

3.2 Research Philosophies

Research philosophy depends on the researcher's thinking and assumptions about the progress of knowledge which, in turn, affects the way the research is done (Saunders et al., 2011). Other uses of the term worldview or paradigm or broadly conceived research methodologies for the assumptions (Creswell, 2009). It contains essential assumptions that will underpin the research strategy and methods chosen as part of that strategy. Within the layer of research philosophy, the formation is made by ontology, epistemology, and axiology.

3.3 Ontology

Ontology is the nature of reality. The term refers to the philosophical assumption about the nature of reality (Creswell, 2009). Reality happens when it is thought in the mind of the players involved in the situation. It is not separate from the mind of the players in the situation. Ontological paradigms include objectivism and constructivism.

3.3.1 Objectivism

Objectivism in this aspect means an ontological position that asserts that phenomena and their meanings have an existence that is independent from the actors (Bryman & Bell, 2007; Saunders et al., 2011). It is the philosophy of reality that includes the theory about the nature of the world and how we acquire knowledge of it. It is the step of referencing reality to determine the truth. In view of the above definition, objectivism will not be adopted to underpin the position of this research.

3.3.2 Constructivism

The constructivists hold assumptions that individuals seek understanding of the world in which they live and work with subjective meanings through experiences. Meanings are developed by human beings as they engage with the world they are interpreting.

This paradigm leads the researcher to look for the details of views rather than narrowing meanings into a few ideas only. The research aims to rely much on the respondents' opinions of the situation being researched (Creswell, 2009).

3.4 Epistemology

The study of knowledge is also known as epistemology. It answers the questions of how do we know what we know. Epistemology is concerned with the claims of what is assumed to happen can be understood. Positivism and interpretivism are examples of epistemological positions.

3.4.1 Positivism

Positivism is an epistemological position that advocates the application of the methods with an observable social reality and beyond (Bryman & Bell, 2007; Saunders et al., 2011). This paradigm also believes that the only reliable knowledge is that which is based on sense, facts and positive justification (Bryman & Bell, 2007; Creswell, 2009). It recommends that the real world is objective and there is a relationship between the world and our understanding and perception of it. The positivist stance is not appropriate and does not fit with the objectives of this research.

3.4.2 Interpretivism

The purpose of an interpretive explanation is to encourage understanding. The interpretive theorist tries to discover the meaning of an event or practice by placing it within a specific social context. The researcher tries to appreciate or believes the operation of the social world, as well as get a sense or to see the world as another person does (Neuman, 2007). Also, interpretive inquiry uses qualitative and naturalistic approaches to inductively and holistically understand human experience in context-specific settings.

3.5 Axiology

Axiology is the science of value. It is a subset of philosophy that studies judgment about value which seeks to provide a theoretical account of the nature of values relative to morality, prudential or aesthetic (Saunders et al., 2011). It is an assumption on the value that the researcher attaches to the knowledge about social enquiries in deciding whether the reality in the research is value-free or value driven. In value-free, the choice of what to study and how to study can be determined by objective criteria, while in value-laden, the option is determined by human beliefs and experiences (Saunders et al., 2011). This research is value-laden.

3.6 Philosophical Position Adopted

The positioning of the research paradigm for this study is summarised as having these three qualities as follows:

a) Ontological assumption

In developing a new framework, this research is directed from the respondent's view, based on their reality of actual experience and practice (constructivism) instead of an unpracticed opinion view (objectivism) relating to the knowledge sharing practices in implementing BIM within the Malaysian construction industry. Furthermore, this research aims to generate precious data to build up theories. Therefore, this research is theory building rather than theory testing. Additionally, the research environment is not expected to be controlled and simplified with assumptions and hypotheses as in the deductive approach used in positivist studies.

b) Epistemological undertaking

As discussed earlier, the nature of this research leans more towards interpretivism. Therefore, it is rooted in the notion of lived-world experience that involves a socially constructed instead of ideality among multiple practitioners to seek the information for developing new knowledge sharing practices in implementing BIM framework. Thus, the research environment cannot be controlled as human

beliefs and interests determine the idea constructed whereas the knowledge is gained from the participation. Accordingly, constructivism assumption has been identified as the most appropriate research epistemological for this study based on knowledge gathered by examining the variety of knowledge sharing frameworks, practices, and tools in an organisation and construction.

c) Axiological purpose

This research also validates the developed framework of KS practices for an effective BIM implementation in the Malaysian construction industry. The phenomenon under this research is interpreted within a context through direct interactions and involvement among BIM practitioners (client, designers, integrated designer and contractor). In this context, this study leans towards the value-laden research.

In conclusion, the philosophy of this research leans more towards constructivism of the ontological stance, while on the epistemological perspectives, it leans towards the interpretivism and the axiological view of being value-laden. Some of the research (Egbu, 2013; Haron, 2013; Kulatunga, 2008; Nawi, 2012b) in Built Environment studies also adopted this paradigm as the research required the researcher to understand, explore, and elicit opinions, views and perceptions from the respondents. Thus, this justifies the research philosophy as relevant within Built Environment studies. The philosophical position of the research influences the selection of an appropriate research approach as described in the next section. The following section focuses on the second layer of the onion model, establishing the proper research approach for this research.

3.7 Research Approach

The research approach is used to support the interpretation of data; it can be either inductive, deductive or a combination of the two (Saunders et al., 2011). Understanding these approaches is essential to provide the researcher with the choice

of the appropriate research paradigm and enhance the efficiency of the research. The significant differences between deductive and inductive approaches to research are shown in Table 3.1. As shown in Figures 3.2 and 3.3, deductive reasoning works from the more general to the more specific while inductive reasoning works from the ground up rather than being handed down entirely from a theory (Cavana, Delahaye, & Sekaran, 2001; Creswell, 2009; Gill & Johnson, 2010).

Table 3.1: Major differences between deductive and inductive approaches to research (Saunders et al., 2011)

Deduction emphasises	Induction emphasises
Scientific principles Moving from theory to data The demand to explain causal relationships between variables The collection of quantitative evidence The application of controls to ensure the validity of data The operationalization of concepts to provide clarity of definition A highly structured approach Researcher independence of what is being researched The necessity to select samples of sufficient size to generalise conclusions	Gaining an understanding of the meanings people attach to events A close understanding of the research context The collection of qualitative data A more flexible structure to allow changes in research emphasis as the research progresses A realisation that the researcher is part of the research process Less concern with the need to generalise

3.7.1 Deductive Approach

The deductive approach is a method by which the researcher starts with a theoretical proposition and then moves towards concrete empirical evidence (Cavana et al., 2001). The deductive approach is more formalised and structured where the data categories and codes for analysis are taken from theory and followed with a predetermined analytical framework. Hence, a deductive research approach is associated with the positivism paradigm, which includes a hypothesis to prove assumptions. It also allows the researcher to establish a hypothesis by using theory. In the deductive approach, the researcher collects different types of data and information to confirm or reject the hypothesis to resolve the issue (Gill & Johnson, 2010). The deductive method relies on instruments like surveys and experiment. It is used in

research where questions are raised by the hypothesis that is deduced from theory and needs to be tested. Saunder et al. (2011) highlighted that it is a must to collect an adequate sample size for a generalised conclusion. Figure 3.2 shows the steps of the deductive approach development from the development of theory to confirmation of hypotheses.

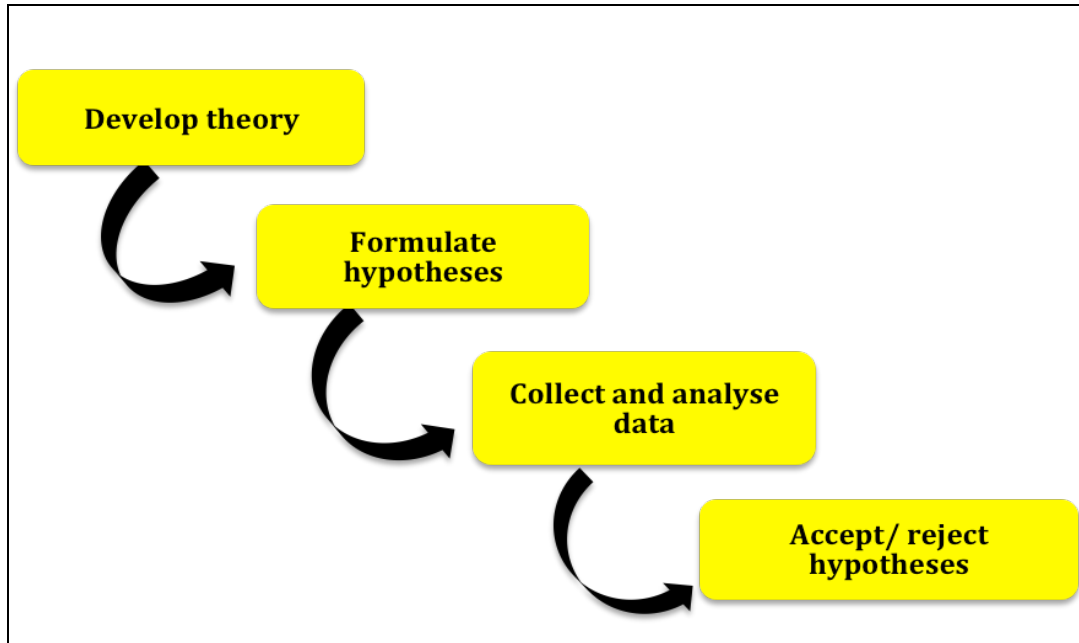


Figure 3.2: Deductive reasoning in business research (Cavana et al., 2001)

3.7.2 Inductive Approach

The inductive approach relies on interpretation and is less structured. Procedures that are inductive are without a prior analytical framework, categories, and codes that direct researcher analysis. Thus, an inductive research approach is linked with interpretivism. This inductive approach allows the researcher to gain and understand the study context with the help of various human experience to the phenomena or events (Saunders et al., 2011). Inductive research is a flexible approach because there is no requirement for a pre-requisite theory to collect data and information. The researcher uses observed data and facts to analyse patterns and themes and formulate relationships to develop a theory with regards to the research problem. The inductive approach relies on instruments like interviews, where themes and theories occur after the collection and analysis of some or all the data. It is entirely a reversal in method from the deductive approach. Figure 3.3 shows the steps of observation, pattern,

themes, relationships and theory development in the inductive approach. It is an approach by which a phenomenon is observed, and some conclusions are derived.

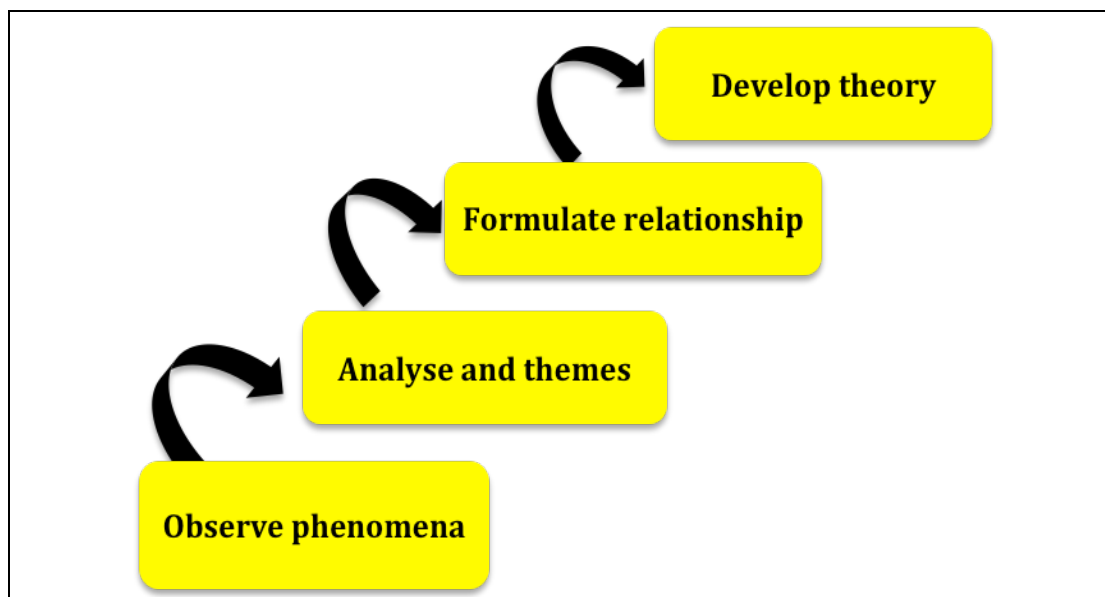


Figure 3.3: Inductive reasoning in business research (Cavana et al., 2001)

This study explores and investigates the current knowledge sharing approaches, processes, and the benefits and challenges in implementing BIM in Malaysian construction organisations. After considering the nature of the research problem, this research leans towards the interpretivism paradigm. The data in this study leans toward qualitative (subjective) rather than quantitative (objective) analysis. A semi-structured case study interview has been used as a research strategy. By this means, the research is associated with qualitative research and does not involve any testing of a theory or hypothesis. Consequently, an inductive approach which is aligned with a qualitative research method, has been used as the research approach. However, the researcher began the research by deducing from literature to obtain some understanding and concepts related to the context of the study. According to Saunders et al. (2011), using both approaches makes it very easy to estimate a logical and correct result but it is necessary for the researcher to combine the right pieces of these approaches. In conclusion, the researcher adopted both the deductive approach (conducted literature review) and the inductive (interviewed respondents in case studies) in this research to obtain data; constructing meaning and relationships to validate the result.

3.8 Research Strategy

According to Remenyi, D., Williams, B., Money, A. and Swartz (2003), a research strategy provides the overall direction of the research including the process by which the study is conducted. However, no research strategy is inherently superior or inferior to any other (Saunders et al., 2011). Consequently, a research strategy will enable the researcher to answer researchers' particular research question(s) and meet researchers' objectives. It depends on the researchers' research question(s) and objectives, the prior knowledge, the availability of time and resources, together with a philosophical stance (Saunders et al., 2011). Research strategies are types of qualitative, quantitative, and mixed methods design, which direct the procedures in research design (Refer Table 3.2). The research design is defined as a logical plan that connects the empirical data to the initial research questions and, ultimately, to its conclusions (Yin, 2009). The research design is also known as approaches to an inquiry or research methodologies (Creswell, 2009).

Table 3.2: Alternative Strategies (Adapted from Creswell, 2009)

Alternative Strategies		
Quantitative	Mixed Methods	Qualitative
-Experimental designs -Non-experimental designs, such as surveys	- Sequential - Concurrent - Transformative	- Narrative research - Phenomenology - Ethnographies - Grounded theory studies - Case study

Yin (2014) listed five different strategies i.e. an experiment, a survey, archival analysis, history and case study. Saunders et al. (2011) also highlighted another three strategies of action research, grounded theory, and ethnography in addition to the list by Yin (2014). Fellows and Liu (2007) also suggested that specifically for construction, five methods can be considered; action research, ethnographic research, surveys, case studies, and experiments. As the research was positioned within a qualitative approach based on the research questions posed, the options available were

action research, ethnographic research, and case studies. A summary of the relevant situations for different research strategies based on the literature reviews (Yin, 2014; Saunders et al., 2011) has been referred to as a guideline to be followed in the research and is shown in Table 3.3 below.

Table 3.3: Relevant Situation for Different Research Strategies (Adapted from Yin, 2014; Saunders et al., 2011; Denscombe, 2010)

Research Strategies	Advantages	Disadvantages	A form of a research question	Requires control of behavioural events?	Focuses on contemporary events?
Case study	In-depth, capture complexities, relationships; multiple data sources and methods; flexible time and space, less artificial	The problem of generalisation; focus on the natural situation; unpredictable; unacceptable for some course	How, why?	No	Yes
Action research	Collaborative; the researchers and context integrity; for practitioner-researchers; professional and personal development; practical	Difficult for new researcher; exclusive; work setting influence; unacceptable for some course	How?	Yes	Yes
Grounded theory	Generating theory from research; flexible structure; detailed set of rules and procedures	Too specific; ignore the previous knowledge to the analysis; many variants of the strategy	'How,' focus on process	No	Yes
Ethnography	Feasible within the constraint of time and researches; direct observation; no specific data collection methods; rich data; deal with culture, inclusive	Difficult for new researcher; high skill needed; descriptive to explanative; ethical issues; limited accessibility; the problem of generalisation	'Why,' to understand context and perception	No	No
Archival research (documentary study)	Independent researcher; the researcher will not influence the quality of the documents; can repeatedly be reviewed	The documents might be produced for a specific reason; lead to bias; can be difficult to find (irretrievability)	Who, what, where, how many, how much	No	Yes/ no
History	Applicable deal with 'dead' sources of evidence; can repeatedly be reviewed	The data is limited in term of in-depth descriptions (not produced specific reason)	How, why?	No	No
Survey	Widely used; quantitative and qualitative; directive; affordability of large data; high predictability	Misplace findings; challenging to obtain truthful data; less detail and depth; maybe not applicable for phenomenon studies	Who, what, where, how many, how much?	No	Yes
Experiment	Clear possibility & answer; controlled context, replicable generable; safe time and resources; causal relationship	Requires specific knowledge; artificial; ethical problem due to variable control; quantitative does not explain	How, why?	Yes	Yes

3.8.1 Experiment

Experiments are often highly structured, one-off, and artificial. It commonly involves quantitative data; which requires specific knowledge.

3.8.2 Survey

Surveys are often highly structured, cross-sectional, and shallow. Hence, they may not be best suited for capturing the key factors of knowledge sharing in the way it naturally happens. Surveys may result in what people claim to do rather than what they may actually do.

3.8.3 Ethnography

With its longitudinal nature and potential application of several methods, ethnography provides a major means of capturing an intact cultural group in a natural setting. Its main strength of ecological validity is derived from the use of participant observation (Creswell, 2009). Ethnographies are based on observational work in particular settings. It involves a researcher as a participant in an extended period of observation. Anthropological (the initial thrust) fieldwork routinely involves immersion in a culture over a period of years based on learning the language and participating in social events with the people (Silverman, 2010).

3.8.4 Grounded Theory

It is a strategy where the researcher develops a general, subjective theory of a process, action, or interaction in the perspectives of participants with multiple stages of data collection. This design involves the refinement and the constant comparison of data with emerging themes and theoretical sampling of different groups to benefit the similarities and the differences of information (Creswell, 2009).

3.8.5 Action Research

Action research is a valuable variant of quasi-experiments. It entails planned interventions and collaboration between the researcher and a specific context. This design is suitable for a practitioner who is also a researcher that seeks practical

implication. However, it could be difficult for a new researcher as it has exclusive access to the research setting, which new researcher often has the opportunity.

3.8.6 Case Study

Case study research consists of a detailed investigation—often with data collected over a period of time—of phenomena, within their context. The aim is to capture an analysis of the setting and processes, which illuminates the theoretical issues being studied. The event is not isolated from its context (as in, say, laboratory research) but is of interest precisely because the aim is to know how behaviour and/or processes are influenced by, and influence context (Hartley, 2004). Case studies can be based on a longitudinal or cross-sectional time horizon. Hence, making it suited for capturing the holistic views with respect to this study. Its flexibility allows the use of appropriate methods such as interviews to explore naturally and sincerely. This makes it suitable for answering the research question in the context of this study.

3.8.6.1 The Justification for Using a Case Study

Various research strategies offer advantages but also have disadvantages. In order to choose the right research strategy the researcher considered three points as suggested by Denscombe (2010), Saunders et al. (2011) and Yin (2014b) They are firstly the type of research questions, secondly, the extent of control a researcher has over behavioural events and lastly concerns the degree of focus on contemporary events. Yin (2014) pointed out three conditions that can be used to select the relevant strategy. These conditions consist of the type of research question posed, the extent of control the researcher has over actual behavioural events and the degree of focus on contemporary as opposed to historical events.

The selection of case study as the research strategy is strengthened by the following justification:

a) The type of research question

This research poses the question of ‘how’ and ‘what’ in an exploratory way. Yin (2009) described that the question is posed to deal with the operational links needing to be traced over time, rather than mere frequencies or incidence. This research aimed to develop KS practices in implementing BIM framework. The research explored, developed and modified the framework once the data was collected. It is not about describing the frequency of a phenomenon as in surveys, or to describe a culture-sharing group as in ethnography, or to describe dialogue and reflection based on data from experience as in action research.

b) The extent of control a researcher has over 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 history and case study since the researcher had no control over the implementation of BIM by the organisation, condition of participants during data collection, or any policy engaged within the organisations that were investigated.

c) The degree of focus on contemporary events

Since this study is focused on contemporary events which aim to provide a holistic and rich amount of the respondents’ views to the key factors of knowledge sharing in implementing BIM within the context of construction organisations, it eliminates the other research strategies and leaves the researcher with the case study strategy which is best suited to meet the aim and objectives of this research.

Case study focuses on one or just a few instances of a particular phenomenon to provide an in-depth account of events, relationships, experiences or processes occurring in that specific instance (Denscombe, 2010). The case study allows the researcher to focus on particular cases in an attempt to identify the detailed interactive process which may be crucial, but which are transparent to the large-scale survey,

thereby providing a multi-dimensional picture of the situation under research (Remenyi et al., 2003). Thus, the case study is relevant as a research strategy for this study. It allows researchers to take advantage of the focus on the contemporary event by exploring and investigating the current knowledge sharing approaches, processes, key factors in implementing BIM in Malaysian construction organisations. Moreover, the choice of various source of evidence that could be collected from a case study and the flexibility of data collection (Eisenhardt, 2002) make it relevant to this study in understanding the organisations' business process, perspectives of people on KS practices and unique characteristics of the construction organisation's work environment.

3.8.6.2 Determining the Case or Unit of Analysis

Choosing and establishing the case needs to be done carefully using a proper basis. Selection of cases is an essential aspect of building theory from case studies (Eisenhardt, 2002). According to Yin (2014b), the definition of the unit of analysis relates to the way in which a researcher has defined the initial research questions. Miles and Huberman (1994) defined the case as "a phenomenon of some sort occurring in a bounded context". The case is, "in effect, your unit of analysis." Furthermore, Baxter and Jack (2008) suggested to delineate a case by asking and answering the following questions;

- a) Do I want to "analyse" the individual?
- b) Do I want to "analyse" a program?
- c) Do I want to "analyse" the process?
- d) Do I want to "analyse" the difference between organisations?

In determining the "Case" for this study, the researcher focused on the research questions developed (refer to Table 3.4), referred to the definition of a case by Miles and Huberman (1994) and Yin (2014b), and posed and answered the questions suggested by Baxter and Jack (2008). Therefore, the case (unit of analysis) of this research refers to the phenomena of knowledge sharing practices in implementing BIM bounded in the context of Malaysian construction organisations (construction organisations which implement BIM).

Table 3.4: Research Questions and The Case

The research questions	Decision on Case
<p>1) How are knowledge sharing practices in implementing BIM used by the construction organisation to improve the BIM adoption and implementation?</p> <p>2) What are the factors influencing knowledge sharing practices in implementing BIM by the construction organisation?</p>	<p>The knowledge sharing practices in implementing BIM by the construction organisation.</p>

3.8.6.3 Binding the Case

In order to achieve some focus, Silverman (2010) suggested that researchers be geared to specific features of the case. Suggestions on setting the boundaries of a case include: (a) by time and place (Creswell, 2003), (b) time and activity (Stake, 1995), and (c) by definition and context (Miles & Huberman, 1994). Defining the boundaries of the case will ensure that the researcher’s study remains reasonable in scope (Baxter & Jack, 2008). Therefore, the boundaries of the case in this study are as explained in Section 1.5.

This research concentrates on construction organisations which employ BIM in its business rather than a project. The rationale lies in the nature of BIM investment which needs a long-term investment and could only cover the return on investment through some of project implementation and thus requires a long-term effort by the organisation. Smith and Tardif (2009) mention that long-term investment often hid and depends on education and training that will allow an entire organisation to change its business culture, and in the resulting reform of core business processes to achieve higher productivity. The construction organisation which has implemented BIM can be a client, a designer, an integrated design consultant or a contractor. These are all types of organisations involved as players in the Malaysian construction industry and possibly involved in BIM implementation. However, it is important to highlight in this research that the BIM implementation level in Malaysia is still considered low as mentioned in Mohd Nor & Grant (2014), in Zahrizan, Ali, Haron, Marshall-Ponting, and Abd Hamid (2013), and also mentioned by the gatekeeper from the Construction

Industry Development Board of Malaysia (refer to Section 3.13.4.1). This result reflects the number of participants who agreed to participate in this research. Although three out of six organisations are BIM consultants, their involvement in BIM implementation must be according to the scope of this research (refer to Section 1.5). These six organisations covered small, medium enterprises (SMEs) and large construction organisations in Malaysia. Importantly, the involvement of the construction organisation in implementing BIM is the key scope to further explore the research elements and achieve the objectives of this research.

3.8.6.4 Determining the Type of Case Study

The selection of a particular type of case study design will be guided by the overall study purpose (Baxter & Jack, 2008). Yin (2009) and Stake (1995) use different terminology to describe the various types of case studies. Yin categorises case studies as explanatory, exploratory, or descriptive as defined in Table 3.6. Yin (2009) also discusses four (4) types of case study design based on a 2x2 matrix that consists of single and multiple case studies reflecting different design situations. The following are the types of case study designs; (1) single-case holistic, (2) single-case embedded, (3) multiple-case holistic, and (4) multiple-case embedded (Figure 3.4). Stake (1995) identifies case studies as intrinsic, instrumental, or collective. Definitions of these types of case studies are provided in Table 3.5.

Table 3.5: Definitions of Different Types of Case Studies

The Types of Case Study	Definition	Author
Explanatory	This type of case study would be used if you were seeking to answer a question that needs to explain the presumed causal links in real-life interventions that are too complex for the survey or experimental strategies. In evaluation language, the explanations would link program implementation with program effects.	Yin, 2003
Exploratory	This type of case study is applied to explore those situations in which the intervention being evaluated has no clear, single set of outcomes.	Yin, 2003
Descriptive	This type of case study is used to describe an intervention or phenomenon and the real-life context in which it occurred.	Yin, 2003
Single Case study	A single case represents the critical case in testing a well-formulated theory (resemblance the analogy to the critical experiment). The case might serve as an extreme case or a unique case, representative or typical case. It can be used to determine whether a theory's propositions are correct or whether some alternative set of explanations might be more relevant. This design is also applicable to the revelatory case where the researcher has an opportunity to observe and analyse a phenomenon that previously was inaccessible. Also, it is suitable for the longitudinal case.	Yin, 2003
Multiple-Case studies	A multiple case study enables the researcher to explore differences within and between cases. The goal is to replicate outcomes across cases. Because comparisons will be drawn, it is imperative that the cases are chosen carefully so that the researcher can predict similar results across cases, or predict different results based on a theory.	Yin, 2003
Intrinsic	Enables researchers who have a genuine interest in the case to use this approach when the intent is to better understand the case. It is not undertaken primarily because the case represents other cases or because it illustrates a particular trait or problem, but because in all its particularity and ordinariness, the case itself is of interest. The purpose is NOT to come to understand some abstract construct or generic phenomenon. The objective is NOT to build theory (although that is an option).	Stake, 1995
Instrumental	Is used to achieve something other than understanding a particular situation. It provides insight into an issue or helps to refine a theory. The case is of secondary interest; it plays a supportive role, facilitating our understanding of something else. The case is often looked at in detail, its contexts scrutinized, its ordinary activities detailed, because it helps the researcher pursue the external interest. The case probably not as common as in other cases.	Stake, 1995
Collective	Collective case studies are similar in nature and description to multiple case studies by Yin, 2003	Stake, 1995

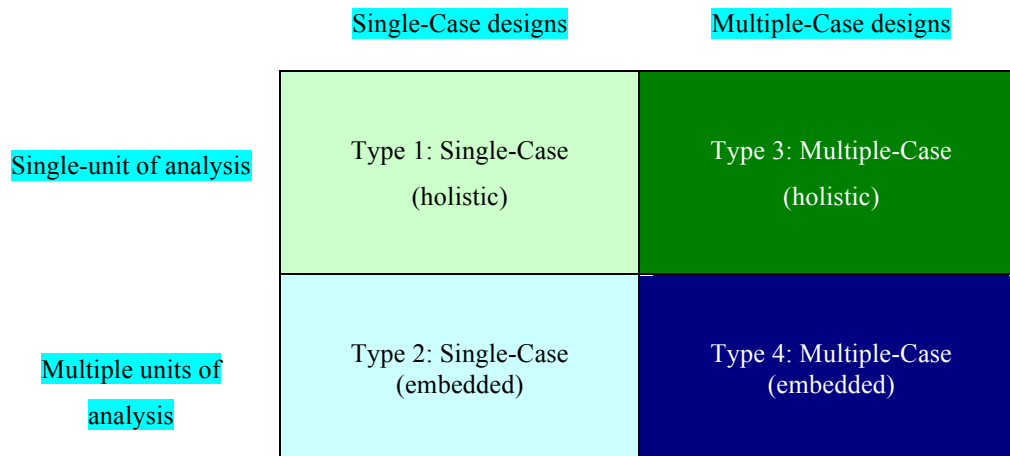


Figure 3.4: Basic Types of Designs for Case Studies (Yin, 2009)

These design classifications provide the choice to select a case according to the nature of the particular research and can be adopted in advance before the commencement of research data collection. According to Saunders et al. (2011), a single case is often used where it represents a critical case or an extreme or unique case. A single case may be selected because it is typical or because it provides an opportunity to observe and analyse a phenomenon that few have considered before. Inevitably, an important aspect of using a single case is defining the actual case. In the same way, a case study strategy can also incorporate multiple cases.

Yin (2009) found that a single-case design is appropriate under several circumstances and all five rationales have been adduced to support single-case design. These rationales have been briefly explained. A single case is necessary when it presents a critical case in testing a well-formulated theory. Satisfying all conditions for theory testing, single-case can confirm, challenge, or extend the theory. Further, it has been established that a single case can be utilised efficiently where the case presents a significant contribution to knowledge and theory building. Additionally, an individual case can be efficiently utilised where the case represents an extreme case or a unique phenomenon. However, the third rationale put forward for a single case by Yin (2009), is that a single case can be a representation or typical case where the objective is to capture circumstances and conditions of an everyday commonplace situation.

Moreover, single-case can be a revelatory case. This type of study is undertaken when the researcher has an opportunity to observe and analyse a phenomenon, which previously was inaccessible to social science inquiry. It is also acknowledged that single-case study can be longitudinal when the same single case is being studied at two or more different points in time. Despite the compelling reasons for a single case design that can be found in Yin (2009), it has emerged strongly from the literature that single case studies produce samples that are often insufficient and such results are therefore quite hard to generalise for the benefit of a larger population. This limit, however, has been addressed by the multiple case studies design. Multiple case studies design is preferred to single case design to improve the robustness and generalisation of case studies results.

Multiple case studies provide credibility to research results and substantially reduce the criticism and scepticism that usually are associated with case studies thereby producing an even stronger effect on the outcome of the research (Yin, 2009). Conducting two case studies research produces a stronger impact on the research process (Yin, 2009). Miles and Huberman (1994) indicated that multiple cases are conducted to increase the methodological rigor of the study by saying they enhance "strengthening the precision, the validity and stability of the findings" (Miles & Huberman, 1994, p. 29). Also, one of the strengths of the multiple case studies approach is that it allows the researcher to use a variety of sources, a variety of data types and a variety of research methods as part of the investigation (Denscombe, 2007). More importantly, the analytic benefits from multiple case studies may be substantial if there is the possibility to have direct replication (Yin, 2009). In the light of this, Yin (2009) advised that having at least two cases should be the researcher's goal. From the discussions, multiple cases provide a clear and compelling credibility to the research process, as it has been granted that research involving multiple case studies is regarded as more robust compared with a single case. Understanding complex situations in case studies research is key. Therefore, in this perspective, multiple case studies provide an opportunity for the researcher to gain access to a variety of data from a broader spectrum. These various forms of data enable the researcher to explain the phenomenon being studied adequately.

Regarding the design of case study, a single-case study or multiple case studies may either be holistic or embedded. The holistic type could be used when the case study has no logical sub-units, for instance the case study examined only the global nature of an organisation or a program. In contrast, embedded design occurs when there is more than one unit of analysis (Yin, 2009). Adopting the embedded design allows a researcher to examine the studied phenomenon from different levels and to search for evidence through different units, but the case study should be large enough to accept such a design.

Considering the various rationales that have been espoused in respect of case study design for qualitative data gathering, this research has adopted the Case Type 3 (Yin, 2009, 2014b), that is multiple-holistic case design. In the context of this research, multiple case studies are the most appropriate approach since the phenomenon being studied does not present a critical, extreme or unique case situation. Also, the event under study is not typical, revelatory or it is to be studied as a longitudinal case. Therefore, single case design is not suitable for the conduct of this research. Nevertheless, multiple-holistic case design has been adopted because principally there is only one unit of analysis that is required to be studied to identify the knowledge sharing practices in implementing BIM within Malaysian construction organisations. In the context of this research, the researcher has the opportunity to understand the phenomenon in real-life i.e. knowledge sharing practices in implementing BIM by construction organisations (BIM practitioners) within the construction industry in Malaysia.

3.8.6.5 Selection of the Cases and Sampling

Yin (2014b) stressed that the cases should be selected according to the purpose of the research. This research developed a framework of KS practices in implementing BIM which encapsulates the key factors of KS that support BIM implementation by the Malaysian construction organisations. Therefore, the selection criteria were based on selecting the firms within the Malaysian construction industry which have implemented BIM. Accordingly, six cases were identified. Miles and Huberman

(1994) stated that in qualitative research, sampling size is less important than the samples selected for quantitative research. Neuman (2007) and Silverman (2010) identified different types of samples such as convenience sampling, quota sampling, snowball sampling, sequential sampling and purposive sampling, deviant case sampling, and theoretical sampling. According to Neuman (2007), purposive samples are samples selected from fieldwork for particular purposes. He gave the researcher control over the sampling selection to judge the ones that meet the specific purpose of the research. Therefore, this research investigates the knowledge sharing practices in implementing BIM in Malaysian construction organisations.

The cases may be chosen to replicate previous cases or extend new theory, or they may be selected to fill theoretical categories and provide examples of polar types (Miles & Huberman, 2002). This research chooses to make the replication logic, thus providing a robust finding. Yin (2009), suggested that replication logic of multiple-case design could be either a literal replication or a theoretical replication of the cases between two to ten. In literal replication, the number of cases is between three to four cases whereas in theoretical replication the suitable number of cases is between six and eight. Accordingly, this study chose a literal replication logic with six cases where the saturation of the data collection was achieved.

3.9 Research Choice: Multi-method

Saunders et al. (2011) claimed that identifying an appropriate 'research choice' is very important for the guidance of research techniques and procedure selection process. There are three types of research choice in social management research; mono-method, multi-method and mixed methods. The researcher can use all the methods either as a single data collection technique and corresponding analysis procedures (mono-method), use more than one data collection techniques and analysis procedures (multiple methods) or use both quantitative and qualitative data collection techniques and analysis procedures to answer the research question or meet the research objective (mixed methods approach) (Saunders et al., 2011).

As explained earlier, this research applied case study as the primary strategy for qualitative primary data collection process and the literature review as a secondary type of data. This research, therefore, involved soft, descriptive and less structured data (qualitative data) whereas the researcher intends to gather deep and rich information on knowledge sharing practices in implementing BIM from the views and reaction of various Malaysian BIM practitioners (knowledge-based experience) who are representing their construction organisation. Accordingly, all secondary sources of data that is related to historical data or with the focus on non-contemporary events, for example archival records, are irrelevant to be applied in this research. The strategy of this research, however, did not focus on the investigation or exploration of interpersonal behaviours and motives thus disqualifying any sources related to participants' observations from being included in this research. Nevertheless, this research explored the organisational knowledge sharing practices in implementing BIM, which also investigated the process, procedure, and environment related to the KS practices during the interview. However, the nature and duration of study did not allow involvement on confidentiality issues, and therefore physical artefacts are not used as data sources as well.

Accordingly, this research approach followed qualitative multi data collection techniques (refer to the research technique section) with corresponding analysis procedure (multi-method qualitative studies) for the research time horizons that will be discussed in the next section.

3.10 Time Horizons: Cross-sectional

In the discussion of the time horizons, there are two main terms known as 'snapshots' time horizon and 'diary' perspective. According to Saunders et al. (2011), 'snapshots' time horizon is referred to as cross-sectional while 'diary' perspective is called longitudinal. Typically, these time horizons depend on the research question.

3.10.1 Cross-sectional studies

The cross-sectional study is a study of a particular phenomenon (or phenomena) in a specific time (Saunders et al., 2011). It could be used either as quantitative or qualitative methods. This research seeks to describe the incidence of a phenomenon or to explore the practice and how factors are related to different organisations by using the case study strategy conducted through interviews. For instance, many case studies are based on interviews conducted over a short period of time (Saunders et al., 2011).

3.10.2 Longitudinal studies

Longitudinal research is based on a long-term period of study. According to Saunders et al. (2011), the main strength of this research is its capacity to study change and development. The best example of this research is from outside the world of business. It is based on the study for a few years to gain a rich source of data for the development of a new theory. This research involves an examination of the particular phenomenon at one specific time. Moreover, this research is undertaken for academic courses (Ph.D.) and is time-constrained. Following the above descriptions of time horizons, the cross-sectional studies are more relevant to be adopted based on this research time and resource constraint.

3.11 Research Techniques

Research techniques and procedures in this context refer to the method for data collection and analysis. The following section discusses the techniques employed.

3.11.1 Data collection

As stated in research choices, this research follows qualitative multi data collection techniques as a primary source for the primary and secondary data. For the case study research strategy, it involves a wide array of procedures as the researcher builds an in-depth picture of the case. Case studies commonly combine data collection methods.

Creswell (2009) listed four main methods of data collection for qualitative studies; namely observation, interviews, documents and audio-visual materials. Earlier on, Yin (2009) had listed six types of data sources; documentation, archival records, interviews, direct observation, participation-observation and physical artefacts. The strengths and weaknesses of various source of evidence are shown in Table 3.6.

Table 3.6: Strengths and Weaknesses of Six Sources of Evidence (Yin, 2009)

Source of Evidence	Strengths	Weaknesses
Documentation	<ul style="list-style-type: none"> • Stable- can repeatedly be reviewed • Unobtrusive- not created as a result of the Case study • Exact- contains exact names, references, and details of an event • Broad coverage- a long span of time, many events, and many settings 	<ul style="list-style-type: none"> • Retrievability- can be difficult to find • Biased selectivity, if the collection is incomplete • Reporting bias- reflects (unknown) bias of the author • Access- may be deliberately hidden
Archival records	<ul style="list-style-type: none"> • Same as those for documentation • Precise and usually quantitative 	<ul style="list-style-type: none"> • Same as those for documentation • Accessibility due to privacy reasons
Interviews	<ul style="list-style-type: none"> • Targeted- focuses directly on Case study topics • Insightful-provides perceived causal inferences and explanations 	<ul style="list-style-type: none"> • Bias due to poorly articulated questions • Response bias • Inaccuracies due to poor recall • Reflexivity-interviewee gives what interviewer wants to hear
Direct observations	<ul style="list-style-type: none"> • Reality- covers events in real time • Contextual- covers context of 'Case.' 	<ul style="list-style-type: none"> • Time-consuming • Selectivity-broad coverage difficult without a team of observers • Reflexivity-event may proceed differently because it is being observed • Cost-hours needed by human observers
Participant-observations	<ul style="list-style-type: none"> • Same as above for direct observations • Insight into interpersonal behaviour and motives 	<ul style="list-style-type: none"> • Same as above for direct observations • Bias due to participant-observer's manipulation of events
Physical artefacts	<ul style="list-style-type: none"> • Insightful of cultural features • Insightful into technical operations 	<ul style="list-style-type: none"> • Selectivity • Availability

Primary data for this research was collected via interviews, company's document reviews including company's website, and direct observation where access was granted. Secondary data was obtained via literature reviews. A literature review is also critical in providing a sound basis for the inquiry and will be conducted through the course of research. There are three common types of interviews; the semi-structured interviews, the focused interviews, and the formal survey. The semi-

structured interviews are typically used in a case study research, as it gives the respondents the opportunity to relate to the research matter in their own opinion and insights, which in return may yield improved information for the researcher. The focused interviews are used to confirm the researcher's proposition with the respondents; however, the effectiveness of these interviews as a data collection tool relies on the ability of the researcher to be inquisitive without appearing to impose their understanding on the respondents. Overall, interviews are an important source of case study evidence because most case studies are about human affairs. These human affairs should be described and interpreted through the eyes of specific participants, and well-informed respondents can provide important insights into a situation (Yin, 2009). To gain a robust theory building, it is necessary for in-depth knowledge to be gained from the organisations. The use of semi-structured interviews gave the researcher the opportunity to retrieve detailed information on the current knowledge sharing practices in implementing BIM.

All interviews in this research had an exploratory and explanatory nature as they gave 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. All the interviews were audio recorded and transcribed for analysis. The use of an audio recorder was not only to increase the accuracy of data collection but also permitted the researcher to be more attentive to the interviewees. When the interviews were being recorded, the researcher also took important notes when necessary. The question list for the interview was emailed to the potential interviewees a few weeks in advance to provide enough time for the participants to think about the issue and make the interview more effective. Before the interviews, all the interviewees were briefed on the audio recording and its purpose for the study in advance. The researcher ensured that the interviewees were comfortable being recorded, for ethical purposes. The interview questions were also kept short and brief to ease the interviewees' responses. The researcher also attempted to acquire a documented source of knowledge sharing practices and BIM implementation such as implementation plan, standard operating procedure, training guide, and many more. However, the written evidence was treated as confidential by

all the companies. Only a few written evidence was collected and the use of the evidence, as requested by the interviewee, were restricted to the use of the thesis only.

3.11.2 Data analysis

The data obtained in this research were analysed using content analysis approach. All semi-structured interview conducted has been recorded and transcribed. The content analysis approach was applied with the aid of a coding scheme to distinguish between the different categories of thinking among the respondents. At this point, the NVivo software was used to assist in analysing the interview data.

3.12 Validity and Reliability Issue

Validity in qualitative research refers to the verification process of the findings employed by the researcher (Gibbs, 2007) whereas the reliability indicates that the researcher's approach is consistent across different cases (Yin, 2014). They require specific procedures, and as suggested by Yin (2009) for the explorative type of multiple case studies, the validity and reliability procedures can be summarised in Table 3.7 below. To address these issues, the research followed a case study validation strategy, as proposed by Yin (2014) and shown in Table 3.7.

For the reliability issue, throughout the process, the case study protocol was also developed and documented. The case study protocol in the form of interview questions can be further referred to in Appendices 3 and 4. 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. In addition, for each individual case that was investigated, reports of findings 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.

Table 3.7: Organisation Tactics and Proposed Measures for Construct Validity and Reliability adopted from Yin (2014)

TESTS	CASE STUDY TACTICS	PROPOSED MEASURES
Construct Validity	<ul style="list-style-type: none"> - Use multiple sources of evidence. - Maintain a chain of evidence. - Have key informants review draft of case study report. 	Triangulation: <ol style="list-style-type: none"> i. more than a single data sources (data – document review, interview), ii. theory (knowledge sharing, BIM), and iii. methodological (data analysis methods: descriptive, content analysis)
Reliability	<ul style="list-style-type: none"> - Use case study protocol. - Develop case study database. 	<ul style="list-style-type: none"> - Documenting procedures and steps used in the case study. - Use verification of transcripts. - Consistent interview

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 organisation’s views and practice. The second type of validation is focusing on generalising the preliminary framework that was produced by the research.

3.12.1 Triangulation

Triangulation refers to the use of two or more independent sources of data or data collection methods to corroborate research findings within a study (Saunders et al., 2011; Tzortzopoulos, 2005). Triangulation refers to the use of multiple data collection methods to pave the way for more credible and dependable information (Saunders et al., 2003). Some use of triangulation of methods and multiple informants are also necessary to confirm and deepen information (Woodside, 2010).

For this research triangulation is achieved as follows:

i. Data triangulation – the researcher utilised a semi-structured interview, document review, website review, and direct observation.

ii. Theoretical triangulation – the research explored literature in different key areas that are relevant to this research such as the construction industry in global and national Malaysian market, innovation, knowledge management concept, knowledge sharing, information technology and Building Information Modelling concept.

iii. Methodological triangulation – the research used descriptive analysis for organisations' background. Also, the researcher used content analysis for the data analysis particularly on the knowledge sharing practices in implementing BIM.

In respect of this research, the researcher first conducted a literature review to understand the issues relevant for research, particularly in the Malaysian construction industry context. This process is followed by extensive literature review in knowledge sharing and BIM in order to understand and identify the key factors of knowledge sharing practices in implementing BIM. The results of the literature review are used to guide the researcher in conducting the semi-structured interviews. Then, the outcome of the semi-structured interviews was triangulated with the survey questionnaires supported by the peers (participants from the data collection stage and some BIM practitioners) interview at the validation stage. The use of peer interviews with the supporting questionnaire in this study gave a comprehensive view and confirmation of the key factors of knowledge sharing practices in implementing BIM within the Malaysian construction industry.

3.13 Research Procedures

The research process covers five stages as discussed below and shown in Figure 3.5.

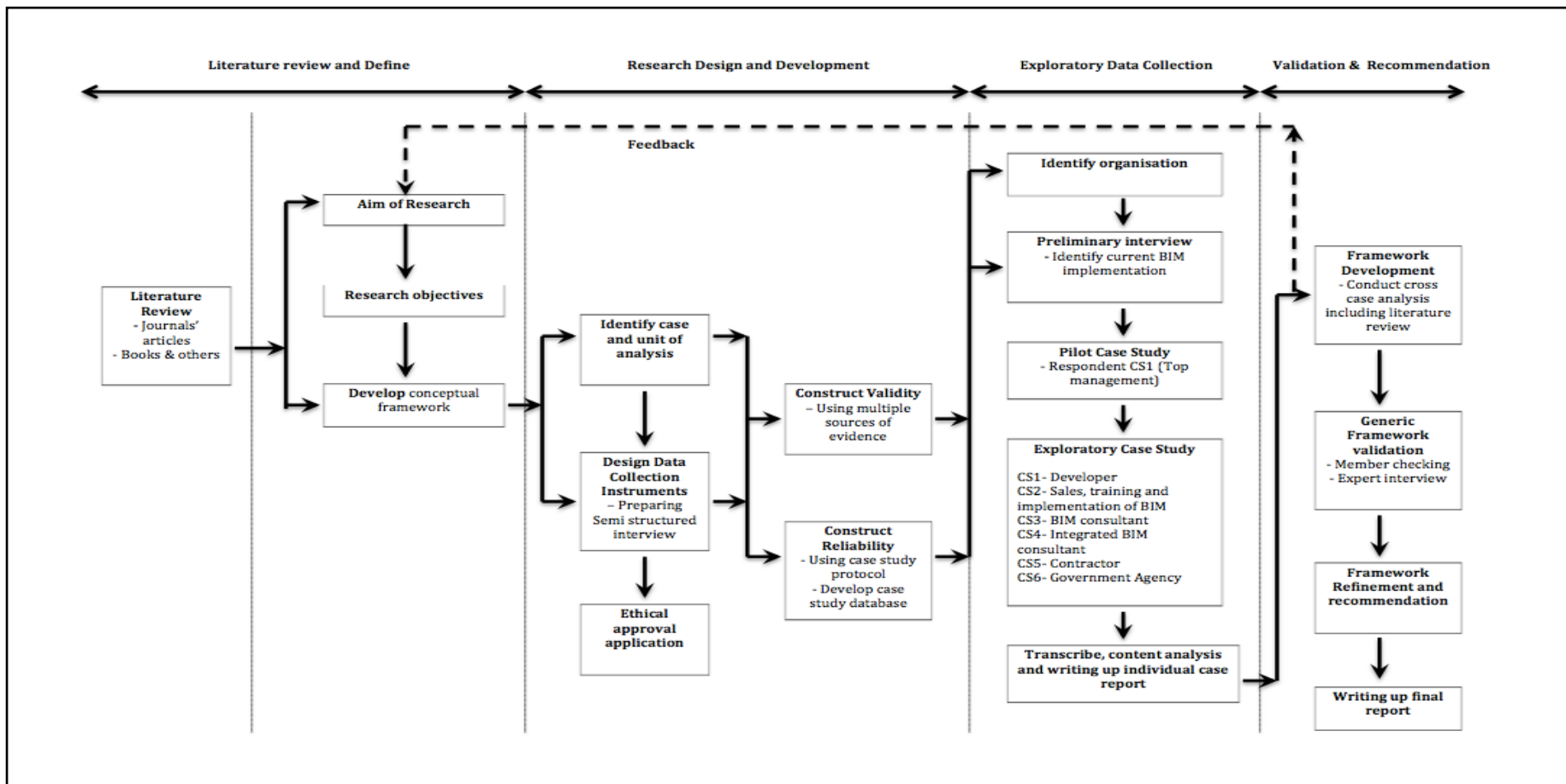


Figure 3.5: Research Process adapted from Yin (2014a)

3.13.1 Stage 1: Literature Review

The main direction of this stage is to form knowledge of the current issues in the construction industry. During this stage, a literature review was conducted which discovered that the Malaysian construction industry needs a rigorous action in adopting innovation for efficiency. Together with the push factor from the government requirement, the concept of knowledge management, knowledge sharing and also Building Information Modelling is reviewed.

3.13.2 Stage 2: Identification of aim and objectives

After an in-depth review of the concept mentioned above, the researcher discovered the importance of knowledge management and knowledge sharing in construction organisations. It is critical for the construction organisation to practice knowledge sharing if the organisation wants to sustain itself in a knowledge-based industry (construction industry is one of it). Meanwhile, the Information Technology implementation like Building Information Modelling (BIM) in the construction industry also gained much attention in this century. In a developing country such as Malaysia, the adoption and implementation of BIM are also promoted to take on the challenges in the construction industry and to gain efficiency. Driven by the government push in the Malaysian construction industry context, the adoption and implementation of BIM are progressing. However, the problem arises from the low level of BIM adoption, which leads to the research aim and related objectives as discussed in section 1.3. The theoretical framework discussed in Chapter 2 based on the literature review was used to guide the researcher in developing the elements for the preliminary framework of this study.

3.13.3 Stage 3: Research Design and Development

The researcher then determined the research strategy considering the relevance of the research and access to information related to achieving the aim and objectives. Soon after the interim assessment, the researcher under the guidance of the main supervisor

prepared data collection instruments covering ethical approval application and interview guidelines. The questions to guide the semi-structured interviews were developed and arranged on the basis of the objectives that the researcher aimed for. The questions are open-ended in nature and used as an interview guideline to allow the researcher to conduct a consistent interview throughout the process of data collection for data reliability. After the submission of the ethical approval, there was a minor correction that needed to be updated and feedback sent back to the ethics committee (Refer to Appendix 1). Ethical approval was obtained as shown in Appendix 2.

3.13.4 Stage 4: Data Collection

3.13.4.1 Identification of company

Once a set of questions was developed as in Appendix 3, the data collection phase began with the identification of company that was going to be used in the study through a preliminary investigation with the Construction Industry Development Board. It was decided that the selection of the company should be made on the basis of their experience with the implementation of BIM. Since BIM is relatively new within the Malaysian construction industry, it was predicted that acquiring a matured implementation case would be a big challenge. Therefore, all companies with no experience or understanding of BIM were omitted. A few techniques were engaged to identify the company that at least has an understanding of BIM,

- a) Reviewing BIM implementation in Malaysian construction industry cases or projects in a published paper, newspaper or webpage that mentioned the parties involved.
- b) Engaging in direct communication with the Construction Industry Development Board of Malaysia (CIDB) officer in charge of the IT department as a gatekeeper.

13 organisations were identified and through their webpages, internal contact and Construction Research Institute of Malaysia (CREAM) networking database, contact numbers and email addresses were obtained. Applications for conducting the

preliminary interviews were then sent through phone calls, emails, and formal application letters. Out of the 13 organisations, nine positively responded to the request.

3.13.4.2 Preliminary Interview

A preliminary interview is a process where the researcher engaged to get a brief picture regarding the current level of implementation of BIM by the organisations. The same question set for the pilot organisation was used but with a different purpose as:

- a) Part of a filtering process to ensure the organisation has fully or partially implemented BIM within their business.
- b) Part of research strategy to develop trust and credibility to gain access for carrying out data collection.

Based on the interviews that were conducted, only six organisations were currently using BIM within their business process and will be described in section 4.1.

3.13.4.3 Pilot and Exploratory Case

Prior to the pilot case interview, interview questions were checked by two academics and two practitioners in BIM to eliminate any ambiguity or confusion in the questions before the pilot case interview and main interviews. According to Yin (2009), a pilot case will help to refine data collection plans concerning 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 asked the right questions that reflect the specific condition of the company. The set of questions in Appendix 3 was used in the pilot study. The pilot interview was conducted with the director of the department in-charge of BIM implementation in Organisation A (Case A) since the company has comprehensively used BIM in the total value chain of the construction environment. For Organisation A (Case A), the researcher also demonstrated what the company was

using with regards to the knowledge sharing approaches/practices in implementing BIM and some of the BIM deliverables was also evidenced. The researcher was also given access to the documented source of knowledge sharing in the BIM implementation such as the BIM implementation plan, standard operating procedure, knowledge sharing forum and discussion portal. However, the written documentation or pieces of evidence were treated confidentially by all of the companies. Only a few documents or written proof were collected. The utilisation of the evidence as requested by the participant was restricted to the use of the thesis only.

3.13.4.4 Exploratory Case Study

After conducting the pilot case, only a few terms were added to give a broader perspective to the questions, and the refined question set in Appendix 4 was used in conducting exploratory organisation. The case study interview was held in a natural setting i.e. the participants' environment at the company's office for each case. The researcher started the process by explaining the purpose of the research. The current uptake of BIM and the minimum requirement was investigated through the semi-structured interview as the main method. Most of the interviews lasted for 1 hour, and a dictaphone was used with an audio recorder back-up to record the participant's feedback.

3.13.4.5 Document Analysis

Data documentation is one of the six sources of evidence mentioned by Yin (2009). According to Yin (2014), documents are represented by different forms such as letters, agendas, administrative documents, formal studies or evaluations, and news clippings. Similar to other elements in the qualitative approach, the analysis of documents can be used as a complementary strategy to the other methods, such as interviews or ethnography, or as a stand-alone method (Flick, 2009). Furthermore, the analysis of documents can provide the researcher with access to the evidence obtained by, and the thinking of, other researchers. In this study, documents were collected from the studied settings and the websites of the case studies. The number of

documents used to gain and analyse some information was recorded as (case-doc-numbers) in each site. Furthermore, the researcher included the analysis of different kinds of documents found in the cases under investigation. However, the number of documents from the cases under investigation was varied and limited to some annual reports, standard or guide.

3.13.5 Data Analysis

Based on the interviews conducted, there were six organisations currently using BIM or starting the implementation process within their business process. The process of data analysis was initiated by transcribing all the interviews into written scripts. Eight interviews were conducted in English while one was conducted in Malay at the request of the respondents. All the interviews were first transcribed into the language used during the interview. The English translation was then made after the data was analysed for the interview conducted in Malay. This process is to reduce the misinterpretation of data if the data is directly translated from its raw source.

The analysis of interviews began with the intra-case analysis of individual cases and was followed by a cross-case analysis for all organisations involved. Intra-case analysis is the individual analysis of cases based on multiple sources of evidence. The analysis was aimed at gaining as much evidence as possible to identify the knowledge sharing practices in implementing BIM. The cross-case analysis was carried out to compare the findings from all case studies. It was undertaken simply by a comparative analysis of data and information gathered during the data collection method. The comparative analysis analysed literal replication between cases and assisted the researcher in understanding the differences and similarities of each case. The answers were classified in the content analysis of the issues, and were still based on the predefined categories from the literature. Subsequently, by using the literature source, the emerging patterns of key factors of knowledge sharing practices were theoretically validated, and a preliminary framework was proposed.

The qualitative data attained from the interviews in this research was analysed using content analysis method. Content analysis is a research technique for making replicable and valid assumptions from texts to the contexts of their use (Krippendorff, 2004). Content analysis aims to achieve a concise and broad description of the phenomenon, and the outcome of the analysis is the concepts or themes describing the event. The analysis of content is a central activity whenever one is concerned with the study of the nature of verbal materials (Kothari, 2004). However, according to Kulatunga (2014), the analysis of content is not only limited to oral sources but varies including printed or visual media such as newspapers, websites, field notes, interview transcripts and visual media. In this research, the content is analysed from websites, organisation documents (standard or guidelines) and interview transcripts. The content analysis for this research was assisted using Computer-Aided Qualitative Data Analysis Software (CAQDAS).

3.13.5.1 NVivo 11 in Use

NVivo 11 software is used to manage and organise qualitative data analysis with the researcher attempting to make sense of massive data from the interview transcripts. The themes of tree nodes were developed from the interview data. This was followed by the identification of the parent nodes and child nodes for the coding framework derived from the data itself in an emergent manner. The parent nodes and child nodes have emerged through the process of close and repeated reading of the transcripts and texts as an iterative process. The example of parent nodes and child nodes developed for Theme 1 is shown in Figure 3.6. The details of all themes, parent nodes, child nodes and sub-child nodes that emerged are discussed in Chapter Four. NVivo 11 facilitates the researcher in handling the tedious process of content analysis by displaying the number of responses coded at each node and allowing the researcher to merge, delete or rename nodes as the analysis progresses. From this process, coding enables the researcher to get into the data and develop some feeling for the issues related to the earlier stage before making sense of the codes and creating conceptual models from the data.

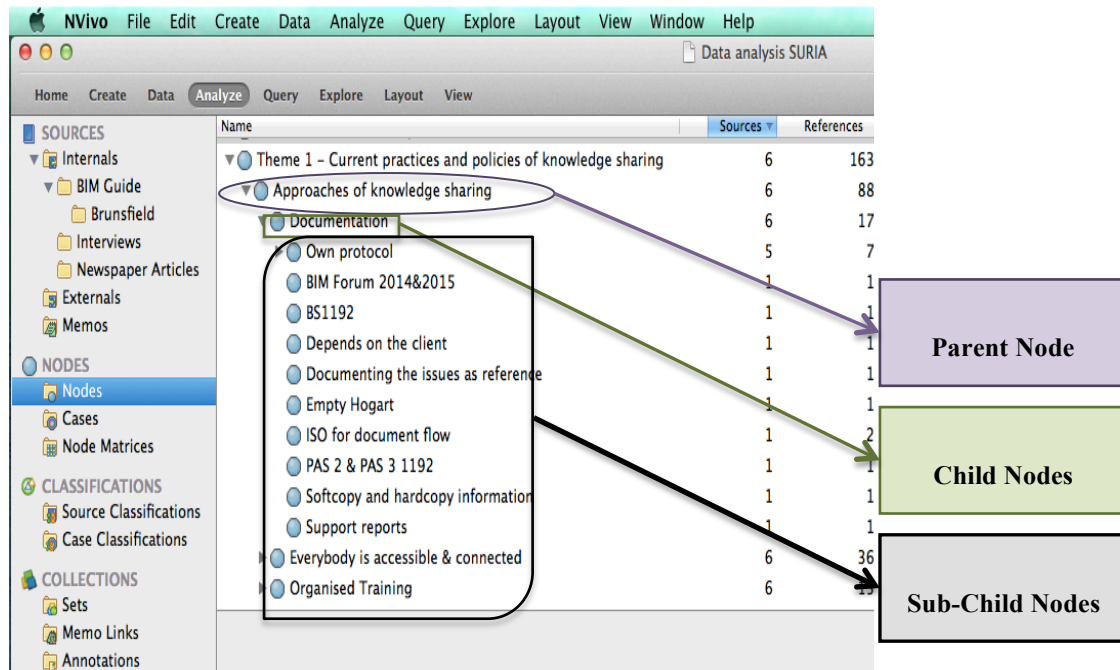


Figure 3.6: Screen shot for example of parent nodes, child nodes and sub-child nodes emerged from the data in NVivo 11

3.13.6 Stage 5: Validation and Recommendations

The validation process involves two stages i.e. data validation and preliminary framework validation. The first one is an individual case validation, which focuses on validating the individual case findings to make sure that the report of the case reflects the actual organisation's views and practice. For the data validation, the researcher used members' checking where all the participants in the case study interviews were contacted to validate the report data. Any changes and feedbacks were recorded and amended based on their comments. Overall, the data reported were validated true as practiced by the organisations and there were only minor changes for typographical and grammatical errors. The second stage of validation is focusing on generalising the conceptual framework that was developed by the research. Initially a focus group discussion was planned; however, the researcher could not get access to the facility that would allow the focus group to be conducted. Therefore, the researcher considered doing peer interviews with other construction stakeholders such as academics and BIM managers who have an understanding of BIM concept and implementation. This peer interviews involved getting feedback from the agreed peers in the Malaysian construction industry. The peer reviewers must also have BIM

experience to get their responses and recommendations concerning the research context.

Within the preliminary framework's validation process, there were two areas used to validate the framework. The first one is to seek an agreement or disagreement with each participant about the framework criteria on the importance of the key factors to knowledge sharing practices in implementing BIM. The second area of investigation within the validation process was to seek an explanation regarding the clarity of the framework (to what extent it is clear), the structure of the framework, the appropriateness of the components of KS practices in implementing BIM, the applicability of the framework, and suggestions to improve the framework.

To structure and ease the participants' feedback, a quantitative approach was first used. This approach was conducted using questionnaire forms, which can be referred to in Appendix 5. The questionnaire forms were distributed earlier before the interview started to allow the participants to respond individually particularly on the key factors of KS practices in implementing BIM and specifically related to question three in the validation interview. The questionnaire administered was used as a "quasi-statistical method" in this validation. It is important to mention that the primary use of the quantitative approach was to demonstrate the consensus and distribution of answers that were given by the participants, but was not intended to generalise a sample of the population within the context of construction organisations in Malaysia. Therefore, the term "quasi-statistical method or analysis" is used to avoid confusion. Furthermore, the limited number of participants (only six agreed to participate) have also disqualified the quantitative approach from being used individually.

In analysing the data gathered through the survey form, two types of analysis were used, which were the Frequency analysis and the Average Index analysis (stated as importance index). The Frequency analysis was used to understand the frequency of

answers given by the participants for the responses, measured on a 5-Point Likert scale. The Average Index analysis was used to provide the values of an average response or answers given by all interviewees. The value is then used to rank the key factors from the highly important factors to the least. The 5-Point Likert scale used are: Highly Important, Important, Neutral, Not Important and Very Unimportant. The ‘average index’ (Lim & Alum, 1995) was calculated for each item using the formula below:

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

where n is the frequency of peer interviewees who answered the following:

Table 3.8: The frequency of n for the level of importance

n	Level of Importance
n ₅	Highly important
n ₄	Important
n ₃	Neutral
n ₂	Not important
n ₁	Very Unimportant

The scores then ranked the items listed in the questionnaire for the importance indices. The overall "quasi-statistical analysis" is attached in Appendix 6. The rating was done according to each element and practice in the draft framework. All the discussion points during the interviews 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. The pattern of responses amongst the participants was determined by the quantitative data from the questionnaire form. The pattern was cross checked with the preliminary framework, and the interview feedbacks were then used to refine the reliability of the final framework and conclusion.

3.14 Chapter Summary

This chapter presented a detailed account of the research onion model regarding the research philosophy, the research approach, the research strategy, the research choices, the time horizon, and the techniques and procedures. Different data collection techniques were used to achieve the research aim and objectives as shown in Table 3.8. Several research methods, such as semi-structured interviews, document analysis, direct observation, and questionnaire (only for key factors of framework validation) were discussed. The different research strategies and the rationale for choosing the case study strategy in this research were explained. This study used semi-quantitative and qualitative data collection methods, including face-to-face semi-structured interviews, document analysis, direct observation, and a questionnaire. The sampling methods used in this research were explained. In addition, the chapter also provided an overview of the qualitative data analysis, which was conducted using content analysis. Finally, the chapter discussed research quality (trustworthiness), authenticity, validity, reliability, and credibility to ensure that the research was conducted carefully to obtain reliable and consistent data.

Table 3.9: Objectives of the research within data collection method

Objectives	Literature review	Interviews	Document Analysis	Website Analysis	Direct observation
To explore and review relevant literature related to the challenges in the local context (Malaysia) construction industry, the needs towards change; innovation, knowledge-based economy and the use of ICT. Also, to review and examine relevant literature related knowledge management concept in general and particularly knowledge sharing. To further explore and review BIM concepts, uses, benefits, and challenges.	X				
To explore the current implementation of BIM within the business process by the construction organisations in Malaysia.		X	X	X	X
To ascertain the current status, practices, policies of knowledge sharing, and organisational culture in implementing BIM in Malaysia.		X		X	X
To identify the factors which are perceived to be barriers and enabling factors to improve knowledge sharing in implementing BIM in Malaysia.		X			
To develop a framework of organisational knowledge sharing for effectively implementing BIM, which encompasses the key factors of knowledge sharing by utilising the emerging findings in objective iii) and objective iv) and then to cross-reference the outcome with the literature review.	X	X			
To validate and refine the framework of knowledge sharing in implementing BIM.		X (Validation interview)			

CHAPTER 4: FINDINGS

4.1 Introduction

This chapter shall elaborate in detail the findings of the case studies in this research. Six construction organisations that practice BIM and are based in Malaysia (refer to Table 4.1) were involved in the case studies. One BIM practitioner's organisation was chosen as the pilot organisation, while the other five organisations were selected for the actual case studies. The key findings from these six organisations in data analysis will be highlighted within this chapter.

The construction industry is a project-based industry. Project-based organisations (PBOs) are defined as organisations that mainly use projects to produce products and/or services (Pemsel & Müller, 2012). Therefore, a construction organisation manages knowledge at the project and organisational level. The types of knowledge involved in project-based industries like Architectural, Engineering and Construction are micro-knowledge and macro-knowledge. Micro-knowledge, needed for performing a single task (or its part), and macro-knowledge (in other words, all the knowledge possessed by people from a given organisational level) are the most important resources needed for project management (Gasik, 2011). This research focused on construction organisations which employed BIM in their business. However, in the Malaysian construction industry, the BIM implementation is still progressing and continues to grow starting with a few selected and pilot projects implemented by construction organisations. It is important to note here that the responses from the participants might have discussed BIM knowledge that they possessed in a project and brought into their organisations for knowledge sharing within the organisation. In other words, a person assigned to a project brings the knowledge he or she possesses at that time to the team members in an organisation. Moreover, Wu, Mayo, Mccuen, Issa, & Smith (2018) asserted that knowledge accrued

from organisations (general and macro-knowledge) and projects (specific and micro-knowledge) should be both considered as critical components of the BIM body of knowledge.

All organisations involved vary in their roles whether as a developer, sales, training, and implementation of BIM, BIM consultant, integrated BIM consultant, contractor or government agency but all of them have experienced implementing BIM within the Malaysian construction industry which is one of the scopes required in this research. The bigger organisations have accumulated experience in the construction industry with some of them having been in the industry for 25 years or more and a few with more than a 100 years' experience. In contrast, small and medium organisations account for about 4 to 8 years of experience each in the construction industry and continue to grow. The organisations have BIM experience which vary from 2 to 10 years each.

The organisation findings were retrieved from some face-to-face interviews, documents and websites review related to the background of the organisation and BIM associated practices. The research by Haron (2013) mentioned that the current BIM uptake in Malaysia is still low. It is expected that the implementation will continue progressing since the research was conducted in 2013. Thus, the selection of respondents is based on a person who has an understanding and knowledge of BIM implementation, at least up to a functional BIM user as defined in Arayici & Coates (2013) and who is able to apply new knowledge with guidance and can be trained on anything new. However, in all the cases, the researcher managed to get access to most of the top management such as a director and BIM manager and also some middle management like an assistant manager and senior engineer, who were BIM key persons in their organisations (refer to Table 4.1). They also had a good understanding of BIM and were involved up to specialist level and considered as BIM specialists as described in Figure 4. The participants' experience in BIM covers their involvement with research as well as real practice in their projects. Furthermore, all of the respondents had more than five years and up to 30 years of personal experience in the

construction industry. The respondents had up to 11 years' experience in BIM implementation, which includes study, research and practice according to their organisation's requirement. This expertise strengthens the case that the individuals representing the organisations had a good background knowledge in BIM along with construction experience.

Accordingly, the data analysis for all case studies aimed to:

- i) Explore the current implementation of BIM by the organisation within their business process and to explore the current implementation of BIM within the business process by the construction organisations in Malaysia.
- ii) To ascertain the current status, practices, policies of knowledge sharing, and organisational culture in implementing BIM in Malaysia.
- iii) To identify the factors which are perceived to be barriers and enabling factors to improve knowledge sharing in implementing BIM in Malaysia.

Table 4.1: Construction organisations involved in case studies and profile of participants

Company	Type of construction organisation	Organisation's experience in construction industry	Organisation's experience in BIM	Participant's Name/ Label	Participants' Position in the organisation	Participants' personal experience in construction industry	Participants' personal experience in BIM	BIM Tools used
Case A	Developer	25 years	10 years	PA1	Director (Top)	25 years	10 years (3 years – research, 7 years – practice)	Autodesk Revit, Naviswork, Oriant, In-house tool
				PA2	Civil Engineer (Middle)	8 years	4 years (Practice)	
Case B	Sales, training & implementation of BIM	8 years	5 years	PB1	Managing director (Top)	16 years	11 years (Research, practice)	Autodesk Revit, Naviswork, Civil 3D
Case C	BIM consultant	4 years	4 years	PC1	Managing director cum BIM manager (Top)	11 years	11 years (Study, research & practice)	Revit, ArchiCAD, Naviswork, Solibre, Tekla
Case D	Integrated BIM consultant	5 years	5 years	PD1	Senior BIM manager (Top)	24 years	12 years (Research, Basic 3D modelling & practice)	Any 3D model tool, whatever platform that suits the project and based on client's preference
				PD2	BIM manager (Top)	16 years	7 years (Practice)	
Case E	Contractor	30 years	2 years	PE1	Senior engineer (Middle)	7 years	2 years (Practice)	Autodesk Revit, Civil 3D
Case F	Government agency	100 years	5 years	PF1	Head of Assistant Manager, BIM Unit (Middle)	31 years	10 years (3 years – research, 7 years – practice)	Autodesk Revit, Civil 3D, Naviswork, mySPATA
				PF2	Senior Civil Engineer (Middle)	8 years	6.5 years (1.5 years – research, 5 years – practice)	

4.2 Organisation Background

This subchapter discusses the background of each of the organisation and followed by the current status of BIM implementation.

4.2.1 Background of Case A (Pilot Case Study)

Organisation A represents a large property development, construction and building management (developer) organisation in Malaysia that have been involved in construction for 25 years. Case A is an organisation that operates in the total value chain that covers a broad spectrum including hospitals, high-rises, condominiums, commercial and residential building. Within the Malaysian context, the organisation is also certified as a Class 'A' contractor under the Construction Industry Development Board that allows the organisation to venture into any construction project with its minimum paid-up capital of Malaysian Ringgit 750,000.00 (approximately 4.5 million GBP). It is made up of seven divisions (refer to Figure 4.1) mainly in 1) Property Development, 2) Engineering, Procurement, and Construction, 3) Mechanical, Electrical, and ICT, 4) Special Trade, 5) Real Estate Management, 6) Share and Outsourcing and 7) International Business, with 500 full-time permanent staff. Due to the anonymity issue, some parts of the website have been hidden. With forward-thinking top management, the organisation had tried many alternatives that would enable them to measure and quantify a whole building as accurately as possible. They discovered BIM in 2000 during a training stint in the USA while searching for new technologies. However, the organisation only started to embark on BIM fourteen years ago in 2005, beginning with a small project considered as its research or pilot study. Their BIM implementation is now under the care of the Share and Outsourcing division. The organisation has produced an internal BIM guide covering seven parts; 1) overview of BIM, 2) architectural, 3) civil and structural, 4) mechanical, electrical & infrastructure, 5) mechanical, electrical & infrastructure shop drawing, 6) coordination, 7) as-built.



Figure 4.1: Organisation A website showing the divisions in the organisation.

4.2.2 Background of Case B

Organisation B represents an organisation classified under small and medium enterprises (SME). It has been involved in sales, training, and implementation of BIM in construction for about eight years. The organisation's operation is primarily focused on consulting work. However, with the recent demand from the Malaysian construction industry, the organisation has also been heavily involved with the contractors mostly for architectural, mechanical, electrical, plumbing and infrastructure works. With an annual revenue of around Malaysian Ringgit (MYR) 10 to 12 million (approximately 60 to 72 million GBP), the organisation operates with 21 permanent staff. The organisation started its involvement with BIM in 2004 and focuses on Autodesk as its BIM tool.

Organisation B's involvement with BIM services as shown in Figure 4.2 includes the following:

- 2D to 3D Model Translation
- BIM Training
- BIM Consultancy
- The pilot project, with on-going mentoring



Figure 4.2: Organisation B website showing its BIM services.

4.2.3 Background of Case C

Organisation C represents a total BIM consulting firm. The main organisation services are BIM adoption, training, management and modelling with its core personnel's background in construction such as architects, civil engineers, and mechanical, electrical and plumbing. The organisation is mainly involved in the private construction industry focusing on complex building, for instance high-rises, mixed development and transit-oriented development (infrastructure near to development). Since the organisation is still new in the industry, its current revenue is within Malaysian Ringgit 500,000 (approximately 3 million GBP) for the past 18 months since 2013. This is expected to increase due to high demand for BIM consultation from the construction industry. The organisation operates with four permanent staff and ten on permanent contracts or project basis.

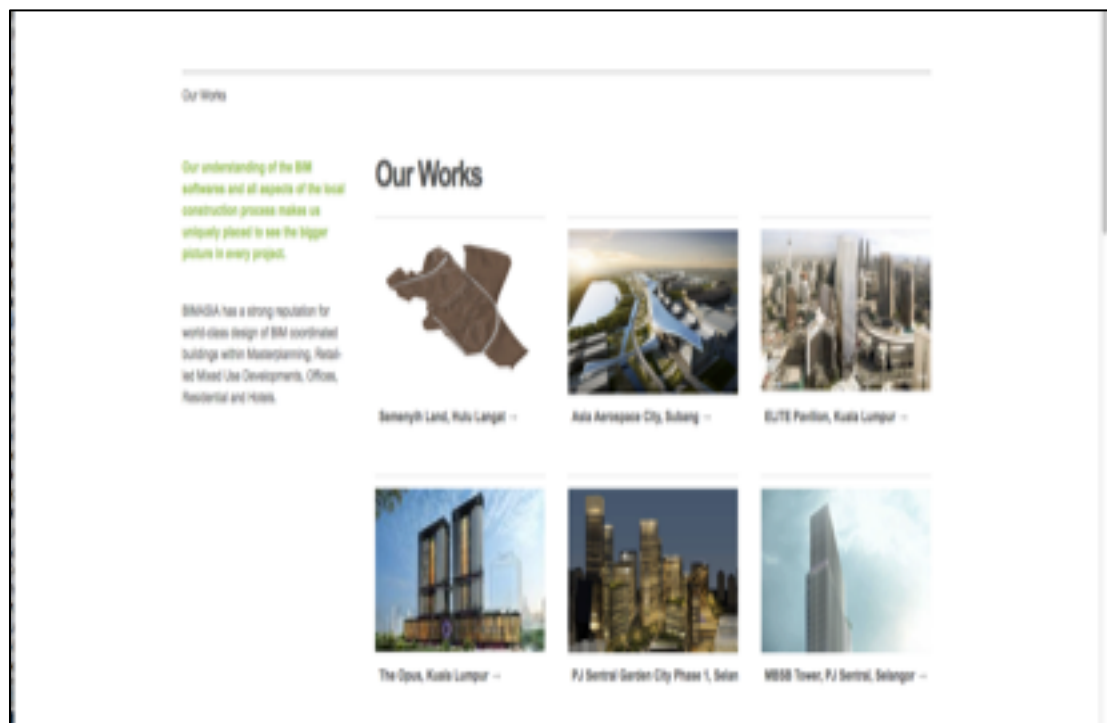


Figure 4.3: Organisation C website showing its projects and promotes BIM in its services.

4.2.4 Background of Case D

Organisation D represents the one-stop engineering firm that has long been in the construction industry, offering structural, mechanical, electrical & plumbing (MEP), project management and consultancy services. The organisation started to provide BIM services as in Figure 4.4 when the management decided to set up a BIM department in 2012 with the aim of offering BIM related services on any project whether infrastructure or structure. The organisation fulfils the whole project development process starting with project development, BIM execution plan, coordination and integration with facility management. The organisation is involved in a vast amount of projects in high-rise buildings and also covers infrastructure projects. At the moment, it is working on the largest infrastructure project in Malaysia—Kuala Lumpur and the MRT Line 1 project. The BIM department has about Malaysian Ringgit (MYR) 25 to 30 million (approximately 150 to 180 million GBP) in gross annual revenue with 160 people working in the department out of 650 in the parent company.

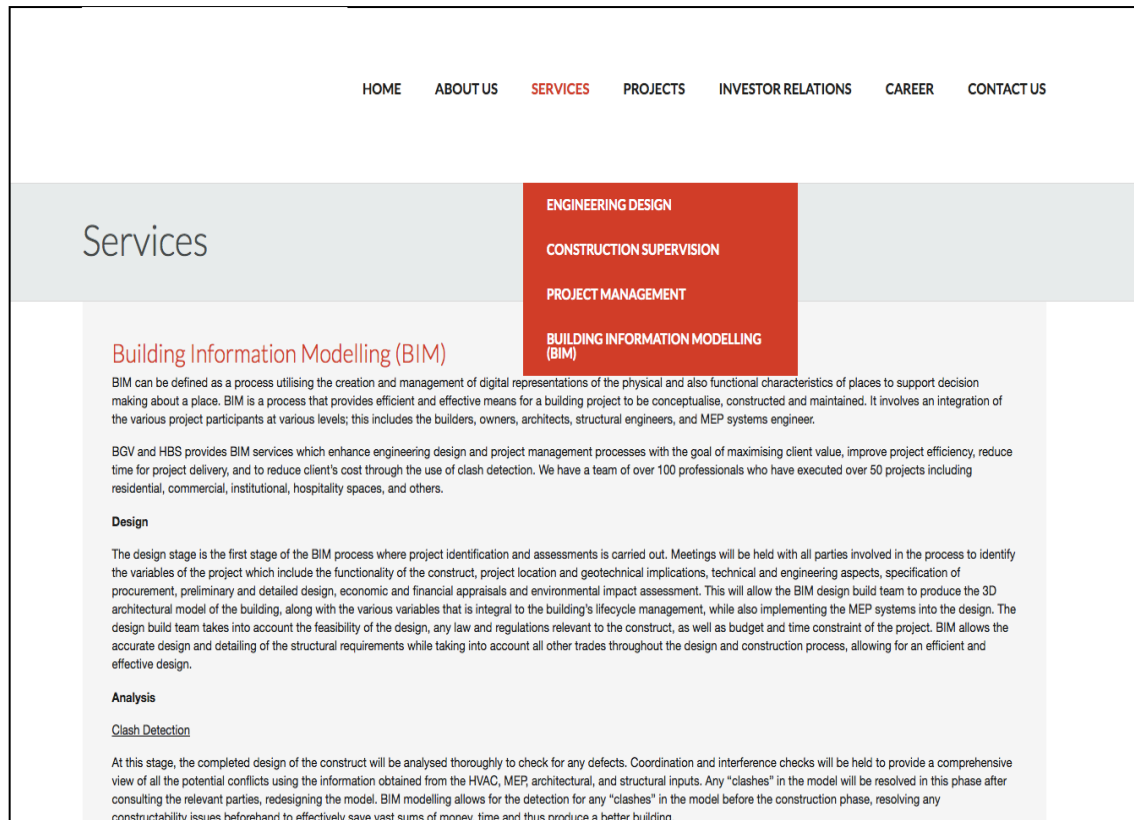


Figure 4.4: Organisation D website promotes its services in BIM

4.2.5 Background of Case E

Construction is the core business of Organisation E. It started in Malaysia 30 years ago and has ventured internationally as well. Besides construction as its core business as shown in Figure 4.5, the organisation has other arms which consists of Property Division, Industry Division, Plantation Division, and Infrastructure Division. The organisation mostly operates in civil and structure works as a Class A main contractor and has multiple sub-contractors carrying out work in its projects. As the main contractor, the organisation is more focused on coordinating and liaising with the project consultants. Currently, the organisation is involved in some highway and expressway projects and many housing projects. Organisation E has about 4000 permanent staff including its staff in India. The organisation has ventured into BIM for about three years. However, its first project using BIM was outsourced to its third-party specialist at that time. Currently, the organisation has trained its staff in BIM implementation and has launched a pilot project within its property projects.

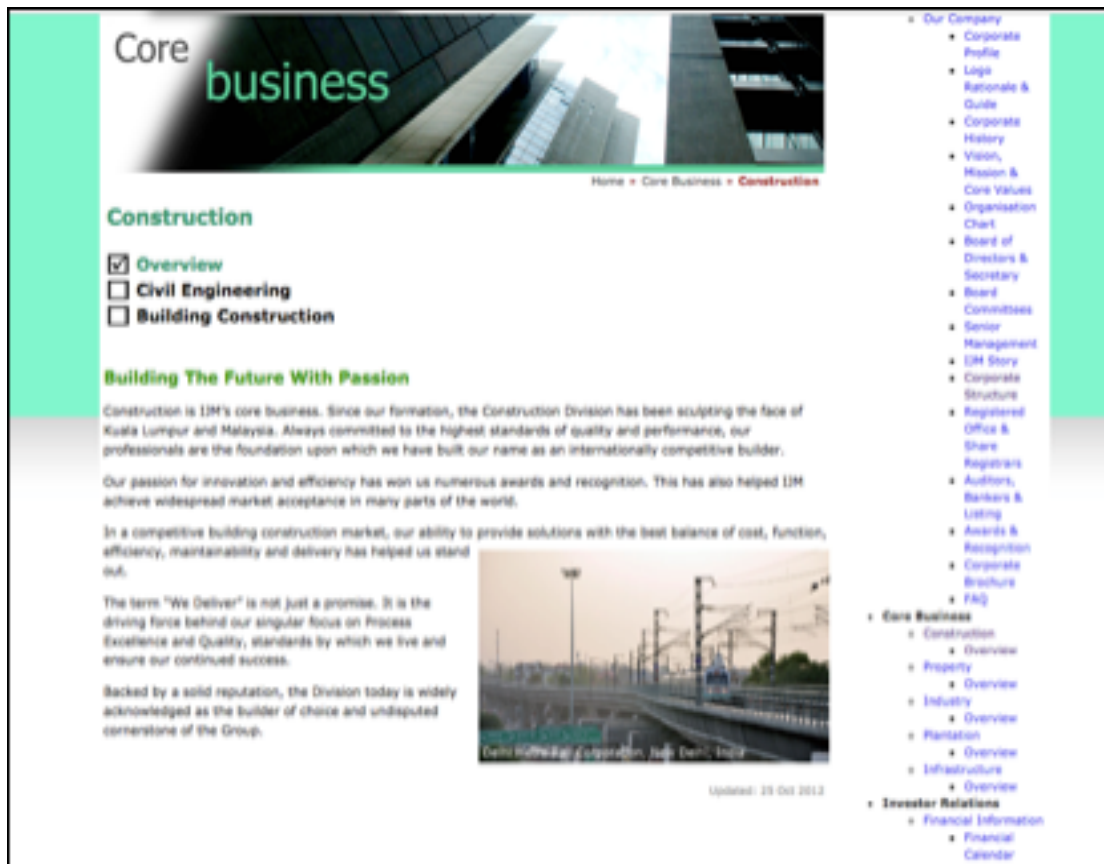


Figure 4.5: Organisation E website indicates construction as one of its core business

4.2.6 Background of Case F

Organisation F is a government agency in Malaysia that is in charge of development projects. It has been established since 1872. It has established its portfolio under three sectors that is building industry, specialist sector and industrial training sector. Its three core services are 1) planning, design, and construction, 2) maintenance and asset management and 3) technical advice (consultation). All of its projects including buildings, roadworks and infrastructure are built with government allocated funding. The organisation has one branch that specifically handles BIM implementation. The Integrated Asset Planning Branch (Figure 4.6) is under its specialist sector and was established in around 2004. Its BIM initiatives started in 2007. Organisation F has about 3700 permanent professional officers and approximately 9000 permanent support officers throughout the country. This resource is scattered in its district and state offices, and its headquarters.

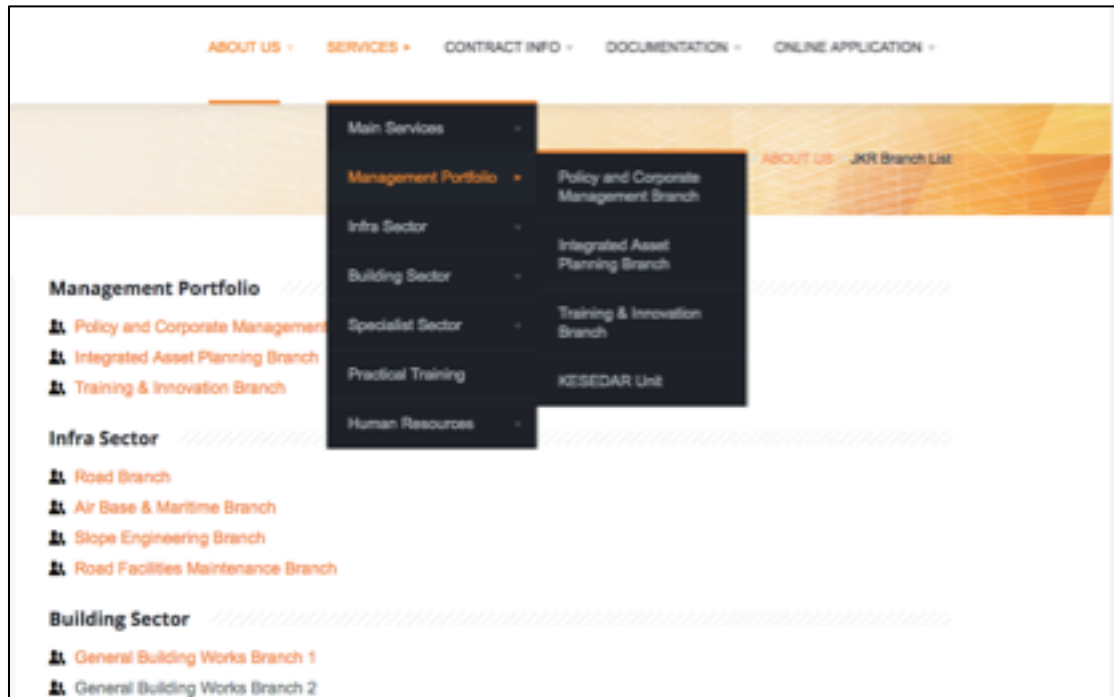


Figure 4.6: Organisation F website showing its services. BIM Unit is managed under Integrated Asset Planning Branch

The organisation is still working towards BIM collaboration but does not involve all disciplines yet because of its high project workload. The organisation launched its first project that used BIM around 2009 and 2010, but was only involved with need statements, procurement, deliverables, financial and monitoring. It used third-party consultants for the design. Organisation F started to fully use BIM in two projects; a SPRM building and a KK5 from design and now up to construction stage. At the same time, the organisation also involves with pre-approved plan projects that already have standard drawing as well as others.

4.3 Current Status of BIM Implementation

The overall status showed the use of BIM in an organisation process flow is to gain efficiency as demonstrated in Cases A, D and F, and also to have a better opportunity for jobs or services as evidenced in Cases B, C and E.

The organisations involved received many benefits from BIM implementation. All of the case studies highlighted time and cost savings due to less rework, less time on site, earlier identification of problems, and consequently, construction could move according to schedule. A higher accuracy and clarity of information also leads to quicker decision making. However, BIM implementation is not without its challenges, which involve resources such as people, tools and cost. The case studies emphasised on the training and education to improve skills and knowledge for a better conceptual understanding and working with different processes when implementing BIM. The details of the level of the implementation for each case, benefits and challenges are further discussed in the following sub-chapters 4.3.1 until 4.3.6.

Training and education are important elements that could improve individual and organisational performance in terms of understanding, applying, analysing and evaluating BIM implementation. Increasing knowledge in BIM implementation via training and education will indirectly allow the flow of knowledge from one individual to other members in an organisation. For example, the approach taken in Case Study D as discussed in Section 4.4.1.3 through a ‘train the trainer’ program will allow knowledge sharing from the coordinator, who has good education background in construction and BIM to his or her apprentice, who is new to the organisation.

4.3.1 Current Status of BIM implementation in Case Study A

The BIM practical implementation was triggered by the top management’s requirement as the participant further elaborated that:

“From my boss, he said that he wants to track every single piece of the mill in the building, that is his requirement. So, we have to explore various software; we even went to the US in the earlier year to look at the software that enables or allow us to do such a thing.”- PA1

Organisation A was also having trouble with a lot of translation errors when scanning bills of quantities documents, this strengthened their need to measure the building as accurately as possible from the first day. Organisation A’s intention was for automation to gain efficiency rather than competitive advantage. Accordingly,

Organisation A created only one new role under the design development department which was set up to establish all the BIM standards or building procedures for everyone to follow including designers and external consultants.

Regarding BIM tools, the organisation has used software such as Autodesk Revit with 50 licenses and Naviswork with ten licenses, together with software developed in-house. The organisation uses Revit for 3D design and modelling. After putting all the models together, Naviswork is used for coordination. It then continues with Microsoft Project for the mechanical, electrical and plumbing elements before the integration work. Organisation A has used and practices BIM as part of their norm or culture starting from planning to facilities management as the participant explained that:

“.... BIM has 3D, 4D, 5D, 6D. Mmmm..we are talking about facilities management already”.- PA2

“BIM implementation cannot be done part by part, and if you do part by part, you will hit the roadblocks somewhere. You must have the end in mind.”- PA1

In the meantime, Organisation A works closely with the external architect and in-house team rather than involving many external parties as the number of organisations working in a 3D environment in Malaysia is considered small. The participant further explained that:

“We mixed them in a team. In this BIM environment, there is no more segregation of architect, we actually put it into a multidisciplinary team, In a team, there is architect, C&S, MEP, ICT inclusive of the QS. As a team, they work together because they work on the same model.”-PA1

This means that Organisation A is using BIM up to Level 1 that is managed CAD in 2D or 3D format with a collaboration tool (extranet) providing a standard data environment, possibly using some standard data structures and formats (Bew & Underwood, 2010). Organisation A is still working on 2D partly because of the authority's requirement on 2D printouts. Organisation A is also helping the Royal Institution of Surveyors Malaysia to review and revise the Standard Method of Measurement where the current SMM2 is to fit the 3D environment and called BIM SMM.

Based on Organisation A's experiences, the participant believes that BIM has serious benefits primarily to the Malaysian construction industry, organisation, and employee. Some of the benefits identified are:

- a) Less rework because BIM forces everyone to come up front, agree and build with the virtual construction first before everyone goes down to the site.
- b) Less 'Request for Information' (RFI).
- c) Speed up the project delivery process.
- d) Construction moves according to schedule.

However, Organisation A has also experienced difficulties in implementing BIM internally and externally as follows:

- a) Firstly, to change everyone's mind-sets from 2D to 3D especially with the older employee who are used to working in the traditional way.
- b) To recruit and train young engineers with no fear of technology but lacking in experience.
- c) To figure out how to make the young and old employee work together.
- d) The need for BIM training.
- e) Human resources inconsistencies.

4.3.2 Current Status of BIM implementation in Case Study B

Organisation B implemented BIM as a method for business advancement. It started by selling the application, and when the market began to realise that Organisation B is an expert in the application, it then started to get offers from others and found opportunities to bid for projects. Based on the required deliverables, Organisation B set up the BIM implementation for internal processes, mainly towards the task that it has needed to do. BIM implementation in Organisation B started by building a model and then looking at how to coordinate the model. As the organisation's infrastructure got better, it then looked at how to collaborate using the models and did it progressively. BIM implementation also suits industry needs and is mainly towards the client's needs.

Due to the nature of its business niche in BIM, Organisation B did not create new roles but already had the positions in place. It does not have a very hierarchical structure, and fundamentally it restructured the functions that it already had as explained by the participant as follows:

“Our structure is pretty much I would say is quite flat, it's not that hierarchical, but normally, in our team, we have BIM coordinator, BIM manager, and this BIM coordinator has discipline-specific, they would be supported by BIM modellers. So, in term of structure, we have BIM modellers as a basis, even if we get the project whereby we don't need BIM manager or BIM coordinator, we still have BIM modellers. So that's the basis. Looking at the complexity of the project, then we start to hire up. Basically, not hire up, just reorganise the role. So, what happens is that then we have BIM coordinator, that will look after the sub-discipline and then we have BIM manager that will go and monitor the overall success of that project.”-PBI

The organisation mostly used Autodesk solution as its BIM tool. Revit is used the most, followed by Naviswork, and Civil 3D. As these are used as primary tools, Organisation B also got into Tekla, but not for the actual projects. Revit is mainly used for authoring, to alter the information and create all the BIM models to cover most of the deliverables. Organisation B uses Naviswork for overall coordination and clash detection. As an Autodesk reseller, Organisation B has unlimited access to the tools with up to 50 licenses. However, the actual license that Organisation B uses is about 10 for all its staff. Organisation B's involvement in BIM is up to Level of Development (LOD) 400 for some projects, and most of the projects go up to LOD 300. The organisation has the capacity to push the deliverables up to LOD 500 depending on the client's requirement. Organisation B typically deals with 3D and 4D up to the level of LOD 300.

Based on Organisation B's experience, the participant believes that BIM provides benefits to the organisation and the industry. BIM provides Organisation B with a revenue opportunity by getting it into services, building models and coordination work. For contractors and clients in the construction industry, the benefits are their experience beyond the 2D drawings, and some of the benefits identified are:

- a) Better clarity and information to make a decision accordingly.
- b) Concerns or problems are addressed quickly.
- c) Financial saving.
- d) Better accuracy of information.
- e) Less time on site.
- f) Less interaction on site.

Organisation B has also experienced challenges in implementing BIM internally and externally. The big challenge is to share their BIM knowledge with actual construction players. This is because Organisation B is young and is able to adapt to new tools quickly but lack the actual construction knowledge to build a correct model and address the construction issues. For the industry, the challenges are as follows:

- a) The need to balance the level of knowledge that an organisation possesses and the level of knowledge that is needed by the organisation.
- b) Skill gap.
- c) The need to have the domain knowledge.

4.3.3 Current Status of BIM implementation in Case Study C

BIM implementation in Organisation C was triggered by many construction problems such as mistakes at sites that caused delays or required demolition or erection, double handling in a project, inefficiency in a process etc. which all involved money. BIM implementation also provided an opportunity for the organisation to secure jobs with the advantage of using BIM as a tool in its project compared to others.

Organisation C is currently heavily using Revit and ArchiCAD as authoring tools and Civil 3D for the infrastructure work. Tools such as Naviswork, Solibri, and Tekla have been used for coordination. Also, the organisation uses Bizarre for initial energy analysis. Apart from that, the organisation is currently embarking on BIM Blue and BIM Field (internal BIM tool development) by AutoDesk based on project

requirement. The organisation has ten licenses and also benefits from a free license used by the students to develop specific things within three years.

Organisation C uses BIM in their projects from Planning to Asset Management for a specific project which involved 3D, 4D, 5D and a little bit of 6D. Currently, a lot of its projects are in the construction stage with LOD 400 and LOD 500. However, the phase of its involvement varies depending on the requirements from its clients as the participant explained that:

“It varies depending on the requirements from our clients. My client such as MNO use from day 1, after they are being appointed as an architect for certain project, they started to use BIM from day one up till now part of the projects being executed on site. Other projects mainly will come just before tender. So the client wants to make sure that the building is being designed and being documented properly. We’ve been tasked basically to tackle basically to ensure the quantity is there, coordination has reached a certain maturity, and then after this exercise has been done, it’s tender up.”- PCI

Based on Organisation C’s experience, the participant believes that BIM benefits the employee, decision maker and in terms of efficiency. Some of the benefits identified are:

- a) Increased the potential or the skill of the individual.
- b) Less time is taken during construction.
- c) Less work problem, management, and resources.
- d) Justified decision.
- e) Higher project visibility.
- f) Efficient information retrieval.

On the other hand, the participant believes that the challenges of BIM implementation can be categorised under people, process, policy, and technology and identified as follows:

- a) Getting people to embark in BIM.
- b) Educating people on understanding BIM correctly.
- c) Eliminate misconceptions about BIM.

- d) Align the contract with BIM.
- e) Inconsistencies of human resources.
- f) Having the right tools.
- g) The high cost of buying and maintaining computers and workstations.

4.3.4 Current Status of BIM implementation in Case Study D

The idea of using BIM was triggered by the top management's forward thinking as the participant further elaborated that:

"Ok, within our organisation, what triggered it is because...we've got a very forward-thinking set of directors. And they realise that BIM is going to be from the next stage within the CI, and they want it to be in the forefront. Therefore, they decided they take it on its as soon as possible, not wait till they were a force to take it on that alliance. That's the reason we're having this..." - PD1

Currently, the organisation does not rely and limit itself to any specific BIM tools but rather it uses any platform that suits the project such as Autodesk base system, Bentley, Civil 3D, Excel or spreadsheet as long as the information can be extracted from the model and accurately updated. Organisation D has used and practiced BIM as part of their norm or culture starting from planning to facilities management with Level of Development (LOD) 100 up LOD 500 as the participant explained that:

"Everything is up to LOD500. From LOD100 all the way to LOD500. And then it's been handed over to the FM tool to be integrated within FM tool". - PD2

Regarding roles and responsibilities, according to the participant, the BIM process requires BIM managers, coordinators, and 3D modellers. Nevertheless, as the BIM process matures in the construction industry, all those roles will disappear with the participant describing it as follows:

"...it's because 2D draughtsmen will convert into 3D modellers, coordinators will naturally turn into a project manager. So, PM will automatically naturally just to coordinate. BIM manager will be required because everybody will work on that platform, everybody will know what they're doing. Therefore, you will need somebody to manage it; it will be automatically be happening." - PD1

The participant believes that BIM provides benefits primarily to the Malaysian construction industry, organisation, and employee in terms of efficiency. Some of the benefits found are:

- a) Designer becomes more efficient in design.
- b) Better visualisation.
- c) An individual satisfaction with the efficient outcome.
- d) Lower price.
- e) 20-25% internal time saving.

On the other hands, the participant believes that challenges in implementing BIM internally and externally are fundamentally related to the educational problem as followed:

- a) Educating people to work in a different process.
- b) Understanding the BIM concepts.

4.3.5 Current Status of BIM implementation in Case Study E

Their competitors were moving toward BIM implementation, and that triggered Organisation E to take it as a competitive advantage when the organisation could see the benefits from BIM use.

The organisation has used software such as Autodesk Revit, Memory Suite, Ultimate Suite and Premium Suite with seven licenses as its BIM tools. For infrastructure work, the organisation used Civil 3D 2015 version as its tool. Organisation E has used and practiced BIM depending on the different stages of the project from the beginning of the project up to the construction stage with LOD 100, LOD 200 or up to LOD 500 as the participant elaborated in detail as follows:

“It depends because we have different stages when we are doing BIM. So we have from the beginning we have tender, the tender stage we do it more on..you know, trying to let knowing the client ...look we are using BIM, this is what we can do, so trying to sell the project laa.. During the tender stage, so the level was 100 or 200 only. And then after tender, if we secure the job, then we have the team, that’s

more on coordination, but that's where we come to; -pLOD300. Aaa...normally this one, we get from consultants and also from the architect, so they gave us first LOD300 drawing, and then we take it to 400 and 500 depending on what the client's requirements are, and then it's always 3D, we have not reach up to 4D and 5D yet. So it's LOD300 3D for coordination purposes, clash detection and all those. But for us contractor, we do not want to go up to facility management, so LOD300 is good enough and 400 also ok and we are very much for coordination and clash detection.”- PE1

In the meantime, Organisation E has created a new department called Building Information Modelling (BIM) and Industrialised Building System (IBS) department. The department has a BIM manager and a BIM coordinator who usually are engineers as well as a BIM drafter or BIM modeller.

The participant believes that BIM gives benefits to the organisation and individual. Some of the benefits identified are:

- a) Organisation gets projects by showcasing its BIM ability.
- b) Save time and cost through clash detection.
- c) Avoid clashes.
- d) Time saving for coordination.

Organisation E also experienced challenges in implementing BIM internally and externally as follows:

- a) Getting top management's awareness of BIM benefits, support, and approval.
- b) Has to invest in the implementation cost and convince senior management on the value for money to the organisation.
- c) Retaining people with BIM skills.
- d) The high cost of software and hardware.
- e) There are needs for continuous training.
- f) People's fear of change.
- g) Lacking in BIM knowledge.

4.3.6 Current Status of BIM implementation in Case Study F

The idea of using BIM in Organisation F was started by its top management's requirement for BIM in its projects. It then moved towards BIM initiatives for transformation and work process improvement in terms of cost, time and increasing project quality.

Organisation F has 45 licenses in BIM tools. It uses Autodesk Revit for 3D modelling of building design, Civil 3D to optimise earthworks, Naviswork for clash detection and Cost-X for cost estimation as well as other tools such as Eco Tech and MySPATA (Organisation F version) that it developed for asset management. Currently, Organisation F implements BIM up to the level of development (LOD) 500 depending on the stage; LOD 300 for tendering, followed by construction using LOD 400 and as-built with LOD 500 from feasibility to construction. Internally, the organisation has a BIM Unit for consultation, developing processes, and developing standards and guidelines for BIM projects. This unit helps the Head of Design Team (HODT) that involves designers in terms of design and also assists Head of Project Team (HOPT) that requires project managers for clash detection and project monitoring using BIM. Although BIM implementation in Organisation F has remained constant, nevertheless the application adds new responsibilities such as the HOPT needing to understand BIM implementation. The participant believes that BIM provides benefits to the organisation and individual. Some of the benefits identified are:

- a) Easier access to collaborate with all disciplines.
- b) Easier quantity take-off.
- c) Improve productivity.
- d) More focus and attention on technology.

However, Organisation F has also experienced challenges in implementing BIM internally and externally as follows:

- a) Needs to improve knowledge in organising the database for collaboration.
- b) Insufficient amount of training.

4.4 Organisational Knowledge Sharing Practices and Policies in Implementing BIM (Theme 1)

The first theme in the interview determines the organisational knowledge sharing practices and policies in implementing BIM among the participants. There are five questions under this theme, with the central idea of exploring the actual practices of organisations to compare with the practices gained from the literature review. The analyses done in this research are focused on the following:

- a) Approaches to knowledge sharing in implementing BIM
- b) Colleagues' responses to the knowledge sharing in implementing BIM
- c) Important sources of knowledge sharing in implementing BIM
- d) Management support and policies to encourage knowledge sharing in implementing BIM

4.4.1 Approaches of knowledge sharing in implementing BIM (Parent Node 1)

For the first parent node (Approaches of knowledge sharing in implementing BIM), there are five child nodes developed, which are everybody is accessible and connected, documentation, organised training, social media medium and external involvement (refer to Table 4.3).

4.4.1.1 Accessibility and connectivity

Regarding accessibility and connectivity for knowledge sharing in implementing BIM, various approaches (including techniques and technologies) are conducted by all organisations either formally or informally.

The responses show that 2 cases (Case A and Case E) use a project portal to ensure that they can openly share all the useful BIM information including BIM design information from the project start including design, drawing and updated design, with every party involved.

The majority of the cases (A, B, E and F) uses meetings to access and connect with the parties involved. In Case A, Organisation A shared its knowledge on BIM during meetings instead of in the public forum. Case B uses the same approach where Organisation B uses the regular meetings to report to their client on the problems and solutions in implementing BIM. Nevertheless, in Case E, Organisation E uses the regular meetings to get management approval to firstly implement BIM. Similarly, in Case F, Organisation F uses a meeting to seek for a potential project or discuss any BIM problems. Due to the hierarchical structure in Case F, the meeting is attended only by the top management and involves all branches once in every four months.

Half of the cases (C, D and F) show that Case C uses workshops throughout the BIM process to communicate and share knowledge with the client, contractors, and subcontractors. Through this, Organisation C also shares its knowledge by answering the client's queries individually. Moreover, Organisation D uses workshops throughout the BIM process to learn about it.

Along with the workshops, the three cases use demonstrations to support the knowledge sharing activities actively. Organisation C uses demonstrations in sharing as quoted by PC1 as follows:

"Share in terms of showing on how you do a thing, showing the latest trend, showing a do's and don'ts when you do a certain project." - PC1

In Case F, for accessibility and connectivity between all its branches, Organisation F uses demonstrations in addition to workshops to share knowledge and guide the design team and project team in implementing BIM. Furthermore, Organisation F shares how to implement the BIM with the demonstrations by conducting them throughout the project and continuously applying it in other projects.

From the analysis, it is found that two cases (Case B and Case C) preferred to have their server for information sharing as well as avoiding communication problems.

Case B also ensures its team members stay close and ask the right questions about getting them to learn and improve the learning curve. These are done by flattening the playing field, so that the team members are more comfortable when approached. Case C believes in the spirit of collaboration and tries to be open in sharing its experience on how it delivers its projects since the essence of BIM is also related to collaboration. The people in Case C are encouraged to gather and share their knowledge.

Furthermore, Case C also employs three stages of information sharing. Firstly, it uses e-mail to share information from a new seminar in regards to a new condition encountered in projects. Secondly, the people in Case C share information via their workstations, and thirdly, they have more relaxed sharing sessions at a restaurant. Meanwhile, during the troubleshooting, Case C always uses the face-to-face approach to solve the problems.

Meanwhile, Case D acts as a central point to ensure everybody gets everything via the central location. Through this (serving as a central point), Case D always gets the right information to the right people. Along with that, Case D uses iCloud, Cloud and Dropbox to ensure that everybody is connected.

At the same time, the Case E uses master roadshows to share knowledge as the participant elaborated on this as follows:

“We have master roadshow from project to project because our project is scattered everywhere, so we go and tell them what BIM is and roadshow.”- PEI

4.4.1.2 Documentation

To ensure that the documentation is easy for everyone to follow, almost all the cases (except Case B) have their own protocol. In Case A, based on Organisation A's protocol, the organisation will first establish templates and disseminate it for the team to follow the standard. The organisation has different sets of standards which include several guides as follows:

- a) Part 1 – General Version 2.0
- b) Part 1 – General (2) Version 2.0
- c) Part 2 – Architectural Modelling Version 2.1
- d) Part 2 – Architectural Modelling (2) Version 2.1
- e) Part 3 – Civil and Structural Modelling Version 2.1
- f) Part 3 – Civil and Structural Modelling (2) Version 2.1
- g) Part 4 – Mechanical, Electrical & ICT (MEI) Modelling Version 2.1
- h) Part 4 – Mechanical, Electrical & ICT (MEI) Modelling (2) Version 2.1
- i) Part 4.5 - Mechanical, Electrical & ICT (MEI) Shop Drawing Modelling Version 1.0
- j) Part 4.5 - Mechanical, Electrical & ICT (MEI) Shop Drawing Modelling (2) Version 1.0
- k) Part 4.5 - Mechanical, Electrical & ICT (MEI) Shop Drawing Modelling (3) Version 1.0
- l) Part 5 – Model Coordination Version 2.0
- m) Part 5 – Model Coordination (2) Version 2.0

To ease the flow of documents, Case A used its ISO team to embrace the BIM process, and ISO procedures related to the document flow process slightly changed as viewed by the participant:

“In the past, documents must go to the central documents and the site. Now, we said no need to go to the crowd there and get it. So, we change some of the ISO processes.”- PA1

In Case C, Organisation C has its protocol including CAD protocol and BIM protocol as its primary reference daily as the participant mentioned:

“In our company, we have two things. We have CAD protocol; now we have BIM protocol. BIM protocol is to manage the expectation, and the quality, for example, BIM modeling that has been done

by our company has to reach that stage or certain criterion before we send this to other parties. So, that's where our BIM coordinator uses as the main reference in their daily jobs.”- PCI

BIM protocol is to manage the expectation, and the quality, for example, BIM modelling that has been done by our company has to reach that stage or certain criterion before we send this to other parties. So, that's where our BIM coordinator uses as the main reference in their daily jobs.”- PCI

Organisation C also strictly follows other documents such as BS1192 (Building Standard) with supporting documents PAS 1192 2 (Specification for information management for the capital/delivery phase of construction projects using building information modelling) and PAS 1192 3 (Specification for information management for the operational phase of assets using building information modelling). For the level of development, Organisation C uses BIM Forum 2014 for building and BIM Forum 2015 for infrastructure work.

In Case D, Organisation D uses its own BIM code work to do everything on its BIM platform. In managing the information, Organisation D follows the client's need with a few recommendations of documents manager in the market as the participant stated that:

“There is huge managing document in the market. What we've like to recommend to any project, they go and find one who wants they like for their project, and implement that in their project. Which one they use is the client requires. We might recommend one or two, but we don't say, you should do this and that. It's the client who's going to be painful. They need to know what information that he might needs and not needs, knows how he want to control their project and how he wants the information will be stored at the end. So he goes, and he takes on board, on document control. We just fit in into it, whatever it is. We've just advice; this doesn't cover this area and this area. Other than that, we let them choose, to end up with the ability software, we don't care. Client picks their software; we will only recommend whether it is a good idea or not.”- PD1

As Case D functions as a central point, it also ensures that all the parties involve received the required information in softcopy and hardcopy format.

In Case E, Organisation E uses its protocol including BIM protocol and BIM standard for reference as the participant mentioned that:

“We have our BIM protocol and our BIM standard, together with our guidelines. So, whatever we want to do, we have to go back to that, how do we have this we go through our protocol, we go through our guideline.”- PE1

Similar to the other cases above, Organisation F has its protocol as a project guide including BIM Guideline, BIM Standard, and BIM Process.

In Case B, according to its managing director, all the issues that arose in implementing BIM are being documented as a reference for others as mentioned by the participant that:

“One way that we do this is through documenting that we do to support our customer. So we make it as an open document, let say that if one party have an issue with the customer and they can solve that issue, so we are sure that the next time if other party/ staff have an issue on that, they can refer to that.” – PBI

Additionally, in Case B, Organisation B also uses support documents for the BIM implementation, for instance, support reports.

This research follows the definition of knowledge sharing in implementing BIM as the process to transfer, disseminate, and exchange knowledge, experience, skills, and valuable information of BIM implementation, which includes explicit and tacit knowledge from one individual to other members within an organisation with continuous interactions through various approaches as discussed in Section 2.4.7 page 57. Thus, the valuable information includes approaches taken such as developing and documenting the BIM protocol used in an organisation. The organisations took the initiative to document their own BIM protocol to guide their employees in implementing BIM.

4.4.1.3 Organised Training

All cases involved in the research preferred to conduct organised training internally as well as externally for some cases (Case A and Case C) to reduce their BIM learning curve.

In Case A, Organisation A practices organised in-house training which includes Revit tool training that is compulsory for any new employee who joins them. Revit modelling is a requirement for experienced engineers who join the company. Also, Organisation A sponsored a programme called ‘Talent Industry Programme’ for young engineers to learn about BIM, evidenced as follows:

“For young engineers, twice a year we will recruit two groups, they will go to the ‘talent industry program,’ it’s a two months program. We finish. We recruited 6-10 engineers. We will put them to this program, learn about BIM, how to do modeling, how to do virtual constructions...”- PA1

In Case C, Organisation C also has an internal programme slightly similar to Case A called ‘Train the trainer’ for coordinators to become its apprentice. The participant explained how the organisation came up with that programme as follows:

“Yaa, probably for our company we have the train the trainer, is basically for the coordinators like I can’t do every single thing, I need to train my apprentice. BIM coordinator is my apprentice, so and normally has this sharing@ their stick with me and go to meeting on certain stuff and they follow and learn. So, after certain point normally around 3months, I started to go back and let them because I think without proper exposure, you do in the office, it doesn’t work like that. Give them to the real scenario, real situation because we keep on talking about this in theory, but when they’re exposed in the meeting, then they know how.”- PC1

In Case D, there are four types of in-house training organised by Organisation D. The organisation usually conducts its training under a programme called Smart Team and Boot Camps as the participant elaborated further as follows:

“...They go around and introduces to prospective client@ prospective contractors@ big consultant, and then we go along and offer them a quick slideshow presentation on what we do and how we do it. And we educate them on what’s it’s all about. Normally take half a day, 8 hours, something like that.”- PDI

“We have what we’ve called Bootcamps which run over the weekends, or Friday, Saturday or Sunday, Monday and we go down, and we give different lectures explaining different aspects. So those around this Bootcamps, they get an overview from not just one person, but from a group of people in different area compare to one of it because all of us are specialists perhaps in a different area to one of it, in the whole team. Therefore, some of us control more on BIM execution plan, some on QS side of thing, some on the construction side, some controls more on consultancy side.”- PD1

At the same time, two cases (Case A and Case D) run classroom-based training internally. In Case A, Organisation A utilised their construction team in sharing and spreading the construction knowledge to the employees for a solid two month classroom-based training. In Case D, following from its Smart Team and Boot Camps, if they require additional information, Organisation D runs a classroom-based training for eight people in a half day or full day course. Furthermore, the organisation encourages constant and continuous learning through any workshops, lectures etc. to gain new knowledge. It also provides further training as the participant mentioned that:

“If ever some other people that I know, they have a got a free half a day, I’ll get them to come down and give a lecture to all of them, people in the office. It may be a different thing, so therefore we do a lot of internal. We try to have something like that at least every of the month, sometimes it’s not every other month, sometimes two months, then we go a couple of months. So, we try to do that. We try to keep everybody being constantly educated.”- PD2

As Case B has a training organisation background, B organises training all the time and uses a high technology screen to show the training needed. Organisation B also uses social media such as Facebook, Google and WhatsApp to share and organise information within the team members. Other approaches used by Case E and Case F is yearly courses. Internally, Organisation E has sent two batches for its employee training, and the participant explained further as follows:

“We’ve sent our batch; we have batches, we have two batches already now. So, the batches, those who are involved, they go training at least 1-2 months every end of the year.”- PE1

Similarly, Organisation F has a yearly course, and sometimes the organisation call in external parties to give talks to share knowledge in BIM implementation.

Alternatively, two cases (Case A and Case C) always send their employees to external training such as conferences and seminars organised by professional bodies in Malaysia.

4.4.1.4 Social Media Medium

Social media provides interactive communication between one individual or organisation to another. According to Parveen, Jaafar, and Ainin, (2015) the interactive nature of social media creates a two-way communication between organisations and the public, which has helped them to improve their relationships. It has the capacity to reach larger audiences at minimal cost and time. Literature asserts that social media could have a powerful impact on organisations in digital advertising and promotion, handling customer service issues, collecting ideas, and developing customer relations (Tajudeen, Jaafar, & Ainin, 2018). Thus, when organisations use social media effectively for various tasks like information searching, marketing, and customer relations, it is likely to have a positive impact on the organisation in terms of cost reductions, time saving, improvements in customer relations, and enhanced accessibility of information. The studies conducted by Parveen, Jaafar, and Ainin (2015) and Tajudeen, Jaafar, and Ainin (2018) show that social media has a greater impact on the performance of organisations in terms of enhancing customer relations and customer service activities, improvement in information accessibility and cost reduction in terms of marketing and customer service. The finding is consistent with previous research that found significant relationships between technology usage and organisational performance (Apigian, Ragu-Nathan, & Kunnathur, 2005; Stone et al., 2007). Also, a study of small and medium enterprises (SMEs) in the UK hotel industry confirm that use of social media results in better performance for the firm (Tajvidi & Karami, 2017).

In Case C, Organisation C utilises social media as a medium to share knowledge internally and externally (with the public). Some of the texts in the group are hidden to secure organisational anonymity. It has a Facebook group and shares its knowledge via the forum and chats as shown in Figure 4.8. Anyone within the organisation and

outside of the organisation who seeks knowledge could access the Facebook group. Organisation C uses this medium to share their knowledge in BIM implementation, for instance they answer the questions posted in the group regarding problems occurring based on their experience and skills in implementing BIM and are open to any discussion. By doing that, Organisation C shares their knowledge and helps their employees or BIM community to overcome the problems that they faced. This practice indirectly might reduce time for the group that faces problems in implementing BIM to find the right solution instead of trial and error. Externally, Organisation C also has a website to share its knowledge with external parties.

In Case F, Organisation F also uses its website to share knowledge specifically on BIM implementation as mentioned in the following:

“...then, we have our organisation’s website sharing on the progress of BIM implementation. Not general news, but only on BIM. If you want to know about Organisation F history and BIM in our organisation, browse organisasif.gov.my.” - Participant F

Organisation F has also used an internal online forum called J-CoP (Organisation’s community of practice) to ask, answer and discuss any queries regarding BIM as well as project queries as shown in Figure 4.7. Moreover, Organisation F uses J-Pedia as its user group to store and share any documents related to BIM that its people got from the seminars, courses, etc. All records could be accessed by anybody internally.



Figure 4.7: The screen shot of Facebook group used by Organisation C to share knowledge

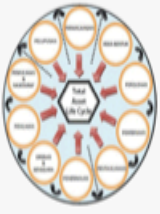







Tools	What links here	Related changes	Special pages	Printable version	Permanent link	Page information	
				WikiTAM	ECKM wiki	JCoP	WikiGreen
Devoted to project and asset management knowledge base, aimed at those involved in managing the total asset life cycle	Information on enterprise content and knowledge management framework, governance and initiatives implemented in JKR	Community of Practice	A collection of JKR Green Technology documentation				
				PM Wiki	VM wiki	BIM wiki	Wiki Cost
Information on PM competency framework, standards, best practices developed by PROKOM	Information on VM processes, collection of VM reports, lessons learned aimed at those involved in VM	Information on BIM roadmap, processes, projects, standards aimed at those involved in BIM	Wiki Cost is a platform for user to search price list from suppliers				

Figure 4.8: Screen shot of J-Pedia and JCoP for interaction in Organisation F

Although PB1 agreed that Facebook is great as a medium for knowledge sharing, nevertheless in Case B, the organisation did not use it because of the company size that was considered still small. Therefore, in Case B, the organisation could always rely on WhatsApp due to its current size. Case B also preferred to use Google engines to organise information within its team members.

Research on social media usage in knowledge sharing continues to develop and further research will continue to surface. The work of Ali, Nazir, and Ahmad (2019) is the latest research which focuses on knowledge sharing through social media. They have identified three main activities of social media applications, which include knowledge-seeking, knowledge-contributing, and social interactivity across a range of businesses, education services, health services, disaster management, general professional services, and other entities. Four research topics or themes were identified in their study, related to social media for knowledge sharing, which leads to the conclusion that a large number of studies have focused on users' behaviours regarding social media usage in knowledge sharing, followed by utilisations, benefits, platforms and tools, whereas concerns over privacy have not received sufficient research attention. Therefore, there is a potential to look further into this social media approach for knowledge sharing that could benefit the construction industry and BIM implementation, as well as finding its risk or limitation.

4.4.1.5 External Involvement

Two cases out of six (Case A and Case B) contributed to external involvement. Externally, Organisation A runs knowledge sharing sessions with the industry through talks and seminars with government agencies as well as private companies. Another approach used as external involvement by Organisation B is being a speaker and a sponsor. Speaking engagements are opportunities for knowledge sharing or spreading the knowledge in implementing BIM to others. Organisation B has prepared its employees towards making that contribution. Alternatively, being a sponsor also benefits Organisation B as evidenced by the following:

“We can participate as a sponsor so that we can have a go. That is how I mean we get involve and get our knowledge level intact, just to make sure that we are aware of what’s happening in the market.”-
PBI

The findings from the interviews identified many knowledge sharing approaches used by the BIM practitioners in the entire BIM implementation process. The approaches that have been highlighted are summarised below in Table 4.2.

Table 4.2: Summary of knowledge sharing's approaches in implementing BIM (Parent Nodes 1) under Theme 1

THEME 1: CURRENT PRACTICES & POLICIES OF KS IN IMPLEMENTING BIM									
Parent Nodes 1	Child Nodes	Sub-child Nodes	CA	CB	CC	CD	CE	CF	
KS Approaches	1. Documentation	Own protocol	X		X	X	X	X	
		BIM Forum 2014 & 2015			X				
		BS1192			X				
		Depends on client				X			
		Documenting the issues as reference		X					
		ISO for document flow	X						
		PAS 2 & PAS 3 1192			X				
		Softcopy and hardcopy information					X		
		Support reports		X					
	2. Everybody is accessible and connected	Regular meeting	X	X				X	X
		Workshops			X	X			X
		Demonstration	X		X				X
		Organisation as a central point				X			
		Portal	X					X	
		Server		X	X				
		Assure right information to the right people					X		
		Assure team members asking right questions		X					
		E-mail		X	X	X			
		Face-to-face			X				
		Flatten the level		X					
		Gather and share			X				
		iClouds, Clouds & Dropboxes					X		
		Informal way			X				
		Roadshow						X	
		Spirit to collaborate				X			
		Via work station				X			
	3. Organised training	In-house training	X	X	X	X	X	X	X
		External training	X		X				
	4. Social media medium	Facebook			X				X
		Website	X	X	X	X	X	X	X
		Forum							X
		Google engines		X					
		User group/ CoP			X				X
		Whatsapp		X					
	5. External involvement	As a speaker	X	X					
		As a sponsor		X					

4.4.2 Colleagues' response to the knowledge sharing in implementing BIM (Parent Node 2)

There are eight child nodes emerging from parent node 2 in exploring colleagues' response to the knowledge sharing in implementing BIM as shown in Table 4.3. In general, all participants agreed that colleagues' response to the knowledge sharing in implementing BIM is significant to solve any issues as evidenced by the following:

"...normally if we know, I mean what the issue is, we can quickly solve that because, with the team, you can do that. So you don't have to wait for other things to be in place. If you are talking about CAD, so you know there is a problem, but you need to refer to floor plans, sections and details at the same time. With Revit and BIM, you can scroll and go there; the sections are already there, all the details are already there, if you make a change, it will change everything."- PBI

An experienced company director from a developer background highlighted that colleagues' response must be driven by a leader to ensure that others will keen to follow and implement it as evidenced by the following:

"It's crucial now. In the beginning, everyone is watching and see because it's a new thing, any new project you need a leader to drive first but once that stage over, then everyone will do."- PA1

Also, according to the managing director, who is also a BIM manager (PC1) and senior BIM manager (PD2), colleagues' responses to knowledge sharing in implementing BIM is critical to overcoming a particular problem (child node) as evidenced by the following:

"....but the Malaysian Revit user group, the reason we start to put it on a platform, it's not what a Malaysian Revit user group, when we become the admin, every problem, the admin need to responds to, we are creating a platform whereby it's a free platform for every Revit user in Malaysia that has a problem, they don't have to call the software vendors, and the software vendors come, and they can charge 5 %, etc., they can share there, whoever knows how to overcome it, just share. So that's the spirit that we try to put there for external. The reason we put there, for example, the problem that we have there may be new for me, but ok, it's giving a solution whereby when I encounter that particular problem, I overcome it."- PCI

"It's critical that if we issue RFI, we normally stipulate it within 3-4 days turn around. Even if they get down to the site, that information is not available yet, and it will be available in a weeks' time, all provide information required. If we run workshops, and we may make 5 clashes, and we agree on

resolutions in workshop, it's important that resolutions are taking that to the relevant design team office rather than drawings updated, modified, issue then, to everybody because it's ok to talk about it and say yea, we solve that problem by doing this, for a less that problem resolution follow through in a 2D and a 3D inputs, it's not actually cheat and if you don't physically do it there and then, when you actually come to the finish border, what you end up is you end up with some resolutions have been agreeing in a paper, in a workshop, but not actually been followed through into a 2D @ 3D model. We agree but that's not what been followed through, so therefore, with 2D drawing and 3D model are still not fully coordinated because the real resolution has been agreed but it's not being followed.”- PD2

Furthermore, three participants (PA2, PE1, and PF1) raises that colleague's response to the knowledge sharing in implementing BIM is significant to spread the awareness and knowledge needed (child node) during the transition time before BIM becomes mature and especially to those who are lacking as evidenced by the following:

“Mmmm...it is very important because if we don't support, it's going to be very difficult, right? So, yea we meet with those who are very supportive, those who a bit lacking but the lacking one will try to push them. The best thing, I think is our team are all very young, so younger people are very eager in all this.”- PE1

“Ok, at the moment for me, BIM is in the transition. So, in a future for example if we already matured, maybe new generations might easily learn, for example now if we want to learn on Auto CAD, a new generation is easier to learn because people surrounding them already knows it. In the meantime, only a few know and experts are not many. When experts are many, this will not be a problem anymore.”- PF1

Along with that, instead of general comments for colleagues' response such as to solve any issues or particular problems, PA1 mentioned clearly that for Case A, colleagues' response to the knowledge sharing in implementing BIM is used to spread the knowledge needed to different teams in the organisation, to estimate the cash flow for the finance department, to spread the benefits of BIM to all people in the organisation, to use for material scheduling by the procurement department and to use for estimation by the quantity surveyor.

Table 4.3: Summary of colleagues' response to the knowledge sharing in implementing BIM (Parent Nodes 2) under Theme 1

THEME 1: CURRENT PRACTICES & POLICIES OF KS IN IMPLEMENTING BIM								
Parent Nodes 2	Child Nodes	Sub-child Nodes	CA	CB	CC	CD	CE	CF
Colleagues' respond to the knowledge sharing	1. Very important	To solve any issues	X	X	X	X	X	X
	2. To overcome a particular problem				X	X		
	3. To spread the knowledge needed		X				X	X
	4. Lead by example		X					
	5. To estimate cash flow		X					
	6. To spread the benefits of BIM		X					
	7. Use for material scheduling		X					
	8. Use for quantities		X					

To sum up, all cases stressed the importance of colleagues' response to benefit from BIM. Case A encouraged KS in implementing BIM for many reasons because of the nature of its business that covers the total value chain which includes building a broad spectrum including hospitals, high-rises, condominiums, commercial and residential units. It has several divisions with different focus. Therefore, Case A needs colleagues' response to benefit more from BIM use compared to the other five cases.

4.4.3 Important Source of Knowledge Sharing in Implementing BIM (Parent Node 3)

For the third parent node (Important source of knowledge sharing in implementing BIM), the participants are asked to identify the vital source of knowledge sharing that the participants had encountered in implementing BIM. Different kinds of sources (child nodes) have been listed as essential sources as shown in Table 4.4.

From the developer's perspective, PA1 in Case A believes the primary source of the knowledge sharing in implementing BIM that should be brought in at the very beginning is the top management support to make it happen. This is then followed by

the top management appearance where showing up at the important meetings, construction meetings or development meetings does matter. She also stressed that demand by the top management must be emphasised earlier to ensure the employee will fulfil it as mentioned:

“He insists that he want to see the progress of the project on the screen in 3D form. So, the engineers have no choice but to update the as built on time and every month they have to show it the as-built in 3D form. So, the bosses must ask for it, and in the consultant meeting, you must coordinate the 3D model. To implement this, leaders, bosses or managers, you must demand it. If you emphasize it at the beginning, the staff will consider following, no choice but to follow.”- PA1

She further explained the time spent to foster the top management’s demand in implementing BIM. According to PA1;

“I spend half of my time to educate my board and make sure they ask for it during the meeting. So, demand it, ask for it, at the same time telling the young person to do, that the employee ask them to do that. If you don’t have that coming in, but if the manager asks for it, then it can be done.”- PA1

In terms of technology, a participant from developer background (PA1) and a participant from BIM consultant background (PC1) use a powerful computer to run the BIM tools. Also, PC1 mentioned that a powerful computer is an important source for knowledge sharing in implementing BIM because it has a prestige value. He stated that;

“Like our potential client because we’ve been blessed to be equipped with good facilities. As you know, the workstation @ laptops become our ambassador when we deal with a client.”- PC1

Also, PA1 mentioned that Organisation A uses display screens, for instance, a television screen to display their 3D model for its knowledge sharing activities in implementing BIM.

From the analysis of interviews, three participants (PA1, PC1, and PD1) argued for a trust element. It is found that the trust factor is crucial for knowledge sharing in Organisation A although based on the nature of BIM implementation, the trust should come naturally because BIM encourages the parties involved to work together

sincerely. In line with that, the managing director cum BIM manager (P3) further explained that Case C working relationships always stand on trust as he stated that;

“In Organisation C, we are more like family, the relationship is based on trust, ok. I don’t care whether my staff call me Encik or Mr. or Sir, we still act as a friend, but they know the limitation of the relationship.”- PC1

Accordingly, Case C uses a circle structure and treats its people more like family based on a trust relationship. In contrast, the senior BIM manager (P4) from the integrated BIM consultant believes that BIM implementation does not need trust for everybody to get the right information due to the nature of BIM platform where everybody works from the central data source.

“Trust? The idea of BIM platform is that there is no trust. Nobody trusts anybody else to make sure it’s right. In theory, if you put it all into the central data source, then everybody works from it. So, therefore, you don’t have a trust. Everybody knows that they get the right information.”- PD1

In the context of knowledge sharing, the case studies’ findings stressed the need for building trust via a good working relationship and environment. In the context of BIM implementation, the case studies perceived that trust relationships should develop naturally due to the concept of collaborative BIM environment. This is a good sign for how trust is viewed in BIM implementation for the Malaysian construction industry as trust is an essential factor for strong organisational collaborative relationships. Singh et al. (2011) believed that BIM integration will succeed with trust between different project participants. However, the case studies’ results contradict with other researchers as mutual trust on the completeness and accuracy of 3D models remained a major issue for industry players, resulting in information exchange on 2D drawings only (Gu & London, 2010; Porwal & Hewage, 2013).

Interestingly, PB1 and PC1 agreed that working culture is important rather than working with the model itself although BIM is related to the model or modelling. The analysis reveals that the right working culture is created as important sources for the knowledge sharing in implementing BIM since the first interview of candidates for

Case C. Furthermore, Case C is looking to employ people with a keen and passionate attitude or personality for learning during their interview. The participant believes that people who have a passion for learning can move further and are suited to Case C because of its open environment. From the perspective of sales, training and BIM implementation organisation background, meaningful meetings and discussions are needed to proceed in the implementation and admitted as follows:

“The source that we need is not another document, it is a meeting, and what comes up with it. In construction In here is that we have bad habits is not minute things on what happened in a meeting. They can call meetings at any time. Some of our projects, we stop client t from calling us for the meeting because they were calling for fun. We wanted a meaningful meeting and documented so that we can proceed.”- PB1

He then further explained that via the meetings and discussions, some explanations might be needed as further explained by the participant below:

“...if it explicit, then something needs to be explained, there’s no way that we can do it, unless we go and organise some meetings and go through the discussions, only then we can get through that.”- PB1

Besides, a proactive action was emphasised by PB1 as a source of knowledge sharing in implementing BIM to ensure the organisation’s performance is on track as evidenced by the following:

“I think nowadays is more proactive on what we do, communicating what we need, sometimes we can communicate to them, but if they are not replying to that and they still replying it offline. Then, what we need to do is resend another email. Yes, we always need to follow up because everything is ok up to a point where it becomes a problem where people will start putting the blame. If there’s an information gap, this is where people start with this blame game. So, what we try to do is we try to cover our track, to keep track on our track on what we do. We have this information readily available.”- PB1

PD1 from the integrated BIM consultant background and PF1 from a government agency background, admitted that the knowledge sharing and the process involved are perceived as an important source as the PD2 mentioned that:

“Yeap, the important source is all about knowledge, understand it how people are going to use the information, so, therefore, you’ll understand the process.”- PD2

Also, PF1 highlighted the importance of knowledge in using BIM tools and how to organise to ensure that the analysis can be done.

The same participants (PD2 and PF2) agreed that the critical sources for knowledge sharing in implementing BIM are communication and collaboration. The PF2 further elaborated that the organisation's branches could quickly come to the BIM Unit for clear knowledge sharing in implementing BIM or else could refer to its branch BIM unit. Another source related closely to communication is interaction as mentioned by PB1:

"It's more on interaction if they can draw it, it's not a problem because if they can draw it, it's not a problem, they would draw it, but normally this problem that they have can only be dug out by our BIM model, then we actually can show. For example, if we are talking about a drawing that has angles and how it's going to be supported. The architect is not going to do that; they have this information gap. Most have the time they have flat or some cut sections, but how goes around the corners, nobody knows, how these sections meet with the other section, nobody knows. So, this is where we need actually to fill in the gap."- PB1

Accordingly, Case E has a Google group to spread things and share online within groups that consist of people who are scattered everywhere.

In Case B, all the information must be documented and coordinated as both are important sources of knowledge sharing for BIM implementation. Google Docs and Google Drive are used to update the people in the organisation with the required information. In the meantime, although PF1 admits that some of the things need to be demonstrated, Case F has documented what it has done in BIM implementation in its standard as a guide. Furthermore, the format of the information sharing is considered as one of the important sources as stated by PD1 in the following:

"Important source is to know, what everybody wants to share the information. How they need it to be delivered. So, if you are an architect, you need the information to be given to you in what format? How it needs to be shared with you. You need to understand this, as a BIM consultant, you need to understand, how everyone needs the information and how they are going to use it. How the QS wants information, and what he's going to use it for? How architect wants information and how he's going to use it? How contractor wants information and what he's going to use it for? So, if you don't

understand how your team, how the design team, and how the contractor team is going to work, then you won't understand how to give the information sources information, share the information from within the BIM platform.”- PDI

Moreover, the Head Assistant Manager, BIM Unit from the government agency background perceived that skills and experience are also important in BIM implementation. According to Participant (PF1);

“The truth is more on experience because that is not mentioned anywhere, for example, if we want to build a room, this is the steps. Even if we learn Revit, if we want to build a room, it's room. However, in actual, this is more towards an experience that taught us.....more to skills and experience.”- PF1

Table 4.4: Summary of important source of knowledge sharing in implementing BIM (Parent Nodes 3) under Theme 1

THEME 1: CURRENT PRACTICES & POLICIES OF KS IN IMPLEMENTING BIM									
Parent Nodes 3	Child Nodes	Sub-child Nodes	CA	CB	CC	CD	CE	CF	
Important sources of knowledge sharing	1. Natural trust		X		X	X			
	2. Attitude or Personality				X				
	3. Communication and collaboration					X		X	
	4. Documented information			X				X	
	5. Interaction			X			X		
	6. Knowledge					X		X	
	7. Powerful computer		X		X				
	8. Working culture			X	X				
	9. Circle structure				X				
	10. Coordinated information			X					
	11. Display screen		X						
	12. Experience							X	
	13. Explanation	Explicit information			X				
	14. Meetings and discussions				X				
	15. Proactive action				X				
	16. Sharing information format						X		
	17. Top management	Appearance		X					
Demand			X						
Support			X						

4.4.4 Management's Supports Management Support and Policies to Encourage Knowledge Sharing in Implementing BIM (Parent Node 4)

For the fourth parent node (Management support and policies to encourage knowledge sharing in implementing BIM), the participants are asked to describe management support and policies that the participants have experienced in implementing BIM. Eleven (child nodes) have been listed as shown in Table 4.5.

In encouraging the knowledge sharing of BIM implementation, most of the cases (except Case D) did not employ a reward system to its employees for knowledge sharing. However, PA1 from the developer background suggested that management support and policies for knowledge sharing should be embedded in the organisation's culture. Also, the PA2 believes that management support is compulsory and is primarily by the owner. With that support, the employees will have an opportunity to expand their career as mentioned:

"They see it as an opportunity to go. It's grow and its opportunity in term of career building. We don't need to spend so much time encouraging the young person to use it, only the one who thinks why they want to change but still they are changing already. They change because quite frustrated with the old way of doing things."- PA2

However, PC1 from BIM consultant background, PE1 from builder background and PF1 from government agency background stressed the aspect of non-monetary reward. PC1 explained that employees could benefit such as from the information and knowledge needed, experiences in doing BIM and exposure to knowledge sharing with the industry and BIM community. According to PF1, Case F does have recognition for a certified person. PE1 highlighted that someone who has performed in the BIM department is a person with special skills and opportunity. She further elaborated the following;

"Aaa...when you are in BIM department, and when you work harder, doesn't mean without BIM in your department, you will automatically get that, but obviously it has to come with your performance. The scheme is still regular with everybody else; you are just highlighted."- PE1

Instead of a reward system, the structure of Case B requires information sharing, and a penalty might be imposed for not sharing as mentioned by PB1 as follows:

“We don’t reward information sharing because our structure requires that. So, it’s a must. You might be penalised, but you are not going to be rewarded.”- PB1

Four out six cases; Case B, Case C, Case D and Case E, are promoting trust as their management support ensures the flow of information is communicated smoothly. PD1 indicated that Case D promoted trust by emphasising the benefits of BIM and had a target of working with 3D and the whole BIM process within four years. PE1 stated that Case E is also promoting trust as its management support by sending its staff for training abroad in Singapore and Taiwan. Besides, Case C is putting its upfront policy as “mould, who we are right now” and the participant believes that the policy for knowledge sharing in implementing BIM should be done via top-down enforcement as evidenced by the following:

“The support is, I always believe since I was in XYZ is top-down enforcement. Doesn’t come from below, like from the modeler know, then they will do it by themselves. It doesn’t do it that way especially in XYZ. In my company, I’m the one who’s creating this ecosystem, and if you don’t believe in BIM, you can find other company, you don’t believe in sharing, you think you are better than others, I think it doesn’t fit we are in Organisation C.”- PCI

In terms of the awareness for the information sharing, two cases (Case B and Case F) are supported by their management. PB1 explained that Case B’s management always ensures that any information in implementing BIM is validated by using checks and follow ups. Meanwhile, in Case F, support is given via talks in guiding its branches to implement BIM. Moreover, the management of Case D supports their organisation by ensuring that the relevant education is passed to its people via lectures, seminars, and tutorials.

“..they also make sure that we able with all the relevant lectures, and seminars and educational tutorials that are required to make sure everybody is up and is advanced as possible.”- PD1

In terms of technology, the management in Case D supports the BIM implementation by making sure that the organisation has all the right software and hardware required. The same support is given in Case E as PE1 explained that the management of Case E is very supportive in providing approvals for software and hardware purchases. Case F has also prepared a communication platform such as running a programme to assist designers and using J-Pedia and JCoP (as shown in Figure 4.9) for interaction and knowledge sharing.

Table 4.5: Summary of Management Support and Policies (Parent Nodes 4) under Theme 1

THEME 1: CURRENT PRACTICES & POLICIES OF KS IN IMPLEMENTING BIM								
Parent Nodes 4	Child Nodes	Sub-child Nodes	CA	CB	CC	CD	CE	CF
Management's support and policies	1. No reward system		X	X			X	X
	2. Promote trust			X	X	X	X	
	3. Awareness for information sharing	Ensure information is corroborated		X				X
	4. Right software and hardware					X	X	
	5. Career building opportunity		X					
	6. Compulsory for owner to support		X					
	7. Embedded culture		X					
	8. Ensure relevant education					X		
	9. Non-monetary reward				X			
	10. Prepare communication platform							X
	11. Top-down enforcement				X			

4.5 Organisational Culture and Knowledge Sharing in Implementing BIM (Theme 2)

For the second theme, the researcher seeks to determine the relationship between organisational culture and knowledge sharing in implementing BIM. There are five questions under this theme, with the main idea of exploring the actual practices of the organisations to compare with the literature review. The summary of organisational culture and knowledge sharing in implementing BIM is shown in Table 4.6. The analysis done in this research is focused on the following:

- a) Organisational culture (OC) influences on knowledge sharing
- b) Leader's role
- c) Management's role
- d) The importance of support, commitment, and vision of management

4.5.1 Organisational Culture (OC) Influences on Knowledge Sharing in Implementing BIM (Parent Node 1)

More than half of the participants (P1, P4, and P5) agreed that organisational culture will influence knowledge sharing activities as well as BIM implementation. PA1 thought that the right organisational culture will positively influence the knowledge sharing activities. In Case A, it started with a clear mind-set that its BIM usage is just like using a usual tool such as Microsoft Word. This mind-set will then be boosted by the positive attitudes that could take the organisation another step forward. PD1 also encourages a positive attitude at the workplace for practical knowledge sharing to balance between good and poor people as mentioned below:

“The office is where people work share are highly efficient because some people are good, some people are bad. And everybody runs their place. And in an office where everybody shares, the good people help for poor people, so everybody gets better and better.” - PD1

From the builder's perspective, in Case E, the organisation promotes a positive mind-set to take BIM as a normal task in its culture and thinking skills.

In Case B, an organisational culture influenced the BIM implementation within the organisation. The managing director in Case B mentioned that their team members

performed to the required level because of a strong, trusting organisational culture which is open and inclusive. The participant claimed that culture must begin with trust as the following:

“If you have a culture that in a first-place distrust, I mean there is something that you need to earn, not something that needs to be given. There are many of the companies that start with distrusting, and only then goes to the trust part. Our organisation goes to the opposite of that. We trust you up to the point that you are not worth the trust.”- PBI

It is also advisable to avoid a highly hierarchical culture that discourages information sharing as demonstrated below:

“If you have very hierarchical kind of culture, that also discourages information sharing because what you will end up to is basically people are trying to protect their interest, not their interest in a project, I mean up to a point we don't care about your interest in building up of your relationship with your colleagues, but what we are interest is the wellbeing of your project outcomes. So that's why this organisational culture is significant.”- PBI

Concerning organisational culture influences on knowledge sharing, Case C treats its team as trusted friends by employing a circle instead of a top down structure. Through this structure, Organisation C tries to avoid a hierarchical culture. Organisation C also encourages openness in the organisational environment. This pushes the people to share, learn from their mistakes and enhance performance. The same open concept is applied in Case E for knowledge sharing. Organisation E allows its staff to ask and speak freely.

From the responses, Case D and Case F showed that its organisational culture influences knowledge sharing through its typical approaches of providing education on the benefits of sharing knowledge. PD1 stressed the benefits that people might get when sharing information as mentioned below:

“People believe that if they share the information, they educate another people and another people so that they will get some of the same level or better than them. As in real terms, the more you share, the more you learn, so the better you get all the time. Everybody gets better.”- PD1

From the perspective of a government agency, PF1 pointed out that educating and sharing with others should become a culture in the organisation; this will spread the knowledge and increase the number of people with knowledge. However, PF1 admitted that at the moment, knowledge sharing in implementing BIM is quite slow due to the low number of people with the appropriate knowledge and experience in the project implementation.

Avoiding a team member's isolation is another way to improve the organisational culture in information sharing. Moreover, in Case B, PB1 acknowledged that the organisation practices accountability in implementing BIM towards the project as shown by following:

"The way that we are trying to do this is that everybody has their responsibilities and you are responsible towards what is your responsibility, the more important is the responsibilities towards the project itself."- PB1

Moreover, according to PA1, the skills developed will also push the knowledge sharing in implementing the BIM process to the optimum level.

4.5.2 Leader's Role (Parent Node 2)

The leader plays an important role in setting up the organisational culture, and all participants agreed with that in terms of BIM implementation. According to the director of Case A, a leader is a person who should have an open and forward thinking to inspire others. PA1's thoughts on this issue are as follows:

".... normally manager can see a bigger picture, then they will come with a new idea to ask can you also can do this, and punch into something else, that inspire the young one to do more and find out more because, for them, they can't see so far. So, with that, you balance it and move further and further."- PA1

Leaders are also the ones who should drive the organisation forward because they always think ahead as PA1 believes that:

“Leaders are the one that by right should be visionary. They see things ahead, so I believe the leader must take that role to drive the company in the right direction. Of course, you can have greater revenue at the point somewhere, but I think that will be difficult to drive the company.”- PA1

The leader’s role is also vital in the organisational culture and knowledge sharing in implementing BIM in Case D. PD1 spelled out the importance of senior management to be open and forward thinking in ensuring that the team works together. It is their responsibility as well to make sure that the team works efficiently. In Case E, its leader’s role is to promote their support and motivation in their leadership style by being open and trying to provide whatever is needed in their organisation. Moreover, its management fosters learning and development as well as encourages BIM implementation. The participant perceived that the support, commitment, and vision of management are vital. They practice sharing online and have a top management forum on a yearly basis. It is also perceived by PB1 that there is a link between the organisational culture and knowledge sharing in implementing BIM. The leader should inspire others by being a good listener to his or her team members as their thinking is related to specific problems.

4.5.3 Management’s Role (Parent Node 3)

For the organisation to compete globally, PA1 admitted that the management must lead by example. Under management’s role, many acknowledged (PB1, PC1, and PF1) that active involvement in a BIM process is needed in BIM implementation instead of being an observer as evidenced by the following:

“The role of the management is not to be a spectator, and they must be actively involved BIM implementation itself, in the BIM process. So that means that, if you are to create this Organisational culture, the main thing is you cannot be just like..ok, I am going to need you to do this but you cannot, I mean you do not know what this and that is. I mean is that as a leader, you must understand what this and that is. You must be able to, and if you do not know it, you must admit that you do not know it. Perhaps, you can sit down with team members and start actually to figure it out; this would work at the end.”- PB1

In Case C, according to the PC1, there must be active involvement in planning for the process and team requirements in implementing BIM via a participant experienced in spearheading the team. According to the PF1, in Case F, the management supports its organisation with active involvement by creating a BIM unit or department in charge of BIM implementation in each branch. The unit or department will then help its branch in BIM implementation.

Besides, PB1 and PD1 believed that the management's role is to direct something meaningful and envisioning the outcome. PD1 further explained that the management should play its role to direct something meaningful and envisioning the outcome to ensure that its staff perform at their optimum level. The participant perceived this as the following:

“And its management responsibility, to make sure you stay on top to make sure what's going on around you or what' going on those people around you within the CI in advance to make sure everybody else in your team is up to speed as much as possible, and they're working sufficiently as soon as possible.”- PD1

At the same time, the management is also responsible regarding education. PD1 encouraged the management to learn as much as possible and to pass down the information to its team, to assist the team when they run into a problem and to make sure the problem can be resolved. Correspondingly in Case E, the management promotes learning and development as PE1 revealed that:

“You see, in organisation E we encourage learning, encourage developing people, so exactly encourage BIM implementation.”- PE1

PC1 then suggested to encourage a person that is interested in BIM to be a BIM champion as the participant spelled out that:

“...if I do not have this thing upfront, if I am not a BIM literal person who been tasked to do this thing, I think I will not go far because some company has tried it with little knowledge BIM and try to execute it, it becomes half cooked train, and it has become abandon. Revert to conventional. So, it is important for whose like to start BIM, need to be the BIM champion. When I said bim champion, you are literal in BIM, you are literal in managing resources, the process, managing the technical issue as well. If you know, only process and how to manage people, it is only a normal and typical manager, for BIM we need to manage technical and how you use certain tools, etc.”- PC1

Likewise, PB1 highlights the importance of management in the organisation to handle the project with the right people and the knowledge level in implementing BIM as mentioned in the following:

“The top management because in my experience at looking IT organisation, they set up a BIM organisation, but then there is not actual or clear of what was BIM is. Moreover, what of that would need BIM to be included to make BIM a success, in the sense of..I can get this project, but to ensure that you can go to the project with the right people, with the right knowledge level. So that is how I think, but more importantly is this why it is required by the organisation.”- PB1

4.5.4 The Importance of Support, Commitment and Vision of Management (Parent Node 4)

Regarding the support, commitment and vision of management towards the organisational culture and knowledge sharing in implementing BIM, all participants concurred that it was important.

Two participants (PC1 and PF1) view the importance of support, commitment and vision of management relies on the exposure to BIM knowledge via seminars. According to PC1, Case C invests through exposure in seminars and the chance to spearhead the team for knowledge exposure. For instance, Case F has conducted its BIM Day and called all its branches to attend one half-day seminar. Moreover, the management of Case F shows its commitment and support by sponsoring and conducting any relevant programmes to spread BIM knowledge.

PC1 elaborated further that the critical aspect of organisational culture and knowledge sharing is creating an excellent working condition that includes happiness in the process, as evidenced by the following:

“When you want to make money, you need to make all the people in the company happy. They happy to do the job, they can do the job more efficient, doesn’t need to do OT, more time, etc., when all people happy. The thing or reward coming from outside is better, so the top management needs to ensure that everyone is happy in the process.”- PC1

"I think the environment for me is important. The reason why people left one company mainly not is that of the incentives but its immediate superior, if the immediate superior is good, doesn't mind staying with the same company instead of having the good pay and you get the bad boss."- PC1

However, PB1 argued that a good working condition is part of the encouragement to knowledge sharing, but the principle is having conducive environment for the team members. He further explained that:

"So, it is not so much in encourage knowledge sharing, but this is to have a good working condition for your team members. So, knowledge sharing is just part of it. I mean, you do not have knowledge sharing if it is not conducive for your team members to share anything or in contradict to their best interest to what they are doing or it contradicts with what are the company does."

Also, two participants (PB1 and PE1) agreed that the knowledge sharing in implementing BIM must be led by example to ensure a meaningful sharing as well as for the good of the project. The top management must act to share and view the importance of knowledge sharing as stressed by PB1 below:

"First and foremost before you can see the important, the top management must value this knowledge sharing even the management are not willing to share, the good chance is there will be knowledge sharing if it is not important for the person or board of directors to go and share this."- PB1

"Concerning knowledge sharing is that by the top management to show the willingness to share, not the willingness to share but the act of sharing must begin with the top management."- PB1

With regards to the importance of support, commitment and vision of management, PD1 stressed the need for education investment by the top management for the productive cycle as evidenced below:

"Ok, it is essential because it is important that the senior directors and the board of director within the company understand that certain amount of time has to be put down to what they would cluster as wastage for education because education enables a team to become more efficient. Therefore, the more efficient they are, the less wastage. However, to get to be more efficient, there must be a percentage of wastage, all right. So, therefore, the senior management and board of directors have to understand that out of a working month, they might be 2days of it go to education. That two days of that month will mean instead of the team be 70% productive of that month, the following month, they will be 75%

productive, and that happen continuously after the life cycle. So, therefore, yeah..a little bit of wastage, to create a productive cycle.”- PDI

In Case C, the support is also given by the incentives on a regular basis. According to its managing director who is also a BIM manager:

“Although all of the people in Organisation C is happy about BIM, we need to ensure that they also happy about their incentives that they are getting in every month.”- PCI

Moreover, PA1 acknowledged that management demand is highly important. With the demand of a visionary leader who can see a more comprehensive perspective and has new ideas, the younger generation could be influenced to be more productive and move further. In Case F, the demand was firstly initiated by its top management and was followed by encouraging BIM implementation in its healthcare projects under Rancangan Malaysia ke-11 (RMK-11).

The findings of this study confirmed that organisational culture has a positive influence in encouraging knowledge sharing in BIM implementation. As organisational culture is unique to each organisation, there is no standard KS practices that have been embraced by construction organisations in Malaysia, rather they have been practiced randomly. This is reflected by the different visions of the organisations involved, based on the business process that directs the daily operations of their organisation. For instance, Case F with the background as a government agency stressed many practices that are related with raising awareness, exposure, moral support and education because its role is to help and consult its employees to enhance KS practices in implementing BIM within the organisation. Also, it lies in the different unspoken values that are highlighted by the organisations, such as openness, a positive mind-set and attitude, which guide employees’ actions and perceptions in an organisation. The variances in organisational culture has influenced knowledge sharing actions and have been mentioned earlier (Ardichvili, Maurer, Li, Wentling, & Stuedemann, 2006; Martins & Terblanche, 2003; McDermott & O’Dell, 2001).

Therefore, special attention must be given to carefully formulate a framework, which should include all possible KS practices when dealing with different organisational cultures in BIM implementation, that leads to better KS practices in implementing BIM within Malaysian construction organisations.

Table 4.6: Summary of organisational culture and knowledge sharing in implementing BIM (Theme 2)

THEME 2: ORGANISATIONAL CULTURE & KS IN IMPLEMENTING BIM							
Parent Nodes	Child Nodes	CA	CB	CC	CD	CE	CF
OC influences on KS	1. Openness		X	X		X	
	2. Avoid very hierarchical culture		X	X			
	3. Educate				X		X
	4. Trust first		X	X			
	5. Accountable		X				
	6. Avoid team member's isolation		X				
	7. Inclusive		X				
	8. Skills	X					
	9. Mind set and attitude	X			X	X	
Leader's role	1. Open and forward thinking	X			X	X	
	2. Assure teamwork				X		
	3. Drive the company	X					
	4. Listen to team members		X				
Management's role	1. Active involvement		X	X			X
	2. Direct something meaningful and envisions the outcome		X		X		
	3. Education				X	X	
	4. Lead by example	X					
	5. Be the BIM champion			X			
	6. Handle the project with the right people and knowledge level		X				
The importance of support, commitment & vision of management	1. Exposure to BIM's knowledge			X			X
	2. Good working condition		X	X			
	3. Leading by example		X				
	4. Willingness to share		X			X	
	5. Create productive cycle via education				X		
	6. Incentives			X			
	7. Management's demand	X					X
	8. Moral support						X
	9. Opportunity of spearheading			X			

4.6 Barriers to Knowledge Sharing in Implementing BIM (Theme 3)

For the third theme, the researcher seeks to identify the barriers to knowledge sharing in implementing BIM from the perspective of BIM practitioners. There are five parent nodes emerging from the case studies; people, cost, process, policy and technology factors (refer to Table 4.7).

4.6.1 People

Under the people parent node, three cases (Case A, Case D and Case E) faced the same problem that is fear of change. In Case A, it is found that the main barrier to knowledge sharing in implementing BIM is fear of change in its people even though it has ventured into BIM for quite some time. Thus, by Case A's experience, PA1 agreed that the first thing to do is to get people to change. Fear of change is also considered as the most significant barrier in Case D because people do not understand BIM implementation and its benefits. According to PD1, upon their understanding, the willingness to accept BIM and knowledge sharing will increase. To reduce the barriers, PD1 believes that educating people to get the domain knowledge is the first step needed. Case E is similar to A and D in introducing its senior staff to something new like BIM implementation after they have worked in the traditional way for many years. It was a challenge to change the people's mind-set as perceived by PE1 below:

"I guess is about...it's very difficult for people to change, especially within the industry like they have been doing years and years when you introduce something different, people very hard to accept it. It was a challenge to change a mind-set of the people especially when it comes to the top management who are maybe a bit more on the older generation. It is hard to tell them especially when it comes to BIM, a couple of challenges that you have to face too, talking to the senior staff especially."- PE1

Under the people parent node, two participants (PB1 and PD2) admitted that it is vital in implementing BIM to get the domain knowledge as it must be considered as a basic rather than technological knowledge and perceived by PB1 as follows:

"The technological knowledge about how the tools are being used, how to get the models done, it is not a problem. Basically, the domain knowledge. This domain knowledge in term of, if I'm going to model

of this item, I can see it is there, but then can I be sure especially other people that the professionals when they look at it, they will appreciate it that much, whether it is correct, whether it is done properly in that manner. So this is the challenge, I would say this is our first barrier.”- PBI

Besides, with a different kind of generation, it is found that the barrier to knowledge sharing in implementing BIM is to encourage and make the latest generation understand the value in implementing it as perceived by PC1 and PE1. Also, to get the generation to understand the value of BIM implementation is quite challenging because some are supportive. However, there are also people who are discouraged as mentioned by PE1. Furthermore, PA1 suggested that the organisation has to ensure that the young and old generations could work together for BIM implementation as she explained that:

“We have to think for the young and the old work together. We do not want to lose young or old one. Either party cannot be separated.”-PA1

Another barrier explored is the communication breakdown. The expected quality that the organisation gets has differed as PC1 explained that:

“We have one time of having explored this internal team, but I think the main problem that we identify is a communication problem, communication breakdown. For example, if we engage Indian personnel@ Filipino, @ Burmies@ Vietnamese, the quality of the thing that they send compared to quality that they have here differed, it is not as per our expectation.”- PC1

Also, asking the right or meaningful question in implementing BIM regarding a problem that the organisation faces is seen as another challenge when the organisation wants to practice knowledge sharing.

4.6.2 Cost

Under the cost parent node, three participants (PD2, PE1, and PF1) have the same views that cost becomes a barrier to BIM implementation as well as knowledge sharing. According to PD2, cost becomes a barrier because the BIM implementation requires a continuous process of training and the management needs to spend on this. Also in Case D, Organisation D will have to spend more on software or tool training

when the people are not using it after they have attended the training as described by PD2. In Case E, it is a challenge for the Organisation E to get a return after its investment on BIM implementation as the participant mentioned that:

“...Moreover, then obviously putting your cost implementation and if you can project it and have a return on investment on it, this kind of activities that I am spending millions, yea..those are some of the key challenges.”- PE1

For Case F, the organisation has to depend on the allocation provided and sometimes it faces limited allocation to conduct training. However, according to PF1, if there is still demand from designers, the organisation will still try to provide the training needed.

Half of the respondents agreed that an organisation which intends to venture into BIM requires investment for tools and hardware preparation and continuous training for knowledge sharing and BIM implementation success. In opposition to the views of PD2, PE1, and PF1 that cost could be a barrier in implementing BIM, Case A and Case C made some allocation for this investment to overcome it and focused on achieving the successful implementation of BIM. Interestingly, according to PB1, Organisation B as a training, sales and BIM consultant does not have any problem with cost because all the licensed tools are provided to allow continuous training and services. By this means, the background, the purpose of an organisation and the direction of an organisation in the construction industry would impact the way the organisation strategizes their investment. Also, a detailed cost-benefit assessment to evaluate return on investment (in the short and long term) would be useful to facilitate decision-making.

4.6.3 Process

Under the process parent node, two child nodes emerge as an internal and external factor. Most of the opinions are related to the internal factor except for the suggestion to overcome the communication problems.

Internally, PB1 considered that the barrier to knowledge sharing is to find the best communication channel because the BIM implementation involves 3D modelling and needs an understanding of the 3D model. Although people appreciate the 3D model, according to the participant there is still a challenge regarding communication as quoted in the following:

“.... Internally, we do understand that everybody appreciates the 3D model that we have in BIM but sometimes when we try to communicate this externally, then we have a problem because not many people understand BIM model. They can give you complete BIM model, and they would not have the understanding of how this would help them. So there is a disconnect in term of how we communicate this internally and how this information will be shared externally.”- PB1

With that hurdle, PB1 suggested that the organisation should provide access to the knowledge sharing by levelling down the information to other people externally.

In Case C, the challenges are in demonstrating to the employee the real process, exposure to the value gained and exposure to BIM benefits. Concerning the time constraint, Case D and Case F were facing the same barriers. According to PD1, there is a need to understand that the process to educate people consumes time because it involves a learning process and requires continuous effort to ensure it gets better after a few attempts as the participant perceived it as the following:

“They are too many processes within the BIM process, where design team, where companies will educate their staff in all aspect of it, but then they never use it. Moreover, the reason of why they will not implement it is all that, not implementing BIM within that project, or we do not get time to do it because we do not let them time to do it, or take a longer way to do it than to do it that way. So, it might take the longer the first time, the second will be faster, and a bit faster every time and it became more efficient.”- PD1

“So, it is a learning process; senior management has to understand that everybody has to go through when he or she are learning. The first time you do it, it going to be slow, the second time should be faster, third time should be faster than before.”- PD1

In Case F, Organisation F is facing a time constraint to focus on the project that implements BIM because there are also other projects that needed its attention. PF1 then proposed to allocate a suitable time for a briefing related to BIM implementation.

4.6.4 Policy

Another factor to consider falls under a policy that involved the setting of the environment as agreed by PA1 and PC1. BIM implementation is difficult to implement by separate parties. Thus, the conducive environment and a clear policy that encourages BIM implementation are needed.

For Case A, Organisation A has managed to move further along in BIM implementation because its business model as a total value chain as explained by PA1:

“Another thing is our business model also enable us to move far in BIM because we are a total value chain. We do design, build and manage. So, in our world I would say control, we can push it far. If it a developer or consultant, especially consultant, or architect, engineer, an architect in isolation it is also difficult to implement. We can move so far; we are the client, we issue letter award and say we want it. If you are the consultant to do our job, you will need to comply. So, for us, because we are in a better setting, I will say we have in half of better war already.”- PA1

PA1 expected that rules and government enforcement from the CIDB indeed play a role in pushing the BIM implementation to the optimum level.

Similar to Case A, PE1 in Case E believes that the enforcement by the government is perceived as enabling factor as she explained that:

“...if no mandate from saying government, if they are able.because currently CIDB they do not have enforcement or policy. CIDB and JKR or any related government, if saying all every project will going to be BIM implemented, that is better. So when you want to implement purely based on what we want, so one thing is that mandate from government.”- PE1

The finding in the case studies stressed the need for government intervention to formulate a standard policy to encourage the construction players in implementing BIM. This is in line with the suggestions from previous research that government incentives, enforcement regulations and policies are crucial for utilisation of BIM (Harris et al., 2014; Mahamadu, Mahdjoubi, & Booth, 2014; Mat Ya'acob et al., 2018; Shang & Shen, 2014; Zahrizan et al., 2014).

Despite legal concerns with ownership of data or design or licensing issues raised by several researchers during the project lifecycle (Azhar, 2011; Ghaffarianhoseini et al., 2017; Harris et al., 2014; Mahamadu et al., 2014; Mat Ya'acob et al., 2018; Shang & Shen, 2014; Zahrizan et al., 2014) where the information is provided by outside sources, involved joint authorship of different BIM model developers and separate liability for any errors made (Ghaffarianhoseini et al., 2017), none of the case studies' participants mentioned this. This issue does not appear probably because this research is focused on intra-organisational knowledge sharing in implementing BIM where the information is likely provided by internal sources and did not complicate the process of implementation.

4.6.5 Technology

For technology parent nodes, PC1 believes that the primary barriers should be broken up to permit the organisation to embark on BIM implementation as the participant stressed out that:

“Policy and technology. That is the main barrier. During the implementation in ABC before this four has always been the case, main challenges in implementing BIM. It is the same with knowledge sharing; you need to understand because of the policy, the current process that we have in the project team, contractors, consultants, we do not share our information, if you want to give certain information to the contractor, we tend to be. I cannot give you this is internal office policy. The environment that we have within the industry as well, permit us on engaging or embarking on BIM. So, the first in first if you do not break the main thing, you cannot go to the detail part...” - PC1

Although only PC1 mentioned technology as a barrier for BIM implementation, all case studies did not experience the difficulties regarding technology as all the

organisations have prepared and allocated relevant tools in implementing BIM. Therefore, it appears no barrier concerning technology as shown in Table 4.7.

Table 4.7: Summary of the barriers to knowledge sharing in implementing BIM (Theme 3)

THEME 3: BARRIERS TO KNOWLEDGE SHARING (KS) IN IMPLEMENTING BIM							
Parent Nodes	Child Nodes	Case A	Case B	Case C	Case D	Case E	Case F
People	1. Fear of change	X			X	X	
	2. Getting the domain knowledge		X		X		
	3. To understand the value			X		X	
	4. Communication breakdown			X			
	5. Questioning relevant questions		X				
	6. Separation of young and old generation	X					
Cost					X	X	X
Process	1. Internally		X	X	X		X
	2. Externally		X				
Policy	1. Setting of environment	X		X			
Technology							

Overall, there is no exact trend of the barriers because all case studies have shown their clear direction to fully benefit from BIM implementation and their involvement in the construction industry increased every year, resulting in less barriers that need to be faced. These barriers however, will not appear in the framework but rather the practices and components of knowledge sharing in implementing BIM analysed from the finding in the case studies and literature review that could help to overcome those barriers are presented. For instance, referring to Figure 6.9 in Section 6.6, the fear of change could be minimised through leadership and management support practice, by facilitating teamwork (L1) and leading with clear and meaningful direction and envisioning the outcomes (L3).

4.7 Enabling Factors to Knowledge Sharing in Implementing BIM (Theme 4)

For the fourth theme, the researcher seeks to identify the factors that encourage knowledge sharing in implementing BIM from the perspective of BIM practitioners for overcoming the problems that were identified as barriers. There are three parent nodes emerging from the case studies; internal, external and general factors (refer to Table 4.8).

4.7.1 Internal Factor

Internally, three participants (PB1, PC1, and PE1) agreed that everybody in an organisation needs an open environment. PC1 thought that having an open environment that includes the right information sharing platform is like collaborating on a BIM platform, getting people to engage and brainstorming to consider all the barriers within the organisation. This will help the organisation to remove the barriers. Likewise, having an open environment with a more open organisational setting will allow more space for discussions and expression. In Case E, the openness that is being practiced is through open communication in meetings and discussions.

With regards to the management demand as a culture and endorsement, Case A exploits its management and management demand to push the knowledge sharing practices into its culture and requires their endorsement. Furthermore, PA1 suggested embracing change in the organisation although it takes a long time and process because it involved a different way of working. Also, PB1 believes that enabling factors to knowledge sharing in implementing BIM is an organisational action that is related more to demand as a culture rather than just human resource guidelines. Moreover, PE1 believes that management support is also crucial for knowledge sharing.

From the perspective of sales, training, and implementation of BIM background, PB1 encourages the right information sharing platform to understand the information with regards to a specific project.

Another point of view to encourage knowledge sharing in implementing BIM is stressed by PF1 through active involvement in BIM implementation. Not only that, PF1 suggested that competition could be an enabling factor to encourage learning and knowledge sharing. Furthermore, there is a need for hands-on training instead of a seminar on awareness.

4.7.2 External Factor

Externally, Case A chooses to work with a third party such as the Construction Industry Development Board (CIDB). In Malaysia, enforcement by the CIDB is considered necessary because construction industry players will have to follow their requirements to get approval for their submission. Therefore, PA1 expected that rules and government enforcement by CIDB indeed play a role in pushing the BIM implementation to the optimum level.

Similar to Case A, PE1 in Case E believes that the enforcement by the government is perceived as an enabling factor as she explained that:

“...if no mandate from saying government, if they are able.because currently CIDB they do not have enforcement or policy. CIDB and JKR or any related government, if saying all every project will going to be BIM implemented, that is better. So when you want to implement purely based on what we want, so one thing is that mandate from government.”- PE1

In this context of research, it is clearly shown that the Malaysian construction industry stakeholders need government mandates or intervention to enforce and push forward the BIM implementation to the next level. This factor is also discussed in Section 4.6.4 to overcome the barriers in implementing BIM.

4.7.3 General Factor

In general, PB1 stressed the importance of the information in implementing BIM itself to ensure every party is involved in everything that is related to their project because a project usually involves different people and unclear information could arrive within the team members. Also, BIM is about technology. Therefore, the participant suggested to leverage the existing technology to improve technology sharing as espoused below:

“The way to improve technology sharing further is to leverage the existing technology. The thing is that we are in this age whereby information is everywhere. Our problem is that trying to get the correct information. So, perhaps we have not found that method that will enable one person in our office to look for information and that information whether she@ he does it consciously or unconsciously would be shared among all the other team members. We have not found a way to do that because sometimes we have colleagues who found the information and that information are important to another person. That is why we always look at the available technology that would enable us to do this.”- PB1

Two of the participants (PC1 and PD1) suggested that the Malaysian construction industry should first eliminate all misconceptions about BIM to help people to embark on BIM. PD1 further elaborated that misconceptions about BIM needs to be eliminated. Thus, people need to understand BIM as mentioned by the participant as the whole process, which is 3D with coordination. Furthermore, PD1 encourages the organisation to incorporate BIM tools with its contract to enable knowledge sharing in implementing BIM.

Table 4.8: Summary of enabling factors to improve knowledge sharing in implementing BIM (Theme 4)

THEME 4: ENABLING FACTORS TO IMPROVE KNOWLEDGE SHARING (KS)							
Parent Nodes	Child Nodes	CA	CB	CC	CD	CE	CF
Internal	1. Open environment		X	X		X	
	2. Management demand as a culture and endorsement	X	X				
	3. Use of management	X				X	
	4. Competition						X
	5. Embracing change in the organisation	X					
	6. Need for hands-on training						X
External	1. Rules and government enforcement	X				X	
	2. Work with third party	X					
General	1. Eliminate on BIM's misconception			X	X		
	2. Emphasize the importance of the information		X				
	3. Incorporate BIM tools with contract				X		
	4. Leverage on the existing technology		X				

4.8 Chapter Summary

The identification of the knowledge sharing practices in implementing BIM that is based on the organisational experiences is vital for the development of the knowledge sharing practices in implementing the BIM framework. By conducting data analysis for each case and further cross-cases, a lot of information was captured regarding the knowledge sharing practices among the six organisations. In this chapter, the data and information that were gathered were in a qualitative form. It leads to a better understanding of the logic and rationale behind each of the knowledge sharing practices that were identified, related to BIM implementation.

Overall, all cases use BIM in an organisation process flow for efficiency and to get jobs or services. All the participants fully conceded the benefits of BIM implementation as well as knowledge sharing in improving BIM implementation. The case studies revealed the benefits of time and cost saving due to less rework, less time on site, earlier identification of problems and consequently, construction could move

according to schedule. Also, a higher accuracy and clarity of information leads to quicker decision making. However, the BIM implementation is not without challenges, which involved resources such as people, tools and cost.

Furthermore, all organisations practice KS in implementing BIM to improve the learning curve of each organisation, and it is strongly related to their organisational culture. The case studies emphasised training and education to improve skills and knowledge for a better conceptual understanding and working with different processes when implementing BIM. Accordingly, training and education are vital to improve individual and organisational performance in terms of understanding, applying, analysing and evaluating BIM implementation. Increasing knowledge in BIM implementation via training and education will indirectly allow the flow of knowledge from one individual to other members in an organisation. Some of the cases demonstrated the flow of knowledge sharing via the multiple approaches taken. However, this study found that knowledge sharing plans are not formalised within the organisational strategic policies and practices. Therefore, an intra-organisational KS practices framework in implementing BIM has been developed with the intention to enhance the practices of KS in Malaysian construction organisations that are involved in BIM implementation. The analysis found that people, process, and technology are the elements (refer to Table 4.9 below) used by the organisation in KS practices in implementing BIM to improve the implementation. The most common components of KS that are suitable to promote the implementation of BIM identified from the case studies appear to be L3) Promote trust, L4) Reward and recognition, L5) Ensure relevant awareness and education under Leadership and management support practice, T1) Responsive in solving a particular problem or any issues under Team characteristics and organisation practice and A1) Integrated use of techniques: Non-IT base and technologies: IT base for knowledge sharing under Technology practice. All of these elements, practices and components as shown in Table 4.9 are used to form a basis for the development of the framework.

Table 4.9: Summary of KS practices in implementing BIM (from interviews)

SUMMARY OF KNOWLEDGE SHARING (KS) PRACTICES IN IMPLEMENTING BIM								
Element	Practice	Component	CA	CB	CC	CD	CE	CF
People	Leadership & Management support	L1) Open and forward thinking	X			X	X	
		L2) Lead with clear and meaningful direction and envision the outcomes	X	X				X
		L3) Promote trust		X	X	X	X	
		L4) Reward and recognition	X	X	X		X	X
		L5) Ensure relevant awareness and education on benefits of KS and BIM's knowledge		X	X	X	X	X
		L6) Prepare right software and hardware				X	X	
		L7) Provide continuous training	X			X		X
		L8) Embed KS in implementing BIM culture	X	X			X	
		L9) Active involvement - Top management appearance, demand and support	X	X	X		X	X
		L10) Assure teamwork – Handle the project with the right people and knowledge level		X		X		
		L11) Be the BIM champion	X		X			
	Team characteristics & organisation	T1) Responsive to solve a particular problem or any issues	X	X	X	X	X	X
		T2) Flat, circle or flexible structure		X	X			
		T3) Have skills and experience	X					X
		T4) Trust, open and inclusive involvement		X	X		X	
		T5) Accountability in implementing BIM		X				
	Individual attitude & personality	I1) Positive mind-set and attitude	X		X	X	X	
		I2) Willingness to learn with positive self-improvement	X		X	X	X	
	Process	Communication & collaboration	C1) Natural trust relationship	X		X	X	
			C2) Proactive action		X			
			C3) Coordinate, document and corroborate information		X			X
C4) Clear interaction				X			X	
Policy		P1) Top-down enforcement	X		X			
		P2) Prepare communication platform		X			X	
		P3) Sharing information format		X		X		
		P4) Rules and government enforcement	X				X	
		P5) Work with third party	X	X				
Operational		O1) Embracing change in the organisation	X		X			
		O2) Having understanding on knowledge sharing and BIM implementation				X	X	
		O3) Good working condition and culture		X	X			
Technology		Appropriate tools	A1) Integrated use of techniques: Non-IT base for KS and technologies: IT base for KS	X	X	X	X	X
			A2) Leverage on the existing technology		X	X	X	

CHAPTER 5: DISCUSSION AND FRAMEWORK DEVELOPMENT

5.1 Introduction

This chapter discusses the findings of the research to answer the following objectives of the research, and thus the sequence of this chapter is based on the objectives:

- a) To explore the current implementation of BIM within the business process by the organisation.
- b) To develop a framework of intra-organisational knowledge sharing practice for the effective implementation of BIM by utilising the emerging findings in the case study, cross-case analysis and cross-reference of the practices with the past literature.

Also, the second stage of the literature review was conducted to support the researcher's interpretation and justification for all data findings collected from all case studies with six BIM practitioners' organisations in the Malaysian construction industry to produce the framework.

5.2 Discussion of the Current Implementation of BIM within The Business Process by The Organisation

With regards to the organisational structure, it is reasonably said that all the cases have new position titles such as BIM manager, BIM coordinator and BIM modeller (Refer Table 5.1). However, the titles are created by some cases (Case A and Case C) within their existing structure. In contrast, three cases (Case D, E, and F) developed such positions under a new specific BIM unit to establish the BIM implementation within each context. Interestingly, PC1 and PD1 believed that all the existing roles such as 2D draughtsmen, coordinators, and project managers would disappear as the implementation of the BIM process takes over in the construction industry. This is

only because 2D draughtsmen will become 3D modellers, designers will just naturally turn into coordinators and project managers will automatically become BIM managers.

Table 5.1 : Level of performance expectation adapted from Wu et al. (2018)

Level of performance	Performance expectation	Bloom's taxonomy	Organisation's experiences (practice) in BIM	Case study performance expectation
Entry level	Performance expected for users with a bachelor's degree or equivalent technical education	Remembering Understanding	2 years	Case E
Middle level	Performance expected for users that meet entry-level qualifications plus 3-5 years of experience in BIM practices	Applying Analysing	5 years 4 years 5 years 5 years	Case B Case C Case D Case F
Full performance	Performance expected for users that meet middle-level qualifications plus 5 or more years of experience in BIM practices	Evaluating Creating	10 years	Case A

Based on a research conducted by the Academic Interoperability Coalition (AiC) to develop a BIM Body of Knowledge (BIM BOK) framework, the participants proposed four dimensions which are Level of Implementation (LOIs), Roles of Users (ROIs), Level of Performance (LOPs) and Types of Knowledge (TOKs). Level of Performance (LOPs) were used to reflect the layer of performance depending on educational background and professional experience, and direct the progression of performance from entry and middle levels to full performance through education and training. It is also meant to align BIM learning and training outcomes with Bloom's taxonomy of learning to facilitate training and education curriculum development (Wu et al., 2018). By referring to LOPs dimension, this research indicated the case study performance expectation when learning BIM falls under three levels (refer to Table 5.1). Four cases (Case B, C, D and F) are expected to perform at middle level, which should be able to apply and analyse, while only one (Case A) is expected to perform at full performance and be able to evaluate and create. One (Case E) is still at the entry level of only being able to remember and understand when learning BIM.

Findings from an extended research by (Wu, Mayo, Mccuen, Issa, & Smith, 2018b) show the BIM body of knowledge (BOK) through the heat map of achieved consensus from three rounds of a Delphi study for different users of BIM, different performance levels, types of knowledge either organisational or project level at different stages of BIM implementation. When findings from this research were mapped in the heat map (refer to the heat map produced in Wu, Mayo, Mccuen, Issa, and Smith, (2018b)), based on the different dimensions for case studies involved, the body of knowledge from different cases and different performance levels either full performance, middle or entry, a different body of knowledge for every case involved was shown as laid out in Table 5.2. Case A with full performance expectation should be able to acquire almost all the body of knowledge except life-cycle functional performance and commissioning at all stages (plan, coordinate, manage, do) except only a few that are not reliable to this case such as life-cycle functional performance and commissioning plan (at plan stage) and rendering for marketing, knowledge scripting and knowledge programming (at do stage). For Cases B, C, D and F, categorised under the middle level of performance, it has a strong disagreement to carry out life cycle performance (at plan stage), strongly disagree in protecting intellectual property (IP) of digital assets (at manage stage) and rendering for marketing (at do stage), and totally disagree for knowledge of scripting and knowledge of programming (at do stage). Case E with only an entry level performance appears to have the least body of knowledge, at almost all levels. However, Case E should be able to acquire a body of knowledge for BIM usage and professional development (at plan stage), for technical support for interoperability, model coordination, and software version coordination (at coordinate stage), model quality control, refine BXP (consensus), model validation, standards compliance checking, manage information exchange, pre-construction issue resolution, professional ethics (at do stage).

Table 5.2: Body of knowledge expectation based on organisation dimension adapted from (Wu et al., 2018b)

Identified Case	Mapping based on type of construction organisation	Stage of BIM implementation			
		Plan	Coordinate	Manage	Do
		Body of Knowledge (BOK) description			
Case A FULL	Contractor	All (early strong agreement, strong to early consensus) except life-cycle functional performance and commissioning plan (partial agreement)	All (early strong agreement, strong to early consensus)	All (early strong agreement, strong to early consensus)	All (consensus and early strong agreement), strongly disagree for rendering for marketing, totally disagree for knowledge of scripting and knowledge of programming
Case B, C, D, F MIDDLE LEVEL	Consultant / generalist	Totally disagree for life cycle functional performance.	All (strongly agree to consensus)	All (early strong agreement, to consensus) except protecting intellectual property (IP) of digital assets (strongly disagree)	All (consensus and early strong agreement), strongly disagree for rendering for marketing, totally disagree for knowledge of scripting and knowledge of programming
Case E ENTRY LEVEL	Contractor	All (strongly disagree to totally disagree) except BIM usage and professional development (strongly agreement)	All (partial agree and totally disagree), strongly agree for technical support for interoperability, model coordination, and software version coordination	Model quality control, refine BXP (consensus), model validation, standards compliance checking, manage information exchange, pre-construction issue resolution (strongly agree), professional ethics (early strong agreement)	Rendering for marketing (strongly disagree), site logistics, knowledge of scripting, technical writing (totally disagree)

Furthermore, most of the cases are using BIM up to the level of detail or development (LOD) 500. The organisations were able to develop the model by utilising five progressive detailed levels of completeness in implementing BIM. By this means, the cases involved with the model developed for specific indication of which element will be field verified. Accordingly, this permits the owner to crystallise needs for verification and allows whoever is responsible for producing the as built model to achieve and price the effort involved (AIA, 2013). Nevertheless, for Case B with the sales, training and BIM implementation background and Case E with the builder's background, the organisations were satisfied and mostly used BIM up to LOD 300. LOD 300 involves model elements which are specific assemblies, such as specific wall types, engineered structural members, system components, etc. The design of the model element is developed in terms of composition, size, shape, location, and orientation (AIA, 2013). The reason behind that was because of the client's requirements for Case B although PB1 admitted that the organisation's capability level is up to LOD 500. For Case E, due to its nature of business; the model development was posited as good enough by PE1 when its organisation could work up to that LOD 300 level. The ability of all cases shown to develop models up to the required level seemed to relate with their performance level as discussed above. Starting from entry level up to full performance, all cases have shown their ability to build a model, understand their own model and aggregate model and software usage based on the heat map in BIM BOK.

Among all of the cases that have been investigated, Organisation A is considered to have a quite comprehensive context of BIM implementation within their business process. This is shown by the organisation's BIM standard operating procedure which consisted of 13 documented guides including General Guide, Architectural Modelling, Civil and Structural Modelling, Mechanical, Electrical & ICT (MEI) Modelling, Mechanical, Electrical & ICT (MEI) Shop Drawing Modelling and Model Coordination in two versions. This organisation's experience has been supported by its BIM administrator who has ten years' experience in research and practice with BIM implementation for the organisation. The presence of BIM implementation also incorporates a higher level of detail for the 3D models, progressively from LOD 100 –

LOD 500 from concept drawings up to coordinated construction drawings with a structured flow of inter-disciplinary model coordination as shown in Figure 5.1. According to the Director of the Share and Outsourcing division (P1) in Organisation A, the 3D model has become its main deliverables instead of 2D. The 2D drawings are still being produced for authority submission as required, making it a secondary deliverable. As soon as the key project team members are appointed at the start of the project, the required Organisation A BIM deliverables for the project should be agreed upon with completion dates. The Organisation A BIM deliverables comprise the following; Site models, Massing models, Infrastructure works models, Architectural, Structural and MEI models, Regulatory submissions, Coordination and/or clash detection analysis, Visualisation, Cost estimation, Schedule and phasing program (In BIM or spreadsheet), Construction and fabrication models, Shop drawings, As-built models, and data for facility management.

As for Organisations B, C, and D with their BIM consultancy background, it is probably fair to say that those organisations' level of BIM implementation depends on their client's request and project stage, thus involving different levels although each of it is capable of performing up to LOD500. The interviews revealed that the implementation of BIM varies from educating the parties to participate, building a model, collaborating on the models and inter-discipline coordination. Organisation E with its builder's background and a little experience (about two years) in BIM implementation still requires involvement from a BIM consultant at this very early stage. For Organisation F, the implementation could be considered moving forward independently without relying on BIM consultants anymore. The organisation is taking further initiatives to implement BIM for its pre-approved projects, Malaysian Plan-10 projects as well as Malaysia Rolling Plan 3.

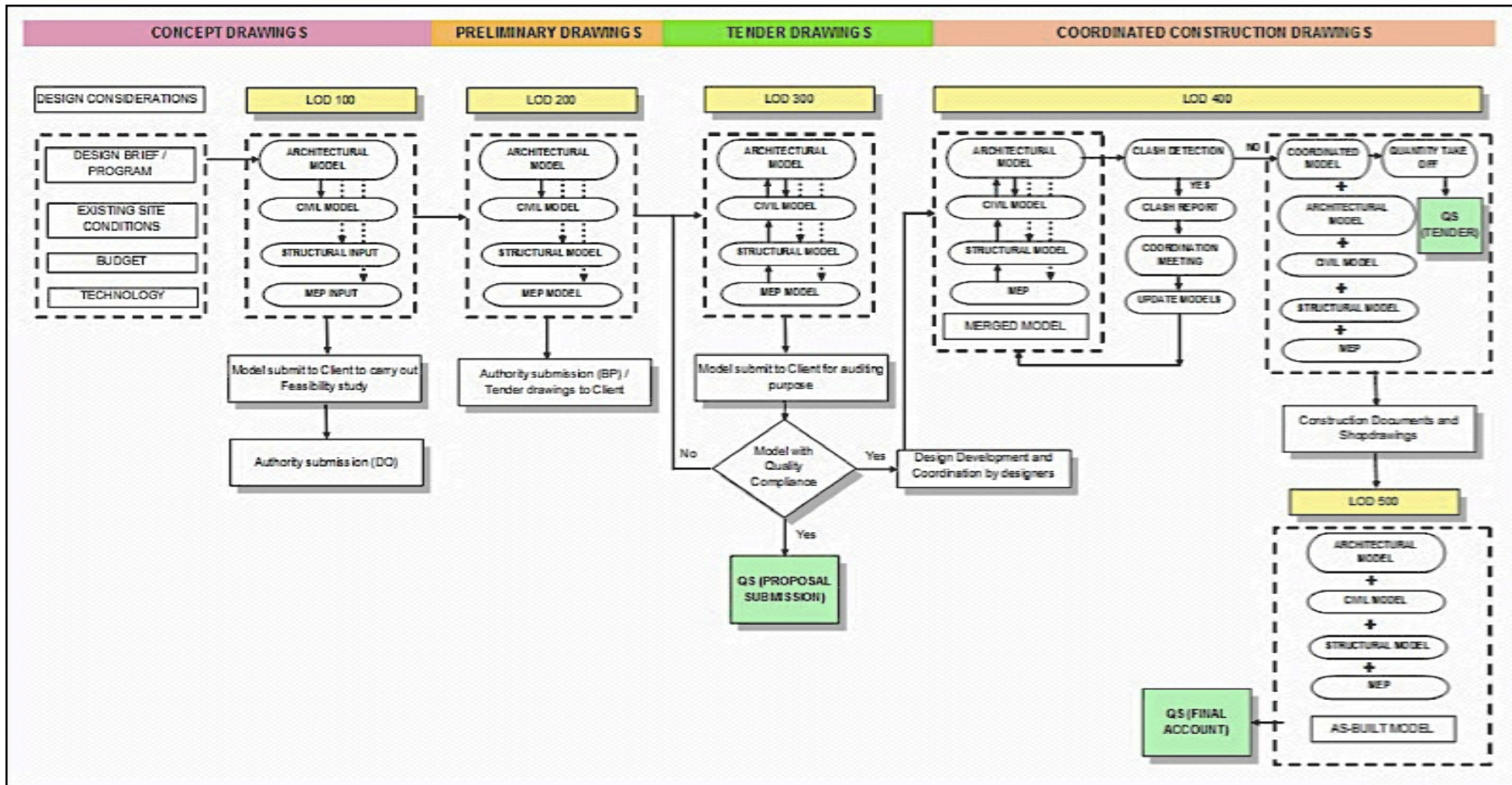


Figure 5.1: Cross-disciplinary model coordination in Case A

Overall, the implementation of BIM in all cases could be considered as still lying between BIM level 0 and BIM level 1 as referred to the model shown in Figure 4 developed by Bew & Richards (2008) of which recognises that BIM Level 0 is usually in 2D environment with unmanaged CAD coordination, most formats are papers and electronic for instance PDF file. These formats are treated as the central data exchange mechanism, and BIM Level 1 is managed CAD in 2D or 3D format with a collaboration tool (extranet) providing a standard data environment, possibly using some standard data structures and formats (Bew & Underwood, 2010). The result appears to be as same as research conducted by Zahrizan et al. (2013). With the time difference of 2 years since the interviews were conducted in 2015, the level of implementation remains the same. Therefore, at the point of research, it can be said the BIM implementation in projects are still limited and requires more efforts to be made if the construction industry wants to gain BIM benefits.

The findings also indicate that although BIM implementation is considered low in the Malaysian construction industry, the participants are in consensus about the benefits from BIM implementation, similar to those found in the literature. BIM implementation benefits as agreed by the participants is a positive way to enhance the task efficiency in project delivery and also contributes to the higher visibility of the project, together with time and cost optimisation. Furthermore, the organisation that has the knowledge and skills in implementing BIM could benefit by getting new jobs or projects as well as being hired as a service provider in the construction industry. However, to ensure the success of BIM implementation, there are several challenges that need to be resolved within the industry. The data analysis had identified several challenges in the implementation of BIM, perceived as barriers by the participants, which are non-technical challenges (human and organisational culture) and technical (technology) challenges. Under the human resource issue, every participant in all cases highlighted the challenge related to resistance to change. The participants agreed that firstly, players in the construction industry need to change their mind-set from working with 2D drawings to the new concept of (3D to nD). Also, it has been stressed by the participants that misconceptions about BIM showed the importance of having the right BIM knowledge. All of them believe that the construction industry

players need to be educated with BIM knowledge properly. It was also found that it was difficult to retain people who have BIM skills in an organisation. Although it looks negative for the organisation that hires people who have BIM skills perspective, in another way it offers an opportunity for the individual to have career development potential. In regard to organisational culture, top management awareness and support are highly recommended in ensuring the BIM has been successfully implemented. Due to the differences in the generations involved in BIM implementation i.e. a young generation with fast technology adaptation but lacking construction experience, and an old generation who is more experienced in construction rather than technology usage, the challenge lies in combining these two generations as a team for BIM implementation. Moreover, BIM implementation is a new approach in the construction industry and requires training. Therefore, the management support in raising awareness and training may help the adoption and adaptation to BIM. Apparently, for a technical issue related to technology, the findings showed the challenges are more towards the financial aspects of BIM tools and cost of investment in BIM implementation.

To sum up, the current status of BIM implementation in each of the organisation involved could be referred to in Table 5.3. Although there are different practices of BIM implementation between the organisations involved in this research, the investigation into the current status of the implementation has given the researcher an understanding into the on-going progress of BIM implementation in the Malaysian construction industry. In addition, the investigation into the level of BIM implementation provides an insight of the research regarding the context of BIM implementation for each organisation. This insight is essential to facilitate the researcher in understanding the rationale for knowledge sharing practices that are explored and identified in each organisation.

Table 5.3: Summary of current status of BIM implementation by the organisations (findings from data collection of this research)

Identified Case	Type of construction Organisation	LOD utilisation	Organisation structure (Role and responsibilities)	BIM benefits
Case A	Developer	LOD100-500	Utilised existing department	Efficiency
Case B	Sales, training and implementation of BIM	LOD100-300, 400, 500 (Depends on client's requirements)	Position in place	Get services
Case C	BIM consultant	LOD100-500	Giving values to the existing process	Opportunity to get jobs
Case D	Integrated BIM consultant	LOD100-500	New: BIM managers, coordinators and 3D modellers	Efficiency
Case E	Contractor	LOD100-300	Created new department: BIM & IBS	Opportunity to get projects
Case F	Government agency	LOD100-500	Developed BIM Unit	Efficiency

5.3 Discussion of the organisation's knowledge sharing practices, policies and organisational culture in implementing BIM

At the data collection stage, this objective was investigated through 2 themes that were derived from the interviews, which are organisational knowledge sharing practices and policies in implementing BIM (Theme 1) and the organisational culture and knowledge sharing in implementing BIM (Theme 2). Themes, various nodes, and child nodes emerged from the analysis of data from various viewpoints; as was discussed in Chapter 4. Knowledge sharing (KS) as a sub-process of knowledge management (KM) cannot be considered as isolation of people, process, and technology. Thus, the KS practices in implementing BIM will be discussed regarding people, process, and technology elements.

Concerning technology, knowledge management tools are used to support KM processes and sub-processes as discussed earlier in Chapter 2. A knowledge sharing

tool or approach is any medium and practice used by individuals or teams in an organisation or organisations to encourage the knowledge flow. It encompasses different techniques and technologies either formally or informally and is based on information or non-information technology, which could facilitate knowledge sharing in implementing BIM. KM technologies rely on an IT infrastructure and consist of a combination of hardware and software technologies (Ruikar, Anumba, & Egbu, 2007). Although BIM tools or software used in the implementation of BIM could be considered as one of the KM technologies which have the characteristics as discussed by Al-Ghassani et al. (2005), this research did not explore the BIM tools as a medium of knowledge sharing but focused on the knowledge sharing practices in implementing BIM as a whole process by taking into consideration the people and the organisational culture elements, as well as technology. Moreover, such technologies only consume one-third of the time, effort, and money required for a KM system (Ruikar et al., 2007), which encompasses knowledge sharing as its sub-processes. The other two-thirds is mainly linked to the organisational culture (Davenport & Prusak, 1998) and human aspects (Davenport & Prusak, 1998; Rezgui et al., 2011).

From the data analysis of the case study interviews, KM tools used to facilitate KS in implementing BIM was balanced between the application of KM technologies and KM techniques as shown in Table 5.4, which indicates the equal importance of both tools in supporting KS in implementing BIM. While KM processes are often facilitated by IT, technology by itself is not KM. Information technology is concerned with information and not knowledge per se (Quintas, 2005). The essential KS techniques come from a few factors described by Al-Ghassani et al. (2005) as discussed in subsection 2.17. Firstly, KS techniques are affordable to most organisations without advanced infrastructure needed. Some techniques, however, require more resources than others, for instance, in-house or external training requires more resources than informal face-to-face interactions. Secondly, KS techniques are easy to implement and maintain due to their simple and straightforward nature. Thirdly, KM techniques focus on retaining and increasing the tacit organisational knowledge, which is a key asset to organisations. Subsequently, this research discovered that some of the KM techniques, which were traditionally applied as non-

IT tools had been used by the organisations in this case studies as integrated tools when sharing knowledge in implementing BIM due to the nature of BIM tools that involve technology characteristics. For example, workshops, demonstration, workstation discussion and training were traditionally applied as sole techniques. However, this case studies research demonstrated that those techniques were used with the BIM tools to demonstrate BIM model and model properties to enhance discussion, ease learning or support arguments clearly during knowledge sharing processes in workshops, training or other techniques.

Table 5.4: Case Studies' Findings on Knowledge Management tools to support KS in implementing BIM

KS technologies (IT tools)	Integrated use of KS technologies & techniques (with the used of BIM tools)	KS techniques (Non-IT tools)
Knowledge base: Companies website, iClouds, Clouds & Dropboxes	Workshops	Documentation: Protocol, Standard, BIM Forum, support reports, ISO documents, reported issues
Intranet/ Extranet: Project Portal	Demonstration	Face-to-face regular meeting
Electronic mail	Via work station discussion	Face-to-face interaction
Groupware: Forum discussion	In-house training	Road-show
Communities of Practice: J-CoP, J-Pedia, Facebook	External training	Apprenticeship
Search Engines: Google, Yahoo	Technical support	Informal way: Gather and share, 'talk over coffee'
Instant Messaging: Instant Messenger, Whatsapp		Involves in Seminars, Conferences as participant or speaker or sponsor.

5.4 Discussion of the development of a framework of organisational knowledge sharing practice for effective BIM implementation

At the data collection stage, this objective was investigated through 2 themes that were derived from the interviews, which are organisational knowledge sharing practices and policies in implementing BIM (Theme 1) and organisational culture and knowledge sharing in implementing BIM (Theme 2). Themes, various nodes, and child nodes emerged from the analysis of data from various viewpoints; as was discussed in Chapter 4. Thus, the development of the framework is based on the literature review and qualitative data collected through semi-structured interviews.

In total, all the cases have used several practices for knowledge sharing (KS) either the organisation's BIM experiences are considered new (2-4 years) or the organisation have been in the industry for some time (5 years and above). The process for knowledge sharing identified in this research, however, not only involves sharing knowledge but began with acquiring knowledge and followed by exchanges before it could be shared and stored. This is similar to the work of Lindner and Wald (2011) and Egbu and Coates (2012) that posit the process of knowledge transfer involves a few steps that begin with knowledge creation, then followed by the use, transferring and sharing, and finally the storage of knowledge in a way that it is easy to retrieve for further use. The result reveals that knowledge sharing allows individuals to gain and exploit each other's knowledge and expertise to improve the BIM implementation. According to McAdam, O'Hare, and Moffett (2008), knowledge sharing has a substantial, positive impact on organisational performance. Liang et al. (2007) also supported that knowledge sharing is to prevent knowledge loss and lessons learned while increasing operational efficiencies. Moreover, Du, Ai, and Ren (2007) stressed that some knowledge sharing dimensions have a significant impact on performance, and the emphasis on them may improve the effectiveness of knowledge sharing significantly. Therefore, it is vital to explore the knowledge sharing practices in enhancing performance and the adequate provision of BIM implementation for BIM practitioners in the Malaysian construction industry.

Knowledge sharing (KS) as a sub-process of knowledge management (KM) cannot be considered as the isolation of people, process, and technology. According to Ruikar et al. (2007), it is essential to consider the combination of people, process, and technology in providing a solution to the KM problem. Hence, the KS practices in implementing BIM will be discussed regarding people, process, and technology elements. According to the findings from the literature review and the case studies, seven practices and 32 components were identified as crucial for KS in implementing BIM as depicted in Figure 5.2.

5.4.1 Aim of the Framework

All the components have been combined to develop a preliminary framework of knowledge sharing practices in implementing BIM within the Malaysian construction industry as shown in Figure 5.2. The framework aims to contribute a set of useful and practical actions that can help BIM stakeholders in construction organisations practising knowledge sharing in implementing BIM to improve its adoption or implementation. The framework can be seen as a guideline for the Malaysian construction industry BIM stakeholders for practising knowledge sharing to improve BIM adoption or implementation. Also, it highlights the key factors that need to be considered in planning and practising knowledge sharing in implementing BIM. However, there are some doubts as to what extent such a framework will contribute to the BIM implementation in the Malaysian construction industry context. Therefore, the framework will go through a validation process. The following paragraph will first discuss the components of the framework in more detail.

For the knowledge sharing process to happen, it is necessary for the actors to communicate and ensure the flow of knowledge exists both ways, from sender to receiver, and from the receiver back to the sender for ongoing feedback or discussion. The knowledge owned by an actor (individual or organisation), according to its specific characteristics, can be shared with another actor by information flows conveyed by appropriate media (Albino et al., 1999). Actors in the knowledge sharing process in this study are considered as either the individual or team members within

the organisation due to the focus of this study. The actor who sends the information and knowledge related to BIM is a sender or sharer, while the actor who receives the information and knowledge of BIM is a receiver.

Knowledge sharing (KS) as a sub-process of knowledge management (KM) cannot be considered as the isolation of people, process, and technology. Thus, it requires a consideration of all three elements when using the framework. The people element in the framework refers to individual, team and human factors, for instance, work attitude, personality, team characteristics and organisation, leadership and management role. It entails that BIM practitioners need to consider people capabilities to share knowledge in implementing BIM. Then, concerning the process, the existing working process needs to be incorporated into trust, precise and coordinated communication, geared towards more proactive action. The process also needs to include enhancements to policy and operation. Finally, knowledge sharing practice has to be supported by technology, which is an appropriate medium or tool for improving knowledge sharing activities in implementing BIM. The following section further discusses in detail, the triangulation process of the findings from both the literature review and the semi-structured interview and their respective contributions to the development of the framework.

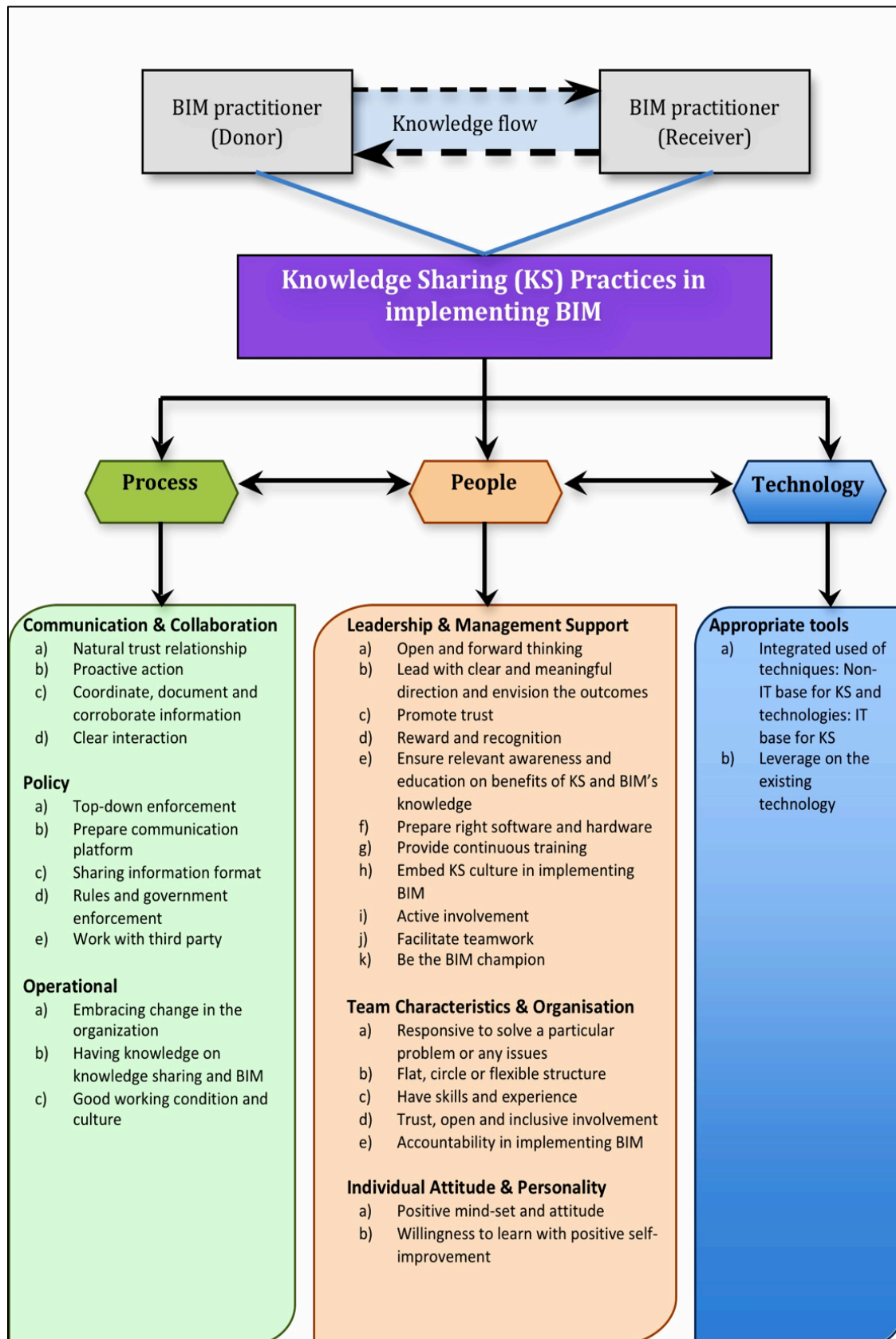


Figure 5.2: A Preliminary framework for KS Practices in implementing BIM in Malaysian construction industry (flow from top to bottom).

5.4.2 People Element

Findings from both the literature review and the workshop showed that the people element is crucial to knowledge sharing in implementing BIM and highlighted below.

5.4.2.1 Leadership and Management Support

The results of the analysis indicate leadership and management support to be a practice for knowledge sharing in implementing BIM in the organisations which implement BIM. The results from the analysis agreed to by all the organisations showed that leadership and management support is vital towards the organisational culture and knowledge sharing in implementing BIM. Most of the respondents interviewed suggested that leadership and management support provides encouragement and motivation for the successful implementation of knowledge sharing in implementing BIM between employees in an organisation, thereby improving their performance in the organisations. Many authors (Akhavan et al., 2006; Al-Adaileh & Al-Atawi, 2011; Moshari, 2013; Zieba & Zieba, 2014), have identified the critical importance of leadership and management support to the successful implementation of knowledge sharing in an organisation. Nevertheless, Sandhu et al. (2011) argue that knowledge sharing is influenced by top management who do not clearly explain the approach of knowledge sharing, hence affecting employees' willingness to share knowledge. Two case studies findings by Gorry (2008) on knowledge sharing in the USA found that one of the main barriers to knowledge sharing is lack of management and leadership support. In a BIM implementation plan, it has been suggested that leadership requires senior management support to have a vision which aligns with the way organisation works (Deutsch, 2011a; Smith & Tardif, 2009).

5.4.2.2 Open and forward thinking

Accordingly, the result from the analysis suggests that leadership and management support is vital when directing a change in the organisation from a regular job to a new technology, for example from using CAD and moving towards 3D or nD modelling. Also, Cases A, D, and E suggested that the leaders and managers must be open to changes and discussion concerning issues and problems in implementing BIM. This evidence is similar to the case study findings by Fong (2005) that leaders have to communicate and deliver the message regarding the importance of knowledge sharing and encourage team members to embrace the open culture. It is then followed by the forward-thinking (vision) to achieve strategic goals such as BIM implementation and sharing of knowledge in implementing BIM. Therefore, the *'Open and forward thinking'* KS practices in implementing BIM component is proposed.

5.4.2.3 Lead with clear and meaningful direction and envision the outcomes

Although the Cases A, B, and F also agreed that KS in implementing BIM must not only be led by a leader to ensure a meaningful sharing as well as for the good of the project, the top management must act to share and look at the importance of knowledge sharing. Also, the leader has to provide a clear and relevant direction identified as a strength in a BIM implementation case study by Kaner et al. (2008). Nevertheless, the analysis of this study from those three organisations also found that 'envision the outcomes' is essential for KS in implementing BIM. Therefore, the following component, *'Lead with clear and meaningful direction and envision the outcomes'* KS practices in implementing BIM component is proposed.

5.4.2.4 Promote trust

Trust involves both leaders' and employees' role in practising their own initiatives. The result from the analysis indicated that management should promote trust in ensuring the flow of information is delivered smoothly as indicated by Arif et al. (2015) that trust within the organisation among the employees and between employees and the leaders is the most critical factor for an organisation in the Jordanian construction industry. In this research, Case D promotes trust by emphasising the benefits of BIM and set a target to work with 3D and the whole BIM process within four years. Case E was also promoting trust as its management support by sending its staff for training abroad in Singapore and Taiwan. The demonstrated willingness of the management and leaders to invest in BIM awareness and training is the proof of their trust. This initiative is in line with Bakri et al. (2010) who stated that willingness to show tangible results from the investment could be committing through trust. It is clear from the findings that trust provides a starting point from a leader and management within the organisation by ensuring that employees understood the benefits of BIM and is aimed towards BIM implementation that leads to knowledge sharing practices in implementing BIM. Therefore, under management and leadership support, the following component, '*Promote trust*' is proposed.

5.4.2.5 Reward and recognition

Reward and recognition have been recommended as vital factors for active knowledge sharing in organisations (Al-Alawi et al. 2007). However, a lack of reward and recognition was found to be among the barriers to knowledge sharing (Nesan, 2012; Sandhu et al., 2011). While research conducted in an American multinational in Malaysia found that the most effective method to promote KS is to link it with rewards, however, the non-monetary reward was perceived as less effective (Ling, Sandhu, & Jain, 2009). Interestingly, this finding contradicts with Ling et al. (2009), whereby in most cases of this research, participants perceived that their organisations did not apply a reward system in monetary terms to its employees for knowledge sharing but was slightly more towards non-monetary rewards such as career development, benefits from the information and knowledge needed, enhanced

experiences in BIM and exposure to knowledge sharing with the BIM community and industry. Zhang & Jiang (2015) suggested that some organisations could also use practices like recognition of internal copyright or patent to protect employees' new ideas or knowledge. PF1 also mentioned that Case 6 used recognition such as BIM certification for its employees to motivate them in implementing BIM as well as knowledge sharing. Thus, the following KS practices component, '*Reward and recognition*' is proposed as part of the framework.

5.4.2.6 Ensure relevant awareness and education of KS and BIM knowledge

To allow knowledge sharing in implementing BIM, the management and leader should support education investment for the productive cycle. The data analysis indicates that the management and leaders in Case B and Case F ensured relevant awareness by carrying out proper checks and follow ups on any information in implementing BIM as well as via consultation in guiding its branches. Also, they allocate some amount of time for education in knowledge sharing and BIM, although they would cluster it as wastage at the beginning to enable team efficiency. In Case D, the support was given by ensuring that the appropriate education is passed to its people through lectures, seminar, and tutorials. PD1 perceived that the support, commitment, and vision of management are significant. They also practice sharing online and organise a top management forum yearly. Moreover, PD1 encouraged the management to learn as much as possible and to pass the information to its team, to assist the team when they run into a problem and to make sure the problem can be resolved. Correspondingly in Case E, the management promotes learning and development. Interestingly, PF1 suggested that competition could be an enabling factor to encourage learning and knowledge sharing. Similarly, Smith and Tardif (2009) stated that in BIM implementation, the more substantial and often hidden investment is education as opposed to mere training. Education will enable the entire organisation to change the business culture. They illustrated that software and training is the tip of iceberg that is visible rather than education that is normally hidden but more impactful for cultural change. Training teaches people how to perform tasks and education develops people how to think (Smith & Tardiff, 2009). For a BIM implementation strategy to be fully effective, Smith and Tardiff (2009) suggested that

BIM tools training must be guided by, or at least accompanied by, education. The need for training and a dedicated education program is also stressed by Arayici and Coates (2012); Haron (2013); and Zahrizan et al. (2014) due to the process and technological changes within the organisation.

Also, providing training for education, personal and team development for effective knowledge sharing is an essential consideration when implementing knowledge sharing practices. Through training, employees gain a better understanding of the fundamentals of knowledge sharing as well as the approaches to achieve it (Siemieniuch & Sinclair, 2004). Training and educating employees about knowledge sharing, the future of knowledge sharing and the benefits of knowledge sharing implementation should be provided. This will assist employees to direct their career more towards knowledge sharing related activities. Training and education is important to low level employees as well as top management. As a result, training and education is treated as a critical success factor for the implementation of knowledge sharing by Wong and Aspinwall (2005). It is agreed by the case studies and literature review that training and education for knowledge sharing and BIM implementation is an important component. Therefore, the following KS practices component, '*Ensure relevant awareness and education of KS and BIM's knowledge*' is proposed for the framework.

5.4.2.7 Prepare right software and hardware

The selection of the most appropriate software solutions and hardware required for individual organisations is significant. Software should be chosen to improve the potential of the organisation after the investment has been made. In all cases, software should enhance the ability of individual firms to communicate with other firms and exchange information reliably for practical use of BIM (Chien et al., 2014; Smith & Tardif, 2009). In an organisational setting, management and leadership should support information and knowledge sharing by preparing the right software and hardware and giving the approval to buy it for BIM implementation. This infrastructure will then be used as a medium to share knowledge in implementing BIM when the employees use

it to share information or demonstrate the model created. Therefore, the following KS practices '*Prepare right software and hardware*' is proposed as part of the framework.

5.4.2.8 Provide continuous training

According to Dainty et al. (2005), one of the strategies to break the knowledge sharing barriers includes training and development of employees so that new knowledge can be embedded throughout the organisation. The author claimed that training per se is a knowledge-sharing process, as well as a primary source of human resource development that contributes to effective knowledge sharing within an organisation. Providing continuous training is vital for management and leaders who want to establish knowledge sharing capability in implementing BIM. The empirical study in manufacturing organisations by Ooi et al. (2012) revealed that training and development showed a positive relationship with employee knowledge sharing. Meanwhile, many researchers (Arayici & Coates, 2012; Eastman et al., 2011; Gu & London, 2010; Kaner et al., 2008; Salleh & Fung, 2014; Smith & Tardif, 2009; Zahrizan et al., 2013) have highlighted the importance of training to deliver a successful implementation of BIM. However, Barison and Santos (2011) highlighted that currently, higher education institutions are unable to meet the demand for BIM-competent personnel in the short term. Thus, Smith and Tardif (2009) suggested that organisations need to develop BIM skills internally among their employees as an alternative strategy. The data analysis showed that continuous training is important and must be supported by management and leaders in the organisation set to encourage learning and knowledge sharing in implementing BIM through various tools. This is in line with findings by past researchers (Arayici & Coates, 2013; Dave & Koskela, 2009; Eastman et al., 2011; Hardin, 2009; Salleh & Fung, 2014; Yang, 2004) who studied knowledge sharing, collaborative environment and BIM implementation, and recommended that proper training sessions which include workshops, brainstorming sessions, seminar and video presentations could be adopted to lessen the scarcity of appropriate knowledge and skills in BIM participants in the short term. Also, PF1 stressed a need for hands-on training as well as a seminar on awareness because BIM involves new technology and processes. Therefore, this will

improve the knowledge and skills needed. Accordingly, the following KS practices component '*Provide continuous training*' is proposed as part of the framework.

5.4.2.9 Embed knowledge sharing (KS) in implementing BIM culture

According to Davenport and Glaser (2002), embedding knowledge into daily work processes is time-consuming and costly. However, they found that the key to success in knowledge sharing is to bake knowledge into knowledge work, which means to embed knowledge into the technology that knowledge workers use to do their work as a norm. They further claimed that this approach ensures that knowledge management becomes a non-separate activity, which requires additional time and motivation. For knowledge sharing in implementing BIM, when the employees are encouraged to share their knowledge in BIM within the organisation as a norm, this then will automatically become their routine that will turn into their culture. Therefore, as demonstrated by this research, Case A really exploits its management and management demand to push the knowledge sharing practices into its culture and requires their endorsement. Also, PB1 believes that enabling factors to knowledge sharing in implementing BIM is an organisational action that is related more to demand as a culture rather than just human resource guidelines. Thus, the following KS practices component, '*Embed knowledge sharing (KS) in implementing BIM culture*' is proposed as part of the framework.

5.4.2.10 Active involvement

The participation and leadership of owners are vital to the success of the collaborative project teams that exploit BIM (Eastman et al., 2011). Almost all of the case studies of this research showed that active involvement from the management and leaders is vital regarding appearance, demand, and support for knowledge sharing in implementing BIM. Three participants of this case studies research posited that active involvement in a BIM process is needed in BIM implementation instead of being an observer. Furthermore, the active involvement includes planning for the process, team requirements in implementing BIM via the participant experienced in spearheading

the team and creating a BIM unit or department in charge of BIM implementation in each branch. Thus, the following KS practices *‘Active involvement’ under Management and Leadership Support* is proposed as part of the framework.

5.4.2.11 Facilitate teamwork by handling the project with the right people and knowledge level

Dainty et al. (2005) highlighted the importance of teamwork for knowledge sharing as a collective responsibility of small groups rather than an individual. Teamwork bonding could break the barriers to knowledge sharing. Meanwhile, Chuang, Jackson, and Jiang (2016) and Ooi et al. (2012) found that management and leadership have positive effects on team and employees’ knowledge sharing while Nesan (2012) points out that one of the factors that inhibit knowledge sharing between parties includes lack of teamwork. By promoting a culture that supports teamwork and information flow between employees, an organisation can enhance the KS among its employees (Al-Adaileh & Al-Atawi, 2011; Ding, 2013). The data analysis of this research suggested by PB1 is that management should facilitate teamwork by handling the project with the right people and knowledge level in implementing BIM. This support helps to ease the dissemination of BIM knowledge when the team identifies and works with people who have the same pace of knowledge understanding. The literature review and interviews showed support that this is an important component to be included in the framework and suggested as *‘Facilitate teamwork by handling the project with the right people and knowledge level’*.

5.4.2.12 Be the BIM champion

A BIM champion is a person who has shown the ability to gain the support of colleagues in implementing technological change (Shepherd, 2015). Eastman et al. (2011) point out that a significant impact to accelerate the pace of BIM implementation requires leadership of senior management who has a strong internal knowledge. Accordingly, PC1 encourages a person interested in BIM to be a BIM champion. The BIM champion does not just have knowledge in BIM but also knows

how to execute, manage resources, the process as well as the technical part. Therefore, this research suggests the following KS practices *‘Be the BIM champion’* as part of the framework to encourage knowledge sharing in implementing BIM.

Findings from the interviews supported the literature finding and confirmed that these KS practices components are vital under leadership and management support for KS in implementing BIM (Refer Table 5.5).

Table 5.5: Cross-referencing of management and leadership support practices based on the triangulation of findings from the literature review and the interviews

KS Practices Components	Literature	Interview
Open and forward thinking	✓	✓
Lead with clear and meaningful direction and envision the outcomes	✓	✓
Promote trust	✓	✓
Reward and recognition	✓	✓
Ensure relevant awareness and education on benefits of KS and BIM’s knowledge	✓	✓
Prepare right software and hardware	✓	✓
Provide continuous training	✓	✓
Embed KS in implementing BIM culture	✓	✓
Active involvement - Top management appearance, demand and support	✓	✓
Facilitate teamwork by handling the project with the right people and knowledge level	✓	✓
Be the BIM champion	✓	✓

5.4.3 Team characteristics and organisation

Team characteristics and organisation in this research refers to a group of people working collaboratively under a structured, managed system to carry out all defined tasks and goals. Accordingly, this research divides team organisation into five components of KS practices, which are *‘Responsive to solve a particular problem’*, *‘Flexible structure’*, *‘Have skills and experience’*, *‘Trust, open and inclusive involvement’* and *‘Accountability in implementing BIM’*.

5.4.3.1 Responsive to solve a particular problem

In the responsive knowledge-sharing situation, the results of the experiments by Zhang & Jiang (2015) showed that receivers' characteristics did not have a significant impact on the sharers' willingness. Furthermore, the mean of responsive sharing willingness was higher than proactive sharing willingness, which suggested that most people would be willing to provide an answer when asked by other colleagues. The action of asking is strong enough to motivate most individuals to share their knowledge. Hence, with the strong effects of just asking, the case studies from this research showed that all interviewees concurred that colleagues' response to the knowledge sharing in implementing BIM is very important. This component of knowledge sharing was mainly to solve any issues related to BIM implementation, which is currently considered as in a transition period before BIM matures.

5.4.3.2 Flexible structure

While the centralisation of an organisation's structure can create a stable medium of control for making a decision, a more informal and flexible structure is needed for knowledge creation and knowledge sharing. Flexible structures lead to better internal communication and more open-freely shared ideas and knowledge (Egbu, 2005). For this research, a flexible structure includes flat, circle or right structures in an organisation, which means an organisational structure with few or no hierarchical levels between design and top management members in the organisation. The interviews confirmed that flexible structures encourage knowledge sharing in implementing BIM.

5.4.3.3 Have skills and experience

According to Eastman et al. (2011), the human resource considerations are vital because the achievement of any BIM application will depend on the skill and attitude of the people assigned to the technology used. As they further justify, BIM is a revolutionary change from drawing production by expressing ideas in two-

dimensional to modelling, which virtually established the construction of the building. Thus, to implement as well as share knowledge associated with BIM requires a different set of skills. While drafting demands familiarity with the language and symbols of architectural, structural and construction drawings, BIM demands an excellent understanding of the way buildings are built. The Head of Assistant Managers, BIM Unit from the government agency background in Case 6 of this research perceived that skills and experience are also crucial in BIM implementation as well as knowledge sharing because in actual the learning is more towards the skills and experience gained while doing it.

5.4.3.4 Trust, open and inclusive involvement

Team characteristics also affect the level of collaboration where achieving a high level of collaboration depends on team members who contribute an openness to change, a willingness to cooperate, and a high level of trust (Jassawalla & Sashittal, 1998). Trust among people can promote a knowledge sharing culture and is essential to facilitate the exchange relationship (Lee, 2001). From the perspective of small and medium enterprises, high levels of motivation and trust between employees are necessary to facilitate the development of a sufficient knowledge sharing culture in organisations (Eze, Goh, Goh, & Tan, 2013). Trust involves both managers and employees' responsibility to practise their initiatives. Workers need the trust of the management to act in their individual capacity to make a practical decision in a group or as individuals. Also, openness makes employees feel more comfortable and will establish communication between all levels in the organisation, and subsequently encourages the sharing of knowledge. For managers to gain trust, they can be part of a team by offering help when needed but not seen as a dictator who always gives the orders. Thus, an environment of trust, openness and teamwork will help to create the potential of a sharing environment (Ahmed et al., 2002) and knowledge sharing happens more efficiently if there is a level of trust existing between employees (Dave & Koskela, 2009; Ding, 2013). Past studies (Akhavan et al., 2006; Arif et al., 2015; Berg et al., 2012; Cai, Goh, de Souza, & Li, 2012) presented supporting evidence of the importance of trust in the successful implementation of knowledge sharing. Moreover, Renzl (2008) in their study suggests that trust within and between teams

increases knowledge sharing by reducing the fear of losing one's unique value while improving knowledge sharing. Two case studies from this research applied the trust component for its organisational knowledge sharing in implementing BIM based on the nature of BIM implementation that involves employees working together with trust, openness and without isolating team members. Furthermore, Case C and Case E applied the openness concept in the organisation's environment, which encourages staff to share, learn from their mistakes and enhance performance as well as to ask and speak freely.

5.4.3.5 Accountability in implementing BIM

Accountability is associated with roles and responsibilities. In this research, team accountability is defined as all team members who are responsible for the duty, progress, and performance towards the project. The team members must, however, understand their necessary duties and responsibilities to avoid any duplication of work on the project to prevent staff redundancies (Jassawalla & Sashittal, 1998). These components are necessary to secure extra effort and commitment from team members for the success of a project (Evbuomwan & Anumba, 1998; Jassawalla & Sashittal, 1998). Meanwhile, several authors (Ahmad Latiffi, Brahim, & Fathi, 2016; Haron, 2013; Smith & Tardif, 2009) reported more on the roles and responsibilities of a team in BIM implementation instead of accountability. Although it is still unclear what the BIM roles are at the industrial level, a customised set of clearly defined roles and responsibilities is essential to be developed and aligned with the company's strategy and business needs (Smith & Tardif, 2009). The defined roles and responsibilities will specify the job scope that the BIM-associated roles need to deliver, provide what the management expects to be fulfilled, and inform the skills and competency set that is required. Furthermore, Deutsch (2011) posits that the introduction of specific job titles also reflects the recognition of the company and commitment to BIM implementation. In Case B of this research, PB1 acknowledged that the organisation practices team accountability in implementing BIM towards the project. The skills developed will then push knowledge sharing in implementing BIM to the optimum level.

Table 5.6 below shows the triangulation findings from the literature review and the interview for KS practices components under the team organisation.

Table 5.6: Cross-referencing of team characteristics and organisation factors based on the triangulation of the findings from the literature review and interviews

KS Practices Components	Literature	Interview
Responsive to solve a particular problem or any issues	✓	✓
Flat, circle or direct structure	✓	✓
Have skill and experience	✓	✓
Trust, open and inclusive involvement	✓	✓
Accountability in implementing BIM	✓	✓

As construction industry involves several individuals or parties and collaborative nature of BIM implementation, all the KS practices components in Table 5.4 as discussed previously are highly important to boost the KS practices in the organisation.

5.4.4 Individual attitude and personality

Individual attitude and personality in this research refer to a person's level of like or dislike for work or a task. Individual attitude and personality may lead to the success of knowledge sharing within a collaborative environment in BIM implementation. Accordingly, this research divides individual attitude and personality into two components of KS practices, which are '*Positive mind-set and attitude*' and '*Willingness to learn with positive self-improvement*'.

Zhang and Ng (2013) determined that attitude dominantly contributes to professionals' knowledge sharing intentions in construction teams. They further identified that knowledge responses lead to individuals' favourable attitude toward knowledge sharing, which implies that professionals in construction teams keep an open mind on learning and self-improvement. This claim is positively admitted in

Case C, which was looking to employ people with an attitude or personality who are keen and passionate about learning during their interview. PC1 believes that people who are willing to learn more about positive self-improvement can move further and suited to Case C because of its open environment. Nevertheless, to create multi interaction or cooperation for knowledge sharing, learning must be automatically embedded in employees' mind-sets (Love et al., 2004 from Watkins and Golembiewski, 1995). The framework of KS practices in implementing BIM was supported by the interviews, which recognized that all components in the framework were significantly associated with successful knowledge sharing in the collaborative team in implementing BIM (refer to Table 5.7).

Table 5.7: Cross-referencing of individual attitude and personality components based on the triangulation of findings from the literature review and the interviews

KS Practices Components	Literature	Interview
Positive mind-set and attitude	✓	✓
Willingness to learn with positive self-improvement	✓	✓

Although Table 5.7 shows that the interviewees confirmed all the components identified in the literature review, the result from the interviews was focused more on individual characteristics, for instance, openness and willingness to change to a new approach whereas the discussions in the literature review concentrated more on relationships between components. The analysis revealed that the younger generation is highly motivated to learn and adopt BIM as it involves modelling and information technology.

5.4.5 Process Element

Within the process element, fifteen components were identified and sorted according to three practices, namely '*Communication and Collaboration*', '*Policy*' and '*Operational*'. The justification for selecting each of the component is further discussed in the following subsection.

5.4.5.1 Communication and collaboration

The results of the analysis indicate communication and collaboration to be a practice for knowledge sharing in implementing BIM in the organisations which implement BIM. Communication is found as an essential factor to facilitate knowledge sharing (Arif et al., 2015) and also seen as a prerequisite for active team collaboration (N. Zakaria, Amelinckx, & Wilemon, 2004). In the context of BIM implementation, Deutsch (2011b) highlighted that communication and collaboration are among the crucial factors that need attention instead of focusing more on technology. Accordingly, this research divides communication and collaboration into four components of KS practices, which are '*Natural trust relationship*', '*Proactive action*', '*Coordinate, document and corroborate information*' and '*Clear interaction*'.

5.4.5.1.1 Natural trust relationship

Trust in management results in higher levels of cooperation, and thus, individuals are more willing to share knowledge and consequently performance increases (Renzl, 2008). From the analysis of interviews, three participants (PA1, PC1, and PD1) argued for a trust element. It is found that the trust factor is crucial for knowledge sharing in Organisation A although based on the nature of BIM implementation, the trust should come naturally because BIM encourages the parties involved to work together sincerely. In line with that, the managing director cum BIM manager (P3) further explained that Case C working relationships always depend on trust. In contrast, the senior BIM manager (PD1) from the integrated BIM consultant believes that BIM implementation does not need trust for everybody to get the right information due to the nature of the BIM platform where everybody works from the central data source. Even though the nature of BIM involves an open environment for information and knowledge sharing, the willingness to share knowledge does not come automatically. An empirical study by Jain et al. (2015) found that trust is positively related to one's own willingness to share knowledge within the organisation as well as one's ability to get colleagues to share knowledge. Therefore, this research maintains that a natural trust relationship component be instilled for

knowledge sharing processes in implementing BIM as suggested by Renzl (2008) in their study that trust within and between teams increases knowledge sharing by reducing the fear of losing one's unique value while improving knowledge sharing.

5.4.5.1.2 Proactive action

Proactive action refers to the act of a person in creating or controlling a situation rather than passive response after it has happened. According to Zhang and Jiang (2015), proactive knowledge sharing refers to a person proactively sharing new ideas or newly learned knowledge with another person to seek further comments or suggestions. Their studies consistently supported that the receivers' professional ability to do something successfully and personal relationship with the sharer is vital in motivating the knowledge sharer. This action means that if one shares knowledge with the purpose of seeking comments or further developing new ideas, he or she tends to select a good friend who has a rich experience and good professional competence to discuss the new ideas. Although a proactive action was emphasised in this research as an important component of knowledge sharing, however, the need is more towards assurance of the organisation's performance in communicating the information and knowledge needed by the organisation to cover and keep track of its progress. By this means, the proactive action in this research is for seeking feedback which is related to team members' accountability. Contrary to Zhang & Jiang (2015), this research did not cover the influence of knowledge receivers' competence, learning attitude or personal relationship with knowledge sharer's willingness to share.

5.4.5.1.3 Coordinate, document and corroborate information

Alshawi (2007) explained that knowledge is generally developed through the experience acquired during the carrying through of the work and proposed to document every procedure as the documented procedure provides a set of logically ordered activities to accomplish specific tasks. The documented procedures, which is also suggested by Smith and Tardif (2009) and Eastman et al. (2011) provides

guidance, suggestions and reference materials to facilitate better performance in implementing BIM. Also, 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. The findings from this research showed that in Case A and Case B, all the information must be coordinated and documented for knowledge sharing of BIM implementation. A BIM manual has been developed in Case A as a guide for the employees to implement BIM as well as for knowledge sharing in implementing BIM. In the meantime, although PF1 admits that some of the items need to be demonstrated, Case F also documented what it has done in BIM implementation in its standard as a guide. Google Document and Google Drive were used in Case B to update people with the required information in the organisation. PB1 also stressed that information not only has to be coordinated and documented, but the team has to corroborate the information too, which means confirm the authenticity of any information given. The combination of findings from case studies and literature reviews strongly showed that coordination, documenting and corroboration is vital for the success of knowledge sharing in implementing BIM.

5.4.5.1.4 Clear interaction

The need to facilitate interaction within and between teams provides a common contextual understanding of the design and facilitates correct prioritisation of information, thereby increasing the efficiency of communication. Ideally, team interaction should be facilitated without imposing rigid, overly formal mechanisms that could reduce team flexibility (Flanagan et al., 2007). In the context of BIM implementation, collaboration requires human interaction to review capabilities in identification of the relevant design issue, in dealing with the issue identifying the problem, reporting on the feedback of the issue raised and ability to track the issues until they are resolved (Eastman et al., 2011; Grilo & Jardim-Goncalves, 2010). Grilo and Jardim-Goncalves (2010) supported that the principle of interoperability in BIM can contribute to efficiency value levels, through supporting communication and coordination interactions between participants in BIM-based projects. Also, Shepherd (2015) suggested that management should provide a BIM suggestion medium for an

employee to interact genuinely and post issues anonymously for developing collective consensus and trust. PF1 elaborated that in Case F, the organisation’s branches could quickly come to the BIM Unit for explicit knowledge sharing in implementing BIM or else could refer to its branch BIM unit because BIM is not merely about drawing but involves modelling which is more complicated. Therefore, the missing information and knowledge can be filled in using clear human interaction.

Table 5.8 below shows the triangulation findings from the literature review and the interview for KS practices components for communication and collaboration.

Table 5.8: Cross-referencing of communication and collaboration components based on the triangulation of findings from the literature review and the interviews

KS Practices Components	Literature	Interview
Natural trust relationship	✓	✓
Proactive action	✓	✓
Coordinate, document and corroborate information	✓	✓
Clear interaction	✓	✓

5.4.5.2 Policy

This research divides policy into six components of KS practices, which are *‘Top-down enforcement, ‘Prepare communication platform, ‘Sharing information format’, ‘Rules and government enforcement’* and *‘Work with the third party’*.

5.4.5.2.1 Top-down enforcement

Organisational commitment and trust act in a critical role in knowledge dissemination and building knowledge sharing (Luo & Lee, 2015). Research by Lindner and Wald, (2011) supported that top management commitment has a direct implication on knowledge sharing effectiveness. Moreover, a harmonious team-management approach does not create itself but must be actively designed and maintained by team leadership in agreement with team members for knowledge sharing culture

development (Zakaria et al., 2004). From the perspective of BIM implementation, a top-down approach to drive the successful implementation was also discussed (Smith & Tardif, 2009). The justification to engage a top-down approach lies in the need to strategically align the BIM implementation with business strategy, which is not possible if the bottom-up approach is used. Nevertheless, Deutsch (2011b) justifies that leading in BIM and integrated design is nearer to followership such as being open, and having the capacity to follow someone in charge, and having middle managers lead from within the organisation. Both justifications are relevant whether the leading could be from the top or middle management, but still similar regarding the needs for a leader's commitment to pursue knowledge sharing in implementing BIM effectively. The data from this research revealed that top management commitment is highly important. A leader should inspire others by being a good listener to his or her team members as their thinking is related to specific problems. Also, two participants (PB1 and PE1) agreed that the knowledge sharing in implementing BIM must be led by example to ensure a meaningful sharing as well as for the good of the project. The act of sharing must begin with top management and prioritise the importance of knowledge sharing.

5.4.5.2.2 Prepare a communication platform

In terms of policy, the organisation may decide on the type of platform to be used for knowledge sharing. Platforms are defined as “a set of prescribed processes, entities, operations and resources that are brought together when producing some relatively standardized output” (Styhre & Gluch, 2010). The research found that the environment created by the management must provide a platform to facilitate knowledge sharing before the technology can be implemented (Arif et al., 2015). For example, research on knowledge transfer within and across organisational boundaries suggested using a central knowledge platform such as websites and blogs, and 3D-models to inform future development (Berg et al., 2012). In this research, Case F has prepared a communication platform such as a programme to assist designers, by having J-Pedia and JCoP (as shown in Figure 4.8) for interaction and knowledge sharing. Through this platform, the programme created allows employees to retrieve BIM documents and news, provide space for questions and answers, as well as

discussions. In Case C, the organisation developed a BIM collaboration platform by getting people to engage and brainstorming to consider all the barriers within the organisation as a knowledge sharing platform. Hence, this component is vital to be included in the organisation's policy to encourage knowledge sharing in implementing BIM.

5.4.5.2.3 Sharing information format

BIM involves sharing data and models through an integrated process. In the BIM Management Handbook by Shepherd (2015), the author suggested the contractual commitment by team members for BIM deliverables, which includes BIM models to the agreed Level of detail (LOD) and comments and approval by agreed deadlines at each stage. Along with that, the team members need to specify matters that jeopardize the deadlines. With a certain degree of commitment for BIM deliverables, the sharing of information and knowledge in implementing BIM requires a standard format from different team members to ease the process. According to PD1, it is essential to know the format of the information sharing, for example, type of file needed, the way it needs to be used and shared whether in softcopy or hardcopy or both, etc. This approach will not only increase interoperability, which can contribute to efficiency, but also improve understanding of the proper way to share information from within the BIM platform.

5.4.5.2.4 Rules and government enforcement

Before the knowledge sharing activities could take place in organisations, the support for BIM adoption at the national level was found to be crucial. In the context of the Malaysian construction industry, past researchers (Harris, Che Ani, et al., 2014; Takim et al., 2013; Zahrizan et al., 2014) suggested that continuous support and government policies and regulations must be developed to encourage BIM adoption. According to PA1 in this research, the enforcement from the Construction Industry Development Board Malaysia is considered necessary because construction industry players will have to follow their requirements to get approval for their submission.

Therefore, PA1 expected that rules and government enforcement from CIDB indeed play a role in pushing the BIM implementation to the optimum level. This expectation is also agreed by PE1 in Case E, who believes that the enforcement by the government is perceived as an enabling factor for knowledge sharing in implementing BIM indirectly as it been seen as a mandate from the government.

5.4.5.2.5 Work with third party

In the transition time between early adoptions of BIM to maturity, the short-term initiative is considered significant. Within a short period, working with a third party such as an outsourced BIM expert is one of the best alternatives to adopt BIM. Moreover, the involvement of BIM experts working together with the existing employees could enable effective knowledge transfers, and sharing in the organisation (CIDB, 2014). This research was demonstrated in Case A, which chose to work and collaborate with third parties such as the CIDB in giving talks and seminars. Case A uses this alternative to share its knowledge and experiences with the industry players to raise BIM awareness and share its experiences in implementing BIM. Table 5.9 below shows the triangulation findings from the literature review and the interview for KS practices components for policy.

Table 5.9: Cross-referencing of policy components based on the triangulation of findings from the literature review and the interviews

KS Practices Components	Literature	Interview
Top-down enforcement	✓	✓
Prepare communication platform	✓	✓
Sharing information format	✓	✓
Rules and government enforcement	✓	✓
Work with third party	✓	✓

5.4.5.3 Operational

This research describes operational as a process or series of actions towards a collaborative work environment for achieving effective knowledge sharing in implementing BIM. Accordingly, this research divides policy into five components of KS practices, which are *'Embracing change in the organisation'*, *'Having knowledge on knowledge sharing and BIM'*, *'Good working condition and culture'* and *'Work with the third party'*.

5.4.5.3.1 Embracing change in the organisation

BIM is recognized as a new management technology that provides an integrated solution to operate businesses while improving the client satisfaction in construction projects (Takim et al., 2013). BIM involves multi-faceted technologies, which strongly pervade every aspect of design and construction practice (Shepherd, 2015). Such a new management technology will take time and processes to encourage employee acceptance, hence requires the cohesive effort of the entire organisation. In regard to the management demand as a culture and endorsement, Case A exploits its management demand to push the knowledge sharing practices into its culture and requires their endorsement. Furthermore, PA1 suggested embracing change in the organisation although it takes a long time and process because it involves a different way of working.

5.4.5.3.2 Having understanding on knowledge sharing and BIM

Smith and Tardif (2009) highlighted that in BIM implementation, the more substantial investment is education that will enable the entire organisation to change its business culture. From the responses, Case D and Case F showed that their organisational culture influences knowledge sharing through the typical approaches of education on the benefits of sharing knowledge. PD1 stressed that people would benefit themselves by having a better or more understanding of BIM knowledge when they are educated or learn more. From the view of a government agency, PF1 pointed out that educating

and sharing with others should become a culture in the organisation, therefore spreading the knowledge and increasing the number of people who know. However, PF1 admitted that at the moment, knowledge sharing in implementing BIM is quite slow due the low number of people with the appropriate knowledge and experience.

5.4.5.3.3 Good working condition and culture

Successful learning organisations develop an organisational environment that combines organisational learning with knowledge management. The sharing of ideas to create and develop new knowledge for the successful learning organisations could be enabled by a conducive work environment, culture and IT infrastructure (Al-Alawi et al., 2007). Uniquely, PB1 and P3 agreed that working culture is essential rather than working with the model itself although BIM is generally related to the model or modelling. The analysis reveals that the good working culture is created as the essential sources for the knowledge sharing in implementing BIM since the first interview of candidates for Case C. Furthermore, Case C treats its team as trusted friends by employing a circle rather than a top down structure. By this means, Organisation C tries to avoid a highly hierarchical culture.

Importantly, most of the organisations (Case A, Case B, Case C, Case D and Case F) also acknowledged the importance of the physical work environment for knowledge sharing by providing a suitable arrangement of employee workspace, cubicles and discussion areas that enable knowledge sharing and encourage a more collaborative culture through the researcher's direct observation during data collection. This practice is supported by Davenport (2005) who stated that some specific physical work environment designs could promote some types of behaviour although there is limited evidence to prove it. Organisation C encourages openness in the organisation's environment, pushing the people to share, learn from their mistakes and enhance performance. The same openness concept was applied by Case E as a knowledge sharing concept. Organisation E allows its staff to ask and speak freely. PC1 elaborated further that an important aspect of organisational culture and knowledge sharing is creating a good working condition that includes happiness in the

process. However, PB1 argued that a good working condition is just part of the encouragement to knowledge sharing, but is the basis to have a conducive environment for the team members.

Table 5.10 below shows the triangulation findings from the literature review and the interview for KS practices components for operational.

Table 5.10: Cross-referencing of operational components based on the triangulation of findings from the literature review and the interviews

KS Practices Components	Literature	Interview
Embracing change in the organisation	✓	✓
Having understanding on the knowledge sharing and BIM implementation	✓	✓
Good working condition and culture	✓	✓

5.4.6 Technology Element

Technology may improve the efficiency of knowledge management processes. Knowledge Management (KM) techniques and technologies could be used to improve and enable the implementation of the sub-processes of KM, for instance, knowledge creation, codification, and transfer (Ruikar et al., 2007). Knowledge sharing, for example, is a sub-process of KM.

5.4.6.1 Appropriate Tools

Appropriate tools for knowledge sharing including KM techniques are used for non-IT KM approach, and KM technologies are used for IT approach to distinguish between both approaches. Also, both formal and informal knowledge processes are considered when the approach attempts to deal with knowledge sharing in implementing BIM. It is evident from the results that the approaches used by all cases are integrated which include both knowledge management (KM) techniques and knowledge management (KM) technologies.

5.4.6.2 Integrated use of techniques and technologies for sharing knowledge in implementing BIM

Implementing BIM in construction organisations involves knowledge sharing between employees in the organisations, as well as project team players from other organisations due to the nature of project-based organisations and the multidisciplinary players. Not surprisingly, regarding accessibility and connectivity between employees or project team players, the result from the analysis showed that KM techniques are still preferable in comparison with KM technologies. According to Ruikar et al. (2007), KM techniques do not require sophisticated facilities, making it affordable to many organisations, effortless to implement and maintain because of its simplicity and direct nature. Among the well-known KM techniques used to share knowledge in implementing BIM are formal regular meetings, workshops, and demonstrations. For example, in Case A the designer and project team discuss the project as well as sharing knowledge on BIM during regular project-based meetings. In Case B, meetings are held to report the problems and the solutions in implementing BIM to its customer while Case E and Case F used the meeting as its medium to get approval for BIM implementation. A past case study in the construction industry by Berg et al. (2012) presented supporting evidence that regular meeting arrangements have been made to enable the sharing of thoughts, ideas, and reflections with each other. It is clear that these techniques gave an opportunity for the people involved to meet and have a clear and interactive discussion about BIM implementation problems and solutions especially when it involves design and BIM model development. Workshops were efficiently used in half of the cases throughout the BIM process to learn, communicate and share knowledge with the client, contractors, and subcontractors. Yang (2004) found that a workshop had a more significant effect than class lectures since the former is more interactive than the latter. Workshops also enable knowledge sharing by answering the client's queries specifically. According to PF1, the BIM workshop is more hands-on, for instance, Organisation F will share how to develop a BIM Execution Plan (BEP). The results showed that workshops were used not only to inform the employees within the organisation, but also others who might be affected within the project players. This result is similar to the suggestion for adoption activities by Eastman et al. (2011) that workshops are suitable for those who are an indirect user but have been impacted by the BIM process. Along with the

workshops, three cases use demonstrations to actively support the knowledge sharing activities such as sharing knowledge and guiding the design team and project team in implementing BIM. Furthermore, Organisation A shares how to implement the BIM with the demonstration by doing it throughout the project and continuously applying it in other projects. By using demonstrations, the organisation indirectly benefits learning from its experience of teaching or showing the right way to implement BIM. This practice coincides with the action research done by Arayici and Coates (2013) which revealed that BIM could be taught efficiently by ‘learning by doing’.

BIM involves collaborative work. Therefore, collaboration technologies could support knowledge creation and share in BIM implementation. The result from the analysis appeared to show that social media was used as a medium for interaction under KM technologies for sharing knowledge in implementing BIM depending on the organisation’s suitability whether the organisation preferred to use its company website, Facebook, online or internet forums, Google engines or instant messaging. Dave and Koskela (2009) compared five technologies for collaboration and found that the internet forum and Wiki are two technologies which satisfy most of the requirements. In contrast, this research revealed that none of the cases used Wiki for interaction or discussion on BIM implementation. PB1, however, highlighted that organisation size does matter in choosing KM technology to manage the flow of knowledge within the people involved in implementing BIM. For example, Case B is using instant messaging such as WhatsApp to communicate and share because it is free and easy to manage within a small group.

In the meantime, considering BIM is still progressing (Mohd Nor & Grant, 2014; Zahrizan, Ali, Haron, Marshall-Ponting, & Abd Hamid, 2013; Won, Lee, & Dossick, 2013) in its development in Malaysia, there is no standard guide for all organisations that wish to venture into BIM. This research evidenced that formal documentation has been developed by most of the organisations as a KM technique to share their own BIM guide or protocol that suits their nature of business within the people involved in their project. Yang (2004) found that written material also helps in supporting

knowledge sharing. Accordingly, a BIM guide is posited as vital in the BIM implementation process (Arayici & Coates, 2013), acting as a knowledge resource. Having a BIM guide as an initiative to spread the knowledge on how to implement BIM is seen as a very helpful and useful practice during the early stage of BIM adoption. Otherwise, the knowledge resource will be wasted.

To learn new technological innovation, the ability of receivers to absorb, adapt and modify new technology through education and training has a massive impact on the receiver to become a sender of technology (Choi, 2009). The implementation of BIM includes some knowledge that should be acquired by people who are working within the BIM context depending on company change processes and needs that will impact the business systems as described by Arayici and Coates (2013). Formal or informal education and training are crucial for an employee to acquire BIM knowledge that involves not only the application of technology but also the management of process and information. Thus, BIM which requires various and correct knowledge in its implementation could benefit from knowledge sharing via education and series of training. The results demonstrate that formal organised in-house training is a KM technique preferred by all of the cases which could improve knowledge sharing among employees, project team or industry players in implementing BIM. Several respondents suggested that education and training should be a continuous effort as the adopters might start with a small-scale project before becoming a champion. This effort is in line with Arayici and Coates (2013) who stressed that in the adoption of BIM, education and training should be an on-going exercise. Alternatively, this research found that external involvement can be seen as an opportunity for the organisation to promote knowledge sharing and expand its business services when it is known by others as a speaker or sponsor.

5.4.6.3 Leverage on the existing technology

It is essential to focus on collaborative technologies, as knowledge sharing is a person-to-person process. Nowadays, different collaborative technologies exist, which include email, Facebook, telephone, instant messenger, video conferencing etc., that may facilitate organisation personnel in knowledge sharing. The degree to which an organisation focuses on collaborative technologies depends on the organisation's approach to knowledge sharing (Egbu, 2013). PB1 suggested leveraging on the existing technology to improve technology sharing because sometimes a colleague who found the information need to disseminate that information which is vital to another person. Hence, with the use of different existing technologies, person-to-person collaboration could be improved. Table 5.11 below shows the triangulation findings from the literature review and the interview for KS practices components for appropriate tools.

Table 5.11: Cross-referencing of appropriate tools components based on the triangulation of findings from the literature review and the interviews

KS Practices Components	Literature	Interview
Integrated use of techniques: Non-IT base for KS and technologies: IT base for KS	✓	✓
Leverage on the existing technology	✓	✓

5.5 Chapter Summary

This chapter has presented the preliminary framework of recommendations as shown in Figure 5.2 in the form of guidelines developed for knowledge sharing practices in implementing BIM within Malaysian construction organisations. It highlights the need for organisations to focus their efforts on seven key practices; Leadership and management support, Team characteristics and organisation, Individual attitudes and personality, Communication and collaboration, Policy, Operational and Appropriate tools. For each area, this chapter has presented a range of guidelines on what organisations should do to implement and improve knowledge sharing in implementing BIM successfully. The next chapter presents the validation process of the preliminary framework.

CHAPTER 6: FRAMEWORK VALIDATION

6.1 Introduction

The development of the theoretical framework that was used to guide the research inquiry for data collection was discussed in Chapter 2. The framework has outlined three elements and seven knowledge sharing practices to guide the researcher in exploring the components for each element during the case study. The theoretical framework was then developed further into a preliminary framework by cross analysing the data collected for six case studies and connecting them with a literature source of reference as can be referred to in chapters 4 and 5 respectively. The preliminary framework at that point was very theoretical and was limited to six organisations that were involved in the case study judging by the source of data that was used for the development of the preliminary framework. Thus, validation is required to obtain a broad view of perspective to generalise the framework. This chapter aims to validate the framework and to further investigate the importance of the key factors in the framework using a secondary validation interview among multidisciplinary Malaysian BIM experts. The following outcome and findings after the validation process will present the final framework for this study.

6.2 Background of Participant and Preliminary Analysis

Ten individuals were invited to participate in the validity interviews, which include eight industrial practitioners (six from the previous participants) and two from academia. Only six of them agreed to participate. An invitation letter (refer to Appendix 5) was sent to them via email. When the agreement to participate was received, the questionnaire and draft of the framework were sent to them. This was followed up by a telephone interview. Table 6.1 shows the profile of the participants who contributed to the validation phase. Due to the limited number of candidates or

experts with construction and BIM experience in Malaysia, three of them that were used previously agreed to participate. They were coming from the primary data collection phase, and had demonstrated detailed knowledge and familiarity with organisational knowledge sharing and BIM implementation. However, the other three respondents counterbalanced the validation results. By having three previous respondents, they were indirectly crosschecking the results again while going through the validation process. Importantly, all of the respondents involved were considered to have a good knowledge of the construction industry with 6-20 years' experience. Their BIM implementation experience, which includes research and industrial practice ranged from 6 to 15 years. The interviews with these participants were conducted in English.

The new participants were also selected based on their involvement and experience in the construction industry and BIM implementation to enhance the effectiveness of the findings of this study. Considering that they were new to the research project, the participants in this validation phase were contacted in advance and provided with all relevant information as regards to the research problem, the data collection methods and the findings to ensure that they had some degree of familiarity with the subject under investigation. In most cases, a pre-dialogue conversation was organised to inform them what was required during the validation phase. It is worth noting that the academics were also selected based on their track record and their heavy involvement in BIM implementation in the construction industry.

Table 6.1: The Background of Participants for Framework's Validation

Type of construction organisation	Code Name	Position	Participants' personal experience in the construction industry	Participants' personal experience in BIM
BIM FM Consultant	PV1	Managing Director	16-20 years	11-15 years (Industrial practice)
Integrated BIM consultant	PV2	Senior BIM manager	More than 20 years	11-15 years (13 years in Industrial practice)
BIM consultant	PV3	BIM manager	16-20 years	6-10 years (7 years in Industrial practice)
BIM consultant	PV4	Head of Consultant/ Academic	11-15 years	11-15 years (6 years in Research, 5 years in industrial practice)
Integrated BIM consultant	PV5	Senior engineer	6-10 years	6-10 years (10 years in Industrial practice)
Government agency	PV6	Senior Civil Engineer	6-10 years	6-10 years (5 years in Research, 2 years in industrial practice)

Based on the data that was collected through the questionnaire forms, a different type of organisation was involved. Two participants were coming from two Integrated Consultants, two participants were coming from BIM Consultants, and one participant each was coming from a BIM FM Consultant and a Government Agency, respectively. One of the participants with a background as a BIM Consultant was also an academic actively involved in BIM development in the Malaysian construction industry. Most of the participants had a working experience between six to twenty years in the construction industry, with one possessing more than twenty years' experience. Three of the participants had between eleven to fifteen years' experience in BIM, and the other three participants had between six to ten years' BIM experience, which includes industrial practice and some research. All participants were from construction organisations involved in BIM implementation to suit the requirement of the research, which is aimed at developing a framework of organisational KS practices in implementing BIM in the context of Malaysian

construction organisations. Meanwhile, the selection of participants for the validation interviews was made according to the following criteria:

a) The participants must be trained in the Malaysian construction industry and possess experience with BIM implementation within their organisations. This requirement is needed to match their experience and knowledge within the context of this study, which are the knowledge sharing practices in implementing BIM within Malaysian construction organisations.

b) The participants' involvement in BIM implementation is limited to at least two years in industrial practice to reflect the practical knowledge, experience, and familiarity of the participant with BIM-associated issues and KS practices related to BIM. Consequently, these experiences will also increase credibility when providing feedback.

c) The participant must come from middle or top-level management and is familiar with the overall business (organisational) practices. This practice may include KS practices related to BIM implementation within their organisation since the framework is designed for an organisational level.

Table 6.1 summarises the background of each participant, which suits the above criteria. The code name was assigned based on the organisation that the participants are representing, to keep the confidentiality and to keep track of their responses. The approach taken for the validation process was discussed in Section 3.13.6.

6.3 Result of Validation and Discussion

The arrangement to conduct the interviews was made via email communication, which occurred immediately after the pre-interview contact with each participant. The telephone interviews took place at a convenient time for each participant. Notes were made, and the discussions were recorded at the time of the interview (which ranged between 20 to 25 minutes). It is important to mention that further discussion in this chapter is a continuity process from the discussion in chapter 5, which discussed the key factors found from the case studies and triangulate it with the literature source.

The importance of the key factors in the preliminary framework was then confirmed through the validation process.

6.3.1 Discussion of the Clarity of the Framework

In the interviews, the first question asked “What do you think about the clarity of the framework?” This question aimed to identify to what extent the framework is clear in terms of the title, general outlook, and the terms and language used. Four out of six participants agreed that the framework is clear and the design simple and easy to understand.

One of the participants from Integrated BIM Consultant stated that "The framework is simple and easy to understand, yet it is also realistic to practice rather than complicated one." Another participant, who is the Head of BIM Consultant in his organisation supported that the framework indicates the clear concept of knowledge sharing in each element of People, Process, and Technology. He added that "The framework is clear and importantly each element, and components of KS practice under each element are practical in the real context of construction organisations. Thus, it is realistic for the construction organisation to practice KS in implementing BIM". Meanwhile, one of the participants, who responded as a Technical Director of Integrated BIM Consultant suggested that the framework should give some description for each of the section or element in the framework, therefore providing a clear meaning for the components included. For example, KS practices in implementing BIM should be described as a TITLE for the framework, and People, Process, and Technology described as the ELEMENT of knowledge sharing.

6.3.2 Discussion of the Structure of the Framework

The second question asked “What do you think about the structure of the framework?” to identify the feedback to the framework’s outlines and the link of each component (including the shapes and the colours used). Five participants from six indicated that the structure of the framework was clear and easy to follow. Also, the colours and the shapes used were suitable for the purpose.

Nevertheless, one of them commented that "I think all looks appropriate, the only part that is not so clear was on the first section before the title, knowledge flow section to title section would be clear if it indicates the arrow start from the middle of knowledge flow (middle of knowledge flow section box) rather than a line." The comments are illustrated in the diagram below (refer to Figure 6.1).

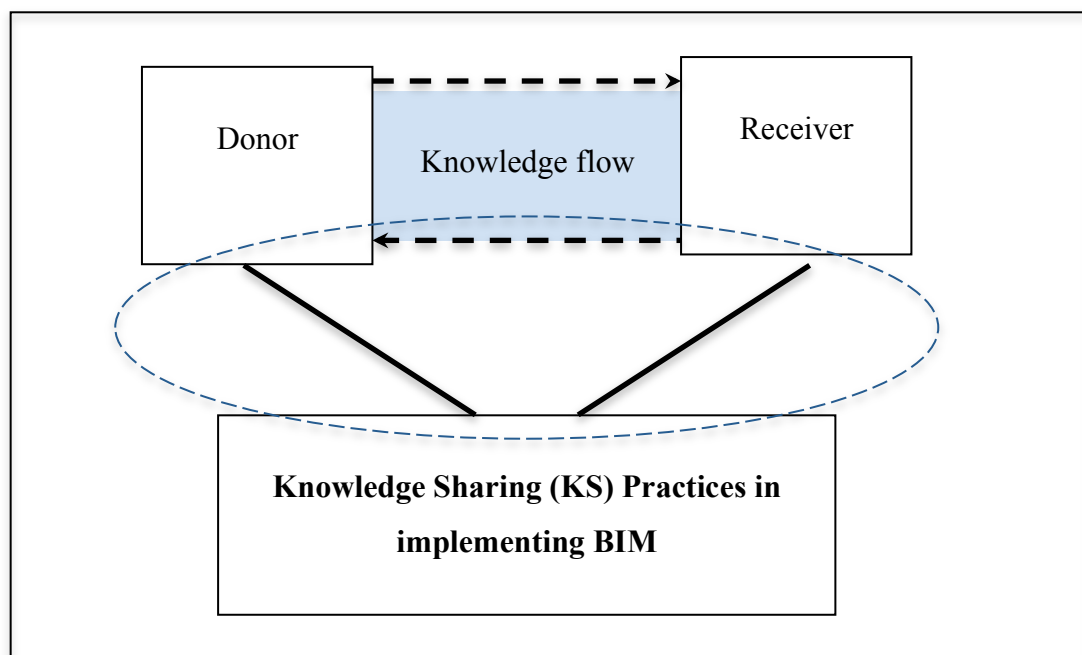


Figure 6.1: Suggested improvement in the dash area as commented for question 2, preliminary framework’s validation

6.3.3 Discussion of the Key Factors of Knowledge Sharing (KS) Practices in Implementing BIM in the Framework

In the third question, the participants were asked: "From the knowledge sharing (KS) point of view, are the components of knowledge sharing (KS) practices which relate to BIM implementation are appropriate or being included in the framework?" This question was to identify and examine to what extent the key factors of knowledge sharing practices in implementing BIM, which encompasses each element, practices, and components are captured in the case studies interviews and literature review and included in the framework. For this question, the discussion includes "quasi-statistical analysis" for each component answered by all the participants in the questionnaire. In general, all of the participants agreed that all the components are appropriate. Participant PV1 with BIM Facilities Management experience and PV2 with Integrated BIM experience strongly recommended the need to rank all the components according to its importance in KS practices. PV1 said that "It is important for you to rank all the components, so it will be easier for BIM practitioners to practice what is more important first" while PV2 mentioned that "It is better for you to rank the components, take responses from other participants, find the average value and rank it." Furthermore, many agreed (PV2, PV3, PV4, and PV5) that component: prepare software and hardware under leadership and management support practice (People element) be moved to Technology element. Therefore, the analysis was carried out after moving the component mentioned above to Technology element, and the result is shown in Table 6.2.

Table 6.2: Summary of the result for People Element in the validation process

KEY FACTORS OF KNOWLEDGE SHARING IN IMPLEMENTING BIM			AVERAGE INDEX	RANKING
ELEMENT	PRACTICE	COMPONENTS		
PEOPLE	Leadership & Management Support	L1) Assure teamwork – Handle the project with the right people and knowledge level	4.67	1
		L2) Open and forward thinking	4.33	2
		L3) Lead with clear and meaningful direction and envision the outcomes	4.33	2
		L4) Embed KS in implementing BIM culture	4.33	2
		L5) Active involvement - Top management appearance, demand and support	4.33	2
		L6) Be the BIM champion	4.33	2
		L7) Ensure relevant awareness and education on benefits of KS and BIM's knowledge	4.17	7
		L8) Provide continuous training	4.00	8
		L9) Promote trust	3.67	9
		L10) Reward and recognition	2.83	10
	Team Organisation	T1) Responsive to solve a particular problem or any issues	4.50	1
		T2) Have skills and experience	4.17	2
		T3) Accountability in implementing BIM	4.17	2
		T4) Trust, open and inclusive involvement	4.00	4
		T5) Flat, circle or flexible structure	3.50	5
	Individual Attitude & Personality	I1) Positive mind-set and attitude	4.67	1
		I2) Willingness to learn with positive self-improvement	4.33	2

6.4.4.1 People Element

Under people element, all the practices and components that were developed from the case study research and literature review that formed a framework in this study were perceived "Highly Important" and "Important" by the participants in the validation interview (refer to Table 6.2), with the average index value above 3.50 except for component L10: Reward and recognition, with the average index of 2.83 and perceived as "Neutral". Although the reward and recognition are perceived as "Neutral", the researcher did not remove it from the framework. From the knowledge management perspective, this component is relevant as discussed in section 5.4.2 and this case study research demonstrated it as a part of all the organisations' KS practice, but more on non-monetary reward rather than monetary. Thus, all the components under People Element remained in the framework and listed according to their rank.

Under people element, leadership and management support practice, and ten components were validated as shown in Figure 6.2. Facilitate teamwork is at ranked first with average index 4.33 indicating that it is "Highly Important", while reward and recognition were ranked last with the smallest average index of 2.83. Five components as shown in Figure 6.2 with labels L2, L3, L4, L5, L6 share the average index value of 4.33, putting them second, which indicated "Highly Important." This component is followed by component L7: Ensure relevant awareness and education on benefits of KS and BIM knowledge, component L8: Provide continuous training and component L9: Promote trust with average index values of 4.17, 4.00 and 3.67 respectively. Components L8 and L9 were also indicated as "Highly important" as the value of the average index are the same and more than 4.00, whereas component L9 falls under "Important" level with average index 3.67.

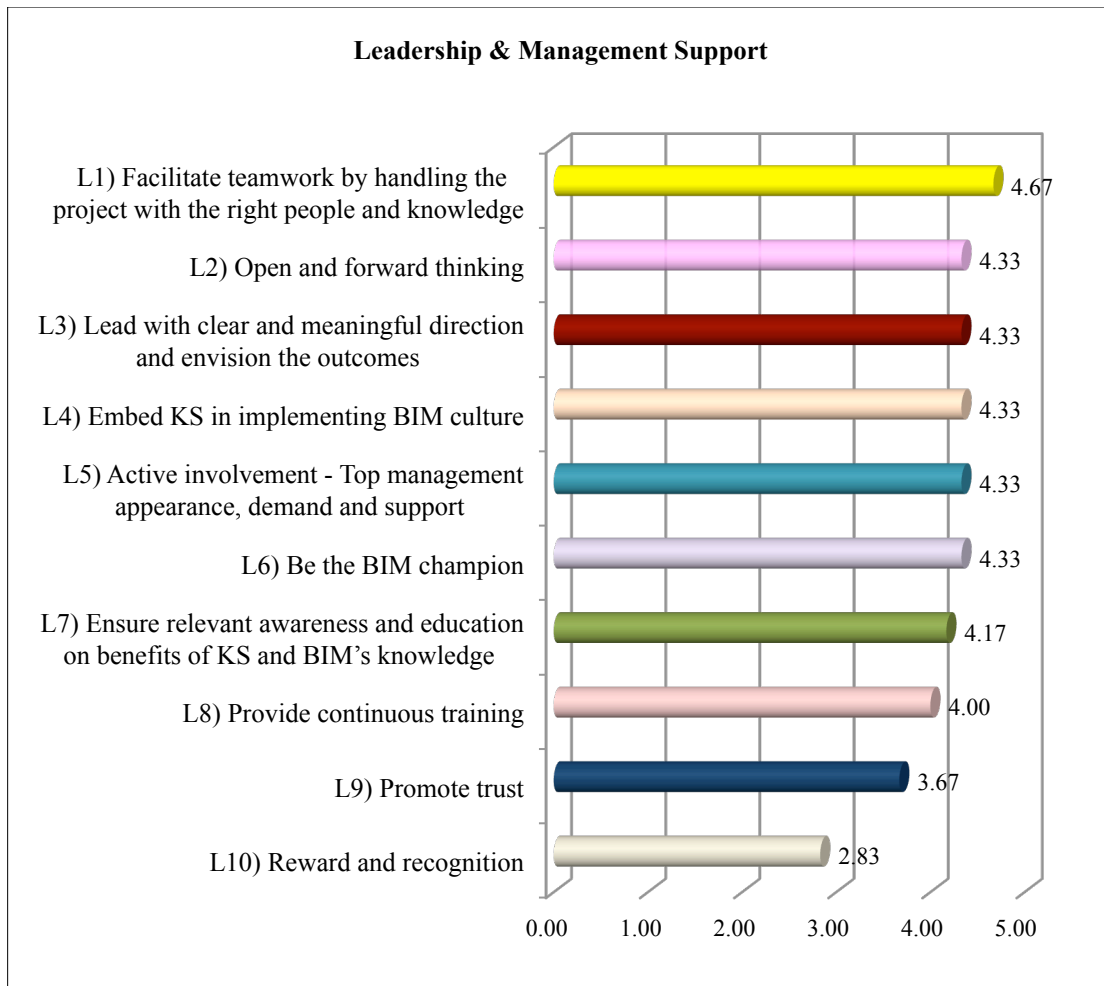


Figure 6.2: Components of leadership and management support practice with the rank

Under people element, team organisation practice, five components were validated as shown in Figure 6.3. Four components, T1, T2, T3, and T4 as shown in Figure 6.3 are perceived as "Highly Important" with average index values between 4.00 to 4.50. Through quasi-statistical analysis, Component T1: Responsive to solve a particular problem or any issues was ranked number one. This is followed by component T2: Have skills and experience, and component T3: Accountability in implementing BIM, with both at rank two and component T4: Trust, open and inclusive involvement at rank three. Ranked last is component T5: Flat, circle or flexible structure with average index 3.50, which indicates "Important" level.

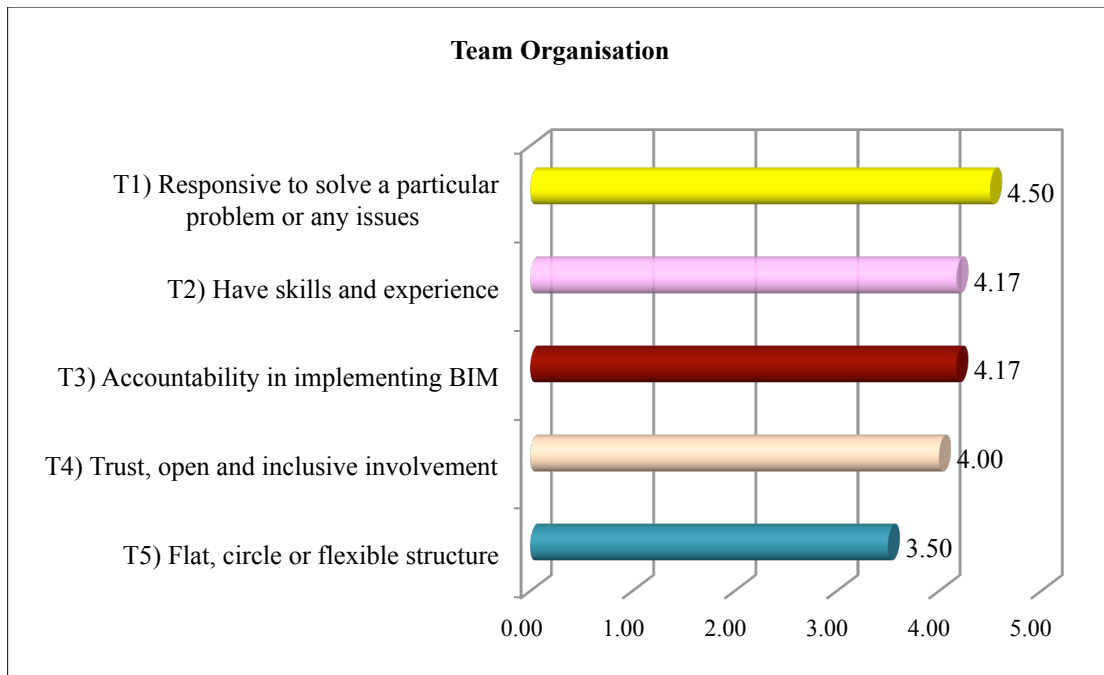


Figure 6.3: Components of team organisation practice with the rank

Under people element, individual attitude and personality practice, two components were validated as shown in Figure 6.4. Positive mind-set and attitude are at first rank with average index 4.67 while willingness to learn with positive self-improvement was second with the value of average index 4.33. Both components indicated that they are “Highly Important” components.

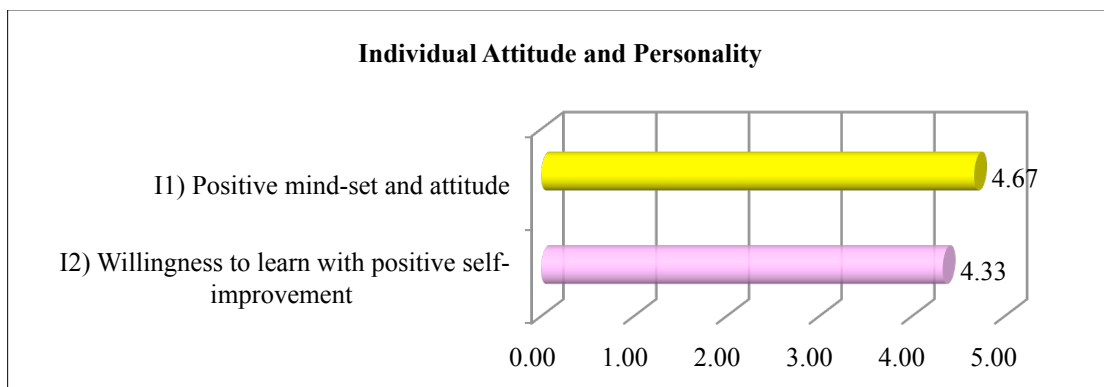


Figure 6.4: Components of individual attitude and personality practice with the rank

6.4.4.2 Process Element

Under process element, all the practices and components that were developed from the case study research and literature review that formed a framework in this study were perceived "Highly Important" by the participants in the validation interview, with the average index value above 3.50. All the components with their respective average index values are shown in Table 6.3. Due to all of the components being perceived as "Highly Important" in the process of knowledge sharing in implementing BIM, none are removed from the framework.

Table 6.3: Summary of the result for Process Element in the validation process

KEY FACTORS OF KNOWLEDGE SHARING IN IMPLEMENTING BIM			AVERAGE INDEX	RANKING
ELEMENT	PRACTICE	COMPONENTS		
PROCESS	Communication & collaboration	C1) Clear interaction	4.50	1
		C2) Coordinate, document and corroborate information	4.33	2
		C3) Proactive action	4.33	2
		C4) Natural trust relationship	4.17	4
	Policy	P1) Prepare communication platform	4.67	1
		P2) Sharing information format	4.50	2
		P3) Rules and government enforcement	4.50	2
		P4) Top-down enforcement	4.17	4
		P5) Work with the third party	3.83	5
	Operational	O1) Having knowledge on knowledge sharing and BIM implementation	4.50	1
		O2) Embracing change in the organisation	4.33	2
		O3) Good working condition and culture	4.00	3

Under process element, communication and collaboration practice, four components were validated as shown in Figure 6.5. The four components of C1: Clear interaction, C2: Coordinate, document and corroborate information, C3: Proactive action, and C4: Natural trust relationship are perceived as "Highly Important" with average index between 4.00 and 4.50. Component C1 topped the list with average index 4.50. Components C2 and C3 both shared second place with average index 4.33 and C4 ranked third with average index 4.17 in the survey.

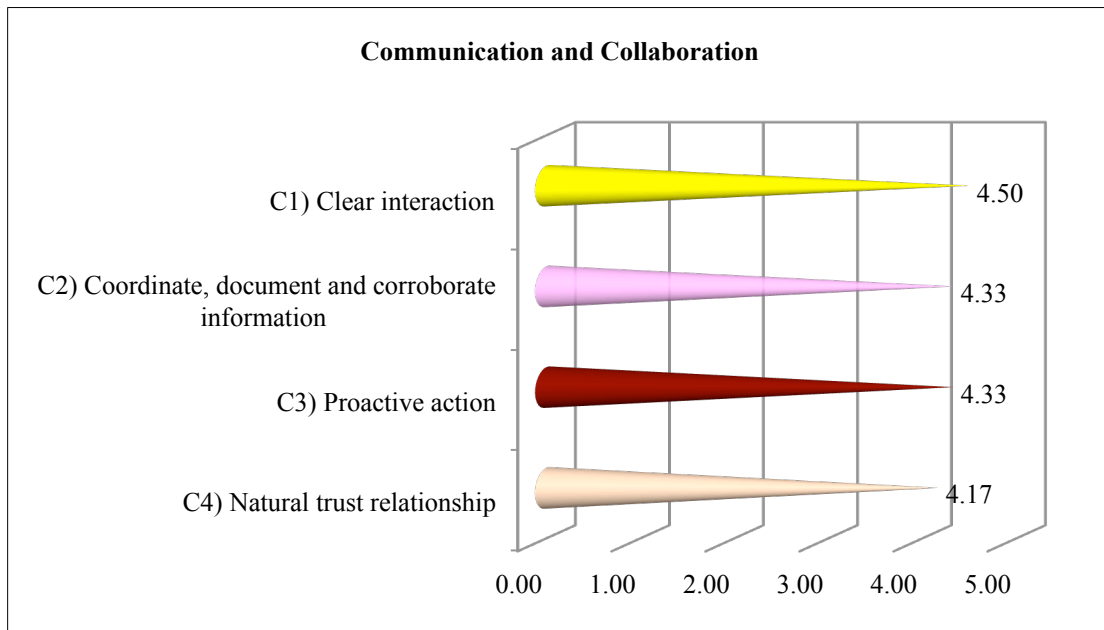


Figure 6.5: Components of communication and collaboration practice with the rank

Through quasi-statistical analysis, under process element and policy practice, five components were validated as shown in Figure 6.6 and all of them are perceived as "Highly important". Component P1: Prepare communication platform was ranked first with the highest average index 4.67. Followed by component P2: Sharing information format, and component P3: Rules and government enforcement, both at rank two with 4.50 average index. The following component T4: Top-down enforcement is ranked third with average index 4.17 and component T5: Work with the third party with average index 3.83 is ranked last.

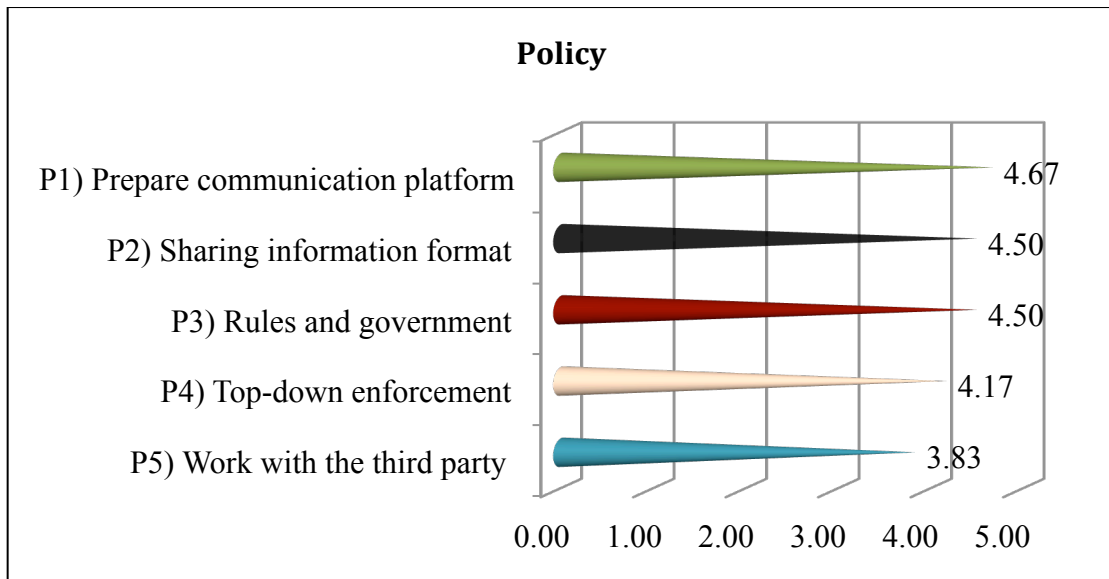


Figure 6.6: Components of policy practice with the rank

The same validation results appeared as “Highly important” for all the components under operational practice and process element and shown in Figure 6.7. Component O1: Having understanding of knowledge sharing and BIM implementation was ranked first with the highest average index 4.50 followed by component O2: Embracing change in the organisation with average index 4.33, and component O3: Good working condition and culture with average index 4.00.

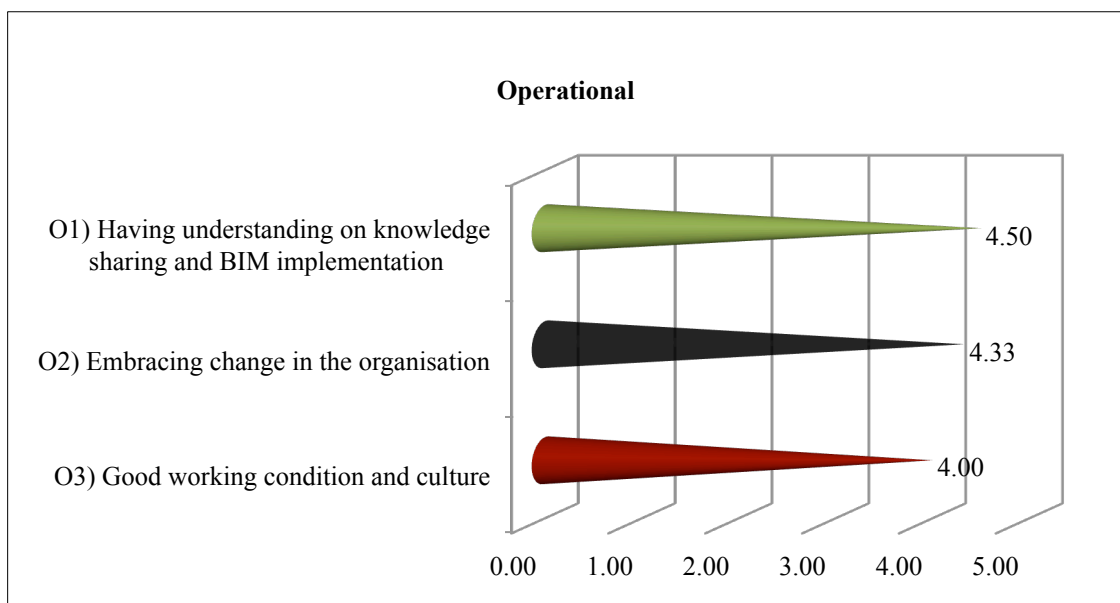


Figure 6.7: Components of operational practice with the rank

6.4.4.3 Technology Element

For the validation of the technology element, many agreed (PV2, PV3, PV4, and PV5) that component: prepare software and hardware under leadership and management support practice (People element) be moved to Technology element as mentioned earlier under validation of people element. Thus, the analysis was carried out after considering the Component A1: Prepare right software and hardware, to be part of the Technology element and the result is shown in Figure 6.8. Moreover, Participant PV4 who has BIM consultant background and is also in academia suggested that there is a need to include IT infrastructure and investment practices in Technology Element. He added "Good IT infrastructure such as strong and capable hardware must be available to facilitate the knowledge sharing in implementing BIM. You should check this with literature in the implementation of IS/IT". This opinion is in line with Alshawi (2007b), who mentioned one of the standard features of learning organisations that integrate organisation learning with knowledge sharing is through the creation of an organisational environment, which includes a conducive work environment, culture and IT infrastructure. Moreover, the success of IT investment cannot be realised if the industry does not fully understood the approach that could maximise the benefits mainly from the organisational factor, which encompasses people and process, enabling work environment, and the IT infrastructure (M Alshawi, Lou, Khosrowshahi, Underwood, & Goulding, J, 2010). Therefore, the IT infrastructure practice is included under Technology element, and A1: Prepare right software and hardware became its component, reflecting the comment by Participant PV4 as mentioned above.

Under Technology element, all the components were analysed together due to a limited number of components as shown in Figure 6.8. Only three components are created from the literature review, case studies and discussion through the validation process and lies above 4.00 average index, which implies a "Highly important" component. Component A1: Prepare right software and hardware was ranked one under IT infrastructure practice with perceived average index 4.67, which indicates "Highly important". Under Appropriate tools practice, Component A2: Integrated use of techniques: A Non-IT base for KS and technologies: IT base for KS was at number

two with average index 4.50, and followed by Component A3: Leverage on the existing technology at third ranking with 4.33 average index value.

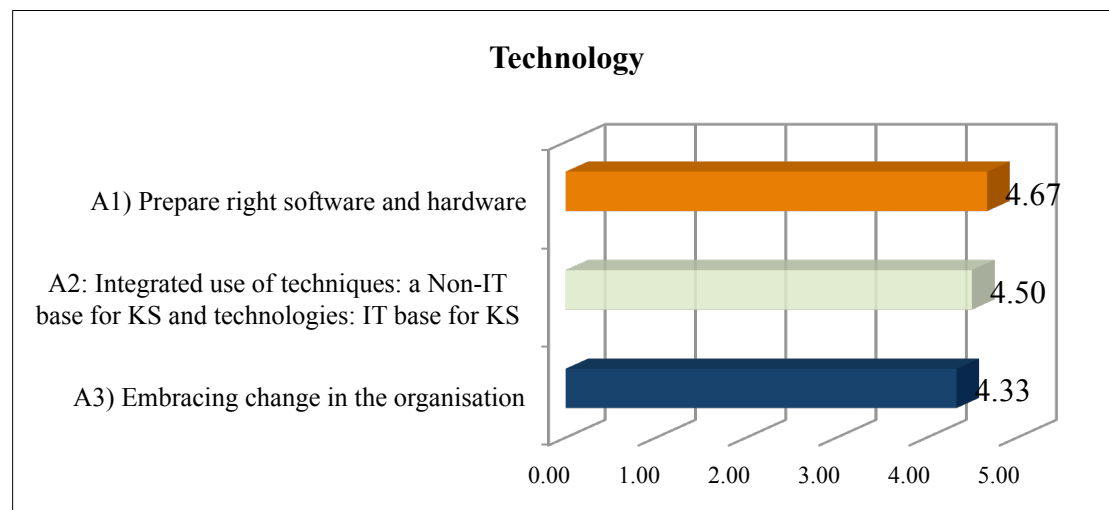


Figure 6.8: Components of IT Infrastructure and Appropriate Tools practice under Technology element with the rank

For component A2, some of the KS tools or approaches added by Participant PV6 are knowledge database for document references, practices and lessons learned. Furthermore, for knowledge dissemination, Participant PV6 suggested using database website links, seminars, and technology updates. Also, she included the need for knowledge support such as workshops and technical expert. This detailed suggestion of knowledge sharing tools or approaches, however, was counter checked by the case studies' finding and literature, which are included in Section 4.4.1 and Section 5.3. All of the KS tools or approaches suggested were also evident in the case studies except a technical expert. Participant PV6 highlighted that "Technical expert is needed for the subject matter regarding knowledge related to BIM tools. Sometimes we need technical advice to overcome or solve the problem when comes to a technical problem in using BIM software". This suggestion was supported by Participant PV3 who posited that "Regular BIM activities such as workshops on the life project will enhance knowledge sharing, but sometimes we still need to refer for detail explanation from a technical expert like software supplier if the problem is highly technical matters". For this reason, the technical expert is included as a sub-component under component A2 and added in Table 5.2 under Section 5.3. One of the participants also added that informal knowledge sharing such as "BIM over coffee",

which represents an informal talk or discussion among colleagues might foster a knowledge sharing culture. This suggestion was also counter checked by case studies' finding and literature, which are included in Section 4.4.1 and Section 5.3. Also, this is evident in the case studies quote under informal way for everybody in the organisation to stay connected.

6.4.4 Discussion of the Usage of the Framework

In the fourth question, the participants were asked "Do you think the framework in its current design will help in enhancing the current practice of KS in implementing BIM in construction organisations? How?" This question was to examine to what extent the developed framework would help the construction organisations to improve the knowledge sharing practice in implementing BIM. All of them agreed that the framework is useful to the practitioner particularly to the construction organisation that wants to adopt or implement BIM. One of them said "It is beneficial to the practitioner, especially BIM practitioner. This framework could help them to enhance knowledge, and boost industry implementation". Another participant acknowledged that "Yes, the framework would improve knowledge sharing practices because it gathers the key strategies to KS practices in BIM implementation". This view also strengthens the usefulness of the framework when three of the participants agreed that the framework is more practical and realistic to the actual implementation rather than a complex framework (PV1, PV2, PV3, and PV4). Participant PV3 further elaborates that, "I like to follow simple guidelines or framework, it is easier to understand, and importantly, it is realistic in a real situation".

6.4.5 Discussion of the Improvement for the Framework

The fifth question asked "Do you have any suggestions to improve the framework?" to seek feedback for improving the framework. Many have said that the enhancement is regarding their comments as in questions one to four. Interestingly, the last participant suggested to enhance the framework in the future by showing the correlation between each of the key elements and each component in detail to

maximise the effectiveness of the KS framework in an organisation. Nevertheless, this research did not attempt to study the correlation of each component. Thus, it did not test any relationship individually.

The framework developed needed to be used by considering those three elements together, which are interrelated in nature. For instance, to support knowledge sharing in implementing BIM, the leader must ensure teamwork in handling the project with the right people and knowledge level (People: Leadership and management support). This practice should be done by promoting clear interaction within individuals or team members (Process: Communication and collaboration) and facilitating the appropriate KS tools (Technology: Non-IT technique and IT technologies) such as BIM guide or procedure to ease operations.

6.5 Refinement of Framework

Concerning the comments and suggestions provided by the respondents, the required amendments to the draft framework for KS practices in implementing BIM, which encapsulates the key factors of KS practices, are listed as follows:

- a) Modifying the structure or arrow used for the actors and knowledge flow;
- b) Describing all of the structures briefly to guide the use of framework;
- c) Rank all the components according to the “quasi-statistical analysis” result.
- d) Removed component prepare hardware and software from People element: Leadership and Management support practice, to Technology element, under IT infrastructure practice;
- e) Add in IT infrastructure practice under Technology element; and
- f) Show the correlation for all the components.

The researcher met the requirements of recommendations a) to e), providing all of them all in the framework (see Figure 6.9), and in response to recommendation f), the future research was addressed in Chapter 7.

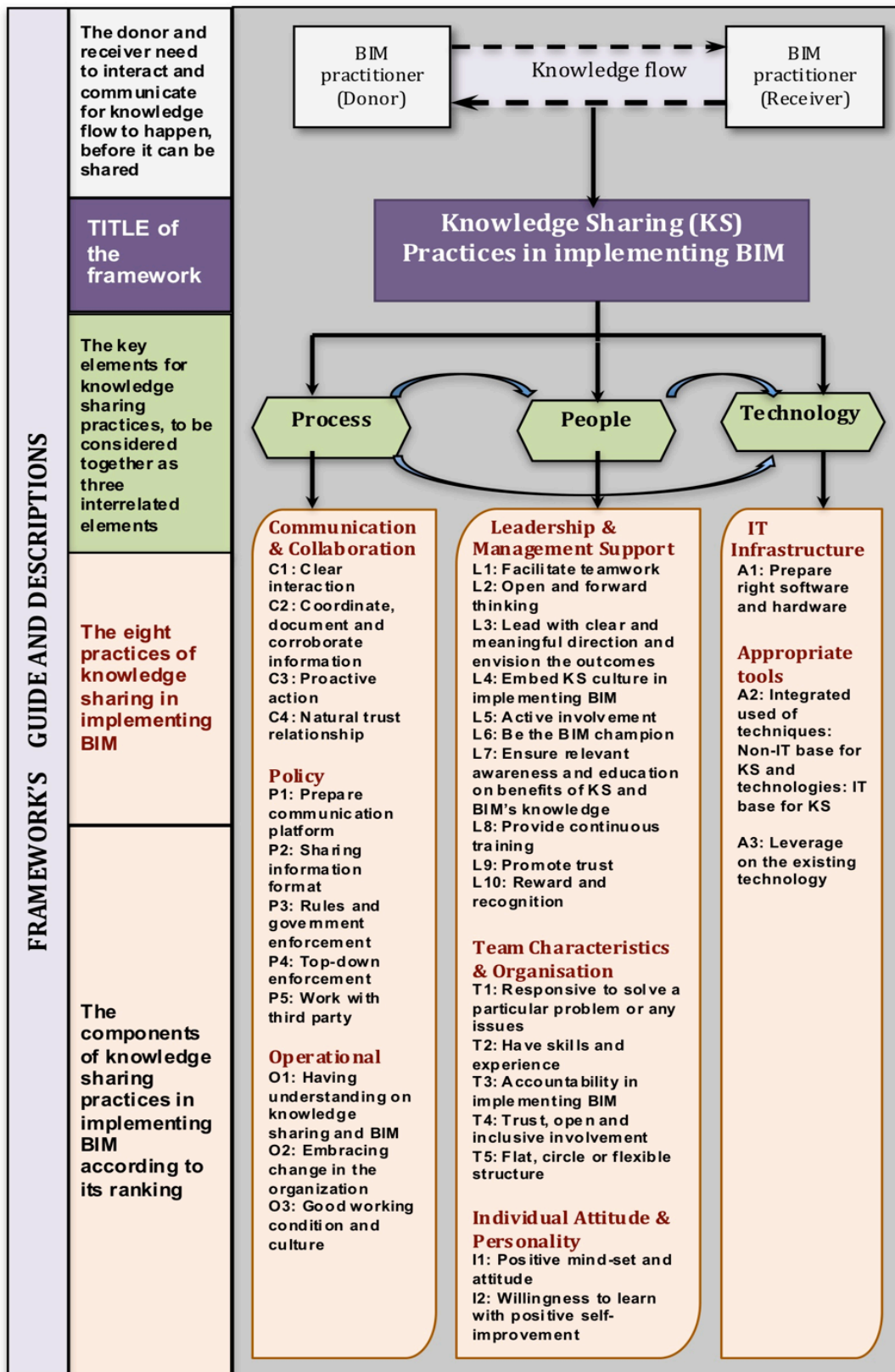


Figure 6.9: A Final framework of Intra-Organisational Knowledge Sharing Practices in implementing BIM

6.6 Final Framework and Its Usage

All of the knowledge sharing elements, practices and components found in the case study research for each respective organisation were gathered, cross-analysed, discussed and theoretically validated in the previous chapter. As a result, a final framework of organisational knowledge sharing practices in implementing BIM is then proposed.

The final framework consists of three key elements, which are Process, People, and Technology, with eight practices and 32 components of knowledge sharing practices in implementing BIM at the organisational level. Referring to Figure 6.9, any construction organisation that intends to venture into BIM and would like to use the knowledge sharing practices framework to improve the BIM process may begin from the top of the framework and refer to the following steps:

- 1) An organisation will need a donor and a receiver to communicate the knowledge in implementing BIM and allow the sharing process to happen;
- 2) An organisation may **select any of the three key elements** either people, process or technology, for instance, the organisation chooses People as the key element;
- 3) Followed by **choosing the eight practices of knowledge sharing under each key element selected**, for example, the organisation needs to select Leadership and Management Support as the practices that need to be developed;
- 4) It then needs to **follow the components of knowledge sharing needed under the practices**, for example, from L1: Facilitate teamwork until L10: Reward and Recognition.

Each of the components describes the knowledge sharing practices in implementing BIM requirement that the organisation needs to develop their capability. The framework is generic in nature, which allows the users to determine the capability of their organisation by comparing each of the knowledge sharing component with their current state of knowledge sharing practices in implementing BIM. If the organisation

meets or fulfils the knowledge sharing component requirement, the status could be said to match or satisfies the requirement for that particular component. The methods used to determine the organisational status are qualitative in nature permitting evaluation using interviews, observations, document review etc. Thus, the more experienced the evaluation person or team in the organisation is the better and more accurate the result will be. The evaluation person or team should come from people who understand the business of the organisation and the nature of BIM implementation. The former requires internal people who understand the overall functions of the business from the management and operational perspectives. The latter could be achieved either by engaging internal people or independent consultants who are competent in BIM implementation. Thus, the evaluation person or team should comprise the middle and/or top management. The result of the knowledge sharing practices evaluation would outline the gap between the current states of the organisation as compared to the knowledge sharing practices in implementing BIM requirement according to the knowledge sharing practices component. Based on the result, the evaluation person or team can then prioritise their development program of knowledge sharing practices in implementing BIM to suit and improve the needs of the organisation.

6.7 Chapter Summary

This chapter highlighted further validation of the criteria within the conceptual framework by the industry and academia via telephone interview. In the validation process, each component of knowledge sharing was validated and perceived as "Highly Important" and "Important" except reward and recognition which is perceived as "Neutral", however, this component is relevant as discussed in section 5.4.2.5 and this case study research showed it as part of all the organisations' KS practice, but more on non-monetary reward rather than monetary. Thus, the component remains in the framework. Additionally, one practice (Technology: IT infrastructure) was also introduced based on the data collected during the interview session. The final framework was then developed by taking into consideration the comments in the validation process, and presented in this chapter. The framework consists of three key elements, which are Process, People, and Technology, with eight

practices and 32 components. The refinement of the framework especially its components was regarded as critical for the use of the organisation to apply knowledge sharing in implementing BIM, thus guiding them in improving the pace of adoption or implementation. The next chapter provides the conclusions of this research and discusses them according to the original aims and objectives of the study. It also outlines some recommendations for both industry and the research community, with respect to the research findings within this thesis. Some ideas for future research will also be highlighted.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This research aimed to develop a framework of intra-organisational knowledge sharing practices in implementing BIM, which encompasses the key factors of knowledge sharing within the Malaysian construction industry. This chapter addresses the main findings of this research and summarises the aim and objectives. In order to achieve the aim of this research, this research reviewed information related to knowledge sharing practices and BIM implementation within the construction organisations which practice BIM. The primary qualitative data collected from multi-case studies were merged with the findings from the literature review (secondary data) in order to ensure that it is more comprehensive, up-to-date and appropriate for the precise needs particularly for developing a process of knowledge sharing practices in implementing BIM framework within the Malaysian construction organisations. Furthermore, the main conclusions drawn from the results of the analysis of the semi-structured interviews and document reviews, as well as the recommendations, are presented. The limitations of the research are highlighted and the contributions to research are presented. Finally, this chapter concludes with the recommendations for further research.

7.2 Achievement of Research Objectives

The research objectives were developed in Section 1.4 of Chapter 1 to determine the aims of the research. Altogether there were six research objectives that were achieved through literature review, semi-structured interviews, documents' review and survey. This section provides a brief summary of the key findings from the research while reviewing how well the aim and objectives have been achieved.

a) Research Aim

To develop a framework of intra-organisational knowledge sharing practices in implementing BIM within the Malaysian construction industry. The framework was developed, detailed in section 5.4.1 and section 6.5, through the analysis of the qualitative data collected and the refinement of the framework from 'quasi-statistical analysis' and peer interviews. The framework provides a set of useful guide and practical actions that can help construction organisations practice knowledge sharing in implementing BIM to improve the adoption or implementation of BIM.

b) Research Objectives

The main conclusions drawn from the research study are presented based on the following objectives as highlighted in Chapter 1 (Section 1.4).

1) Objective 1: To explore and review relevant literature related to the challenges in the local context (Malaysia) construction industry, the needs towards change; innovation, knowledge-based economy and the use of ICT. Also, to review and examine relevant literature related to knowledge management concepts in general and particularly knowledge sharing. To further explore and review BIM concepts, uses, benefits, and challenges.

This was addressed through an in-depth review of existing literature on the challenges in the Malaysian construction industry and Malaysian Government initiatives towards becoming a knowledge-economy country as well as adopting new construction

methods (ICT) to improve performance. The theoretical concept of knowledge and knowledge management was reviewed in Chapter 2. It describes tacit and explicit knowledge sharing and concludes by identifying the various key factors for knowledge sharing practices. It explores knowledge management processes, the concept of knowledge sharing and knowledge sharing frameworks. The findings from the literature review identified knowledge sharing and the effect it has on performance and organisational growth. The effective use of knowledge sharing in businesses and improved collaboration amongst employees has been highlighted as the key to organisational success and a contribution towards the theory of knowledge management. The review of literature also highlighted knowledge sharing key factors from different study contexts. Some of the key factors revealed in the literature review findings are; leadership and management support, communication, trust, working environment and personal and team development. The findings from the review of literature show that knowledge sharing is context specific as detailed in Chapter 2. Thus, each factor is dependent on the context, whereby one factor maybe the key factor of the study but a challenge in another context.

The literature highlighted the growing importance of knowledge sharing for construction organisations and the increasing needs of BIM implementation for improved construction performance, detailed in Chapter 2. The literature review provided a foundation for understanding the need for BIM implementation, the important role of knowledge sharing and the benefits they provide to improve BIM adoption or implementation in construction organisations, which is the context of the research (see Chapter 2). While BIM implementation have been seen as an effective way of improving construction efficiency, the findings from the literature indicate that BIM implementation in Malaysia are progressing but still at a low level and often needs a coordinated guidance. In particular, there is a lack of knowledge and information sharing between employees in construction organisations that implement BIM, which lessen the adoption or implementation.

2) Objective 2: To explore the current implementation of BIM within the business process by the construction organisations in Malaysia.

As discussed in Chapter 4, the qualitative evidence revealed the individual level of BIM implementation by each organisation and discussed the comparison between those organisations. Among all organisations, it is considered that Organisation A has a comprehensive BIM implementation within their business process. It is proven by the organisation's BIM standard operating procedure which consisted of thirteen documented guide. The presence of BIM implementation also incorporates a higher level of detail for the 3D models, progressively from LOD100 – LOD500 from concept drawings up to coordinated construction drawings with a structured flow of inter-disciplinary model coordination. It is probably fair to say that some organisations with BIM consultant's backgrounds implement BIM depending on client's request and project stage, thus involving different levels although each of it is capable of performing up to LOD500. Most of the cases are using BIM up to the level of detail/development LOD 500. It showed that the organisations were able to develop the model by utilising five progressively detailed level of completeness in implementing BIM.

The interviews reveal that the implementation of BIM varies from educating the parties to participate, building a model, collaborating on the models and inter-disciplinary coordination. In regard to the organisational structure, it is reasonable to say that all cases have new position titles such as BIM manager, BIM coordinator and BIM modeller. However, the titles are created by some cases within its existing structure and some developed such positions under a new specific BIM Unit to establish the BIM implementation within each organisation.

3) Objective 3: To ascertain the current status, practices, policies of knowledge sharing, and organisational culture in implementing BIM in Malaysia.

The practices, policies and organisational culture in implementing BIM have been highlighted in detail in Chapter 4, Chapter 5 and Chapter 6. The organisational practices, policies and culture of knowledge sharing have been discussed and considered people, process, and technology element. According to the findings from the case studies and peer interviews, eight practices (three under people, three under process and two under technology) and 32 components were identified as crucial for KS in implementing BIM. Some of the key factors revealed in the literature review findings are leadership and management support, team characteristics and organisation, individual attitude and personality, communication and collaboration, policy, operational, IT infrastructure and appropriate tools. The findings from the review of literature show that knowledge sharing is context specific as detailed in chapter 2. Hence, each factor is dependent on the context of the study. The findings conclude that what is regarded as a factor in one scenario may arguably be seen as a challenge in another scenario. For instance, whilst the participants in this study have identified leadership and management support, team characteristics and organisation, individual attitude and personality, communication and collaboration, policy, operational, IT infrastructure and appropriate tools to be the key factors for effective knowledge sharing in implementing BIM in the context of construction organisations, these factors might be a challenge in another context such as in an education institution.

Regarding technology, KM tools or approaches used to facilitate KS in implementing BIM was balanced between the application of KM technologies and KM techniques, which indicates the equal importance of both tools in supporting KS in implementing BIM as summarised from the case studies findings and validation and shown in Table 7.1.

Table 7.1: Case Studies' findings on Knowledge Management tools to support KS in implementing BIM

KS technologies (IT tools)	Integrated use of KS technologies & techniques (with the used of BIM tools)	KS techniques (Non-IT tools)
Knowledge base: Companies website, iClouds, Clouds & Dropboxes	Workshops	Documentation: Protocol, Standard, BIM Forum, support reports, ISO documents, reported issues
Intranet/ Extranet: Project Portal	Demonstration	Face-to-face regular meeting
Electronic mail	Via work station discussion	Face-to-face interaction
Groupware: Forum discussion	In-house training	Road-show
Communities of Practice: J-CoP, J-Pedia, Facebook	External training	Apprenticeship
Search Engines: Google, Yahoo	Technical support	Informal way: Gather and share, 'talk over coffee'
Instant Messaging: Instant Messenger, Whatsapp		Involves in Seminars, Conferences as participant or speaker or sponsor.

4) Objective 4: To identify the factors which are perceived to be barriers and enabling factors to improve knowledge sharing in implementing BIM in Malaysia.

The barriers and the enabling factors to improve knowledge sharing in implementing BIM has been highlighted in detail in Chapter 4. The findings suggest that construction organisations need to identify and understand the factors facilitating and inhibiting knowledge sharing on BIM implementation, and to promote knowledge sharing with the ultimate purpose of achieving performance improvement. The results from the research indicate five inhibiting factors to knowledge sharing in implementing BIM. The main challenges include internal process, fear of change and cost for sharing knowledge between individual and team in the organisation. The finding from case studies suggested to improve the knowledge sharing practices through the elimination of BIM misconceptions, offering an open environment, strong management support, embracing change, providing appropriate training, working with an external party, emphasising the importance of information and leveraging the existing technology.

5) Objective 5: To develop a framework of intra-organisational knowledge sharing for an effective implementation of BIM, which encompasses the key factors of knowledge sharing by utilising the emerging findings in objective 3 and objective 4 and then to cross-reference the findings with the literature review.

The preliminary framework of recommendations in the form of guidelines developed for knowledge sharing practices in implementing BIM within the Malaysian construction organisations was highlighted in Chapter 5. According to the findings from the case studies and literature review, seven practices (three under people, three under process and two under technology) and 32 components were identified as crucial for KS in implementing BIM. It highlights the need for organisations to focus their efforts on seven key practices; Leadership and management support, Team characteristics and organisation, Individual attitudes and personality, Communication and collaboration, Policy, Operational and Appropriate tools. These seven key practices rely on the combination of People, Process and Technology elements.

6) Objective 6: To validate and refine the framework of knowledge sharing in implementing BIM.

The discussion on framework refinement has been highlighted in Chapter 6. The study offers a holistic way to examine the knowledge sharing practices by developing a framework, which mainly focused on the key factors of knowledge sharing; this study used a systematic methodology that incorporated semi-structured interview and “quasi-questionnaire survey analysis to produce a framework with a set of factors on KS practices for effectively implementing BIM at the organisational level. The framework outlines three elements (people, process, and technology), which consist of eight practices and 32 KS components according to its ranking which is crucial for KS in implementing BIM. Each of the practices describes the KS requirement that the organisation needs to develop to allow the success of knowledge sharing in implementing BIM. It highlights the need for organisations to focus their efforts on eight key practices; Leadership and management support, Team characteristics and

organisation, Individual attitudes and personality, Communication and collaboration, Policy, Operational, IT infrastructure and Appropriate tools.

7.3 Research Contribution

The research objectives have been rigorously explored and all research questions satisfactorily resolved. The challenges to the Malaysian construction industry were explored, as discussed in Chapter 2. Following this, the growing importance of KS in construction organisations and the increasing needs and expectations of BIM implementation for an improved construction industry are not matched by empirical research on knowledge sharing for organisational improvements in this area. Hence, there is an absence of research in this area. This research extended the range of existing theories relating to knowledge sharing and BIM implementation issues by compiling the key factors for knowledge sharing in implementing BIM for organisational improvement in Malaysia. This research contributes to a greater understanding of KS practices in implementing BIM within the construction organisations in supporting BIM adoption and implementation specifically in Malaysia. It will also help to fill the gaps that exist in our understanding of the complex ways in which knowledge sharing affects effective BIM implementation.

No framework exists which is drawn from empirical research study findings on the key factors of knowledge sharing practices for improved BIM implementation in construction organisations. In developing the key factors of knowledge sharing practices in implementing BIM, a qualitative approach through case studies for data collection and peer interviews for framework validation were conducted, which have provided information-rich data on the industrial perspectives which are theoretically validated by literature. The case report prepared in this research could help the industry to understand the knowledge sharing practices in implementing BIM issue within the context of Malaysia and provide a lesson learnt document. The framework developed in this research could be used as an industrial training program in improving the decision making for improving BIM implementation and thus help to increase the uptake.

Consequently, the outcome of this study adds to the body of knowledge in the area of knowledge sharing in the construction industry. It will provide a better understanding of the factors that affect the successful sharing of knowledge practices by the construction organisations in implementing BIM in the Malaysian construction industry. The context however, is limited to Malaysian construction organisations. Finally, this research has proposed a framework that encapsulates the key factors of KS practices in implementing BIM necessary for the construction organisations. This is in line with the research aim of developing a framework, which will serve as a guidance tool for construction organisations and BIM practitioners. This framework has added a new insight through which organisations involved in the BIM implementation can understand the key factors of KS practices for improving BIM implementation between employees or team members engaged in the construction organisations. In addition, highlighting the critical factors which underpin the framework will help BIM practitioners to manage their own organisations' KS practices in implementing BIM without having to learn lessons the hard way. The research will add to existing knowledge on BIM by mapping issues surrounding BIM implementation from the perspective of the construction organisation. This will also assist the organisations and the policy makers, especially the government, in identifying the future direction of BIM, ICT implementation, knowledge sharing and policy in Malaysia.

7.4 Research Limitation

Although the research achieved its aim and all research questions were sufficiently met, there were some limitations. In the course of conducting this research, the following hurdles were encountered:

- a) There were problems in finding appropriate literature information relevant to the study area, as only limited amount of work was available on organisations' BIM implementation and knowledge sharing practices particularly in Malaysia. However, this research has made a contribution to the small body of knowledge that is already available.

- b) The number of selected case studies was restricted to only six organisations although thirteen organisations were initially identified. A low level of willingness to share and cooperate reduced the number to six. To further increase the generalisability, future research should repeat the methodology with larger samples to include participants from the Malaysian construction industry.
- c) The shortage of BIM experts and a limited number of cases knowledgeable in BIM implementation was a fundamental limitation since the components of knowledge sharing practice was based on the experience of just a few experts and may not be seen as general to the wider population of the construction organisation.
- d) Also, this study focused on identifying the key factors for knowledge sharing practices pertinent to the BIM implementation within a construction organisation context; but other determinants of knowledge sharing not covered by this study may be important to other organisations. The findings of this study may not be applicable to other organisations and should not be adopted without a detailed critical analysis. Future research should replicate the methodology used in the study to identify additional KS factors in the context of the study.

7.5 Recommendations

This section proposes related areas of research where additional inquiries could further enhance the value of this research. The many issues and problems encountered throughout the course of this research have inspired several recommendations for future work to extend the boundaries of knowledge sharing in implementing BIM knowledge. These recommendations are as follows:

- a) Investigating further the impact of social media that encourage knowledge sharing, and exploring the disadvantages of knowledge sharing in implementing BIM.
- b) Investigating the relationship between each element, practices and components of knowledge sharing in implementing BIM.

- c) To further increase the generalisability, future research should repeat the methodology with larger samples to include participants from the Malaysian construction industry. A quantitative survey could probably be used to validate each component for a wider sample of population.
- d) Future research should replicate the methodology used in the study to identify additional knowledge sharing factors in the context of different or other studies.
- e) Finally, further research is required to test the application of the framework with construction stakeholders involved in BIM implementation within the context of construction organisations.

7.6 Chapter Summary

This chapter presented the conclusion and recommendations of the research findings. It highlighted the purpose for the research and reviewed the research objectives. Lastly, recommendations were offered for construction organisations and BIM practitioners for further research.

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RELATED PUBLICATIONS

Musa, S., Marshall-Ponting, A., Abdul Nifa, F.A (2018). Building Information Modelling (BIM) in Malaysian Construction Industry: Benefits and Future Challenges. AIP Conference Proceeding: 3rd International Conference on Applied Science & Technology, 10-12 April 2018, Penang, Malaysia.

Musa, S., Marshall-Ponting, A., Shahron, S.A. (2018). Building Information Modelling (BIM) Benefits and Challenges: Malaysian Construction Organization Experience, *Journal of Telecommunication, Electronic & Computer Engineering (JTEC)*. (Accepted)

APPENDIX 1: Research Ethics Application Submission



College Ethics Panel Ethical Approval Form for Post-Graduate Researchers

Ethical approval must be obtained by all postgraduate research students (PGR) prior to starting research with human subjects, animals or human tissue.

A PGR is defined as anyone undertaking a Research rather than a Taught masters degree, and includes for example MSc by Research, MRes by Research, MPhil and PhD. The student must discuss the content of the form with their dissertation supervisor who will advise them about revisions. A final copy of the summary will then be agreed and the student and supervisor will 'sign it off'.

The signed Ethical Approval Form and application checklist must be forwarded to your College Support Office and also an electronic copy MUST be e-mailed to the contacts below at your College Support Office;

CASS: Deborah Woodman – d.woodman@salford.ac.uk

CST: Nathalie Audren-Howarth – n.audren@salford.ac.uk

For applications to the **College of Health and Social Care**, please follow the process mentioned at <http://www.salford.ac.uk/chsc/research/staff-pgr-students-research-ethics>

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<http://www.pg.salford.ac.uk/page/forms>

The forms are processed online therefore without the electronic version, the application cannot progress. Please note that the form must be signed by **both the student and supervisor.**

Please ensure that the electronic version of this form only contains your name and your supervisor's name on this page, where it has been requested.

All other references to you or anyone else involved in the project must be removed from the electronic version as the form has to be anonymised before the panel considers it.

Where you have removed your name, you can replace with a suitable marker such as [.....] Or [Xyz], [Yyz] and so on for other names you have removed too.

You should retain names and contact details on the hardcopies as these will be kept in a separate file for potential audit purposes.

Please refer to the 'Notes for Guidance' if there is doubt whether ethical approval is required

The form can be completed electronically; the sections can be expanded to the size required.

Name of Student: abc

Name of Supervisor: xyz

School: School of Built Environment

Course of study: PhD Construction Management

Name of Research Council or other funding organisation (if applicable):

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1a. Title of proposed research project

Knowledge and information sharing practices in implementing BIM within the Malaysian construction industry.

1b. Is this Project Purely literature based?

NO

2. Project focus

The study aims to develop a framework of good practice organisational knowledge and information sharing in implementing BIM within the Malaysian construction industry.

3. Project objectives

1. To investigate and review relevant literature related to the change agenda within construction, innovation and the use of BIM, knowledge management concept in general and particularly knowledge sharing, knowledge sharing channels, it's benefits for construction innovation and specific focus to knowledge sharing in implementing BIM.
2. To ascertain the current status, practices, policies of knowledge and information sharing, and organisational culture in implementing BIM.
3. To identify the factors which are perceived to be barriers and enabling factors to improve knowledge and information sharing in implementing BIM.
4. To develop a good practice organizational knowledge and information sharing framework for the effective implementing BIM by utilising the emerging findings in objective 3 and to cross reference the finding with the literature review.

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5. To validate and refine the framework of knowledge sharing.
6. To consider the use of conceptual framework in objective 5 in BIM practice.

4. Research strategy

(For example, outline of research methodology, what information/data collection strategies will you use, where will you recruit participants and what approach you intend to take to the analysis of information / data generated)

Research methodology refers to the principles and procedures of logical thought processes which are applied to a scientific investigation (Fellows & Liu, 2008). The aim of this research is to develop a framework of good practice organisational knowledge and information sharing in implementing BIM within the Malaysian construction industry. Accordingly, this study will investigate the current knowledge sharing practices, policies of knowledge/ information sharing, and organisational culture in implementing BIM in the Malaysian construction industry. After considering the nature of the research problem, this research will lead towards interpretivism paradigm. The data in this study leads toward qualitative (subjective) rather than quantitative (objective) analysis. By this means the research is associated with qualitative research and will not involve any testing of a theory or hypothesis which is related to quantitative research. Consequently, an inductive approach which is aligned with a qualitative research method will be used as the research approach.

Case study research is a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information such as; observations, interviews, audio visual material, and documents, and reports a case description and case-based themes (Creswell, 2009). The qualitative methods (multiple case studies) will be employed as a research strategy to gain the insights of the parties involved in BIM implementation.

For the purpose of this research, primary data will be collected via interviews, and document reviews. Literature review is also critical in providing the sound basis of the inquiry, and will be conducted through the course of research. There are three

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common types of interviews; the semi structured interviews, the focused interviews and the formal survey. Overall, interviews are an essential source of case study evidence because most case studies are about human affairs. These human affairs should be reported and interpreted through the eyes of specific interviewees, and well informed respondents can provide important insights into a situation (Yin, 2009). The semi-structured interviews will be used in this research, as it gives the respondents the opportunity to relate to the research matter in their own opinion and insights, which in return may yield enriched information for the researcher. Furthermore, the use of semi-structured interviews will give the researcher the opportunity to retrieve detailed information of the current knowledge sharing practices in implementing BIM.

Due to the fact that this study is being conducted in an attempt to grant the researcher a PhD degree, it was important to take an approach that allows the researcher to conduct the study within the usual PhD timeframe; therefore, a multi case study is relevant. The researcher aims to choose a context that is both accessible to the researcher and rich in data. As a result, 6 private and 2 public sector construction organisations in Malaysia are the target sample.

In terms of data analysis, the data obtained in this research will be analysed using content analysis approach. All semi-structured interview conducted will be recorded and transcribed. The content analysis approach will be applied with the aid of a coding scheme to distinguish different categories of thinking among the respondents. At this point, the NVivo software will be used to assist in analysing the interview data.

5. What is the rationale which led to this project?

(For example, previous work – give references where appropriate. Any seminal works must be cited)

Innovation is important for organisational performance in the construction industry. Innovation involves a wide scope whether new or there are some improvements, and

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can be found in many forms related to new products, new processes, new materials, new methods, and new markets (Yusof, Mustafa Kamal, Kong-Seng, & Iranmanesh, 2014). A paradigm shift is seen as necessary for the construction industry to fully benefit innovation. Heightening challenges of sustainability, fragmentation, inefficiency in the construction industry, innovation stands to improve integration efforts, design, facility performance, project management, sustainability, and legal agreements for construction project delivery (Dubois & Gadde, 2002; Rigby, McCoy, & Garvin, 2012). Various integration practices and management tools are introduced and used such as value management, constructability, benchmarking, reengineering, partnering and total quality management (McGeorge & Palmer, 1997), lean production, concurrent engineering (Mohamed, 2003) to fully benefit the industry including support and commitment from the top management, workforce and stakeholders integration.

Besides many best practices aforementioned, Mokhtar and Bedard (1995) stressed that these approaches were insufficient without the support of IT when dealt with the complexity of construction projects. Furthermore, the efficiency and productivity of the industry can be improved by sharing of information and knowledge when using IT (Mastura Jaafar, Ramayah, Abdul-Aziz, & Saad, 2007). According to study conducted in UK construction industry by Goulding & Lou (2013), the industry does recognise the result of becoming ICT ready was more driven by the engagement of leadership which aligns change management issues to business processes and strategic vision rather than technology. However, they highlighted that industry has recognised the importance of using ICT tools to help the industry shape the transition. Research by Mukelas & Zawawi (2012) also supported that it is worthwhile to both construction projects and construction organisation to invest in ICT, in delivering the project since they encourage effective activities project. As Building Information Modelling (BIM) is one of the IT technology, Li et al. (2014) further supported that productivity is increased where BIM is used to allow easy sharing and high integration of information and convenient collaboration. Thus, Building Information Modelling (BIM) is seen as an emerging technology that enables integration to overcome the fragmentation problems that long have been existed in global construction industry. Besides, Building Information Modeling

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(BIM) can be considered as one of the technological innovation that getting attention from around the world. It is believed that BIM is the future, which in every country, more than 90% of industry stakeholders expect to be using BIM within three years (RIBA, 2014). The impact and study on such technology can contribute to the new knowledge of related country, industry as well as organisation for continuous improvement.

Meanwhile, from a technical innovation standpoint, knowledge sharing and practical application is the essence of technological capability development (Gilbert & Cordey-Hayes, 1996) to start the dissemination process (Larsen & Ballal, 2005; Sexton & Barrett, 2004), to prevent knowledge loss and lessons learnt, also to increase operational efficiencies (Leonard, D., 2007). Thus, in implementing new technology such as BIM, it is crucial that participants need to communicate, transfer and share their knowledge in order to improve an organisation's knowledge base, knowledge acquisition, succeeding to further learning and enhance organisation's capability for new technology towards improving organisation's performance in construction. By practicing knowledge sharing, this will enables learning development in implementing BIM and potentially can avoid the same problems that other organisation faced, hence will speed up the successful implementation process of BIM.

Accordingly, many conflicts arose in Malaysian construction industry lead to poor quality in project outcomes. In order to strengthen the industry development, many initiatives addressing strategic information technology (IT) in construction have been issued specifically by the government to challenge the industry to take advantage of IT utilisation. This in line with Ofori (2000) that suggested construction industry to benefit from the strategic application of information technology. IT has been recognized as a driver for many construction organisations business in the Malaysian construction industry, and moving towards the new information technology (IT) era (Mastura Jaafar et al., 2007). Consequently, IT strategy plan was purposely developed for construction industry in Construction Industry Master Plan (CIMP) Strategic Thrust 6 (CIDB, 2007) to achieve vision 2020. In 2009, early effort on BIM implementation began by providing awareness

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programs and workshops with the industry. In 2012, CIDB was also working closely with Unit Kerjasama Awam Swasta (UKAS) to deploy BIM in the Public Private Partnership (PPP) projects through a concept of 'Affordable BIM' where UKAS contractors and sub-contractors are able to use BIM through a periodical licensing arrangement. At the same time, CIDB was establishing a Committee of Building Information Modeling (BIM) In Construction Industry in order to coordinate the movement of BIM in this country. In the near term, Malaysia is taking rigorous action on the development of Malaysia's Building Information Modelling (BIM) Roadmap (2014-2020) to encourage the construction industry stakeholders towards wide implementation of BIM by 2020 (CIDB, 2012). The roadmap main focus was given on the motivations of the stakeholders to implement BIM aligned with the national agenda. Besides, researches on BIM are also encouraged in the development of new practices and new tools to develop the industry stakeholders' capability in understanding and take full benefit of a new technology.

Moreover, one out of seven strategic thrusts in CIMP 2006-2015 is knowledge sharing initiatives that are in line with the Malaysian government's vision to create a knowledge-based economy (CIDB, 2006). Considering BIM as one of the potential IT application to improve the Malaysian construction organisations, the knowledge sharing practices in implementing BIM is very vital for the competitive advantage of the organisations. As the applications take place, the information and knowledge should be shared and develop to avoid obsolete and forgotten knowledge (Arayici & Coates, 2013). Therefore, this research is attempts to investigate on good knowledge sharing practices in implementing BIM in Malaysian construction industry.

6. If you are going to work within a particular organisation do they have their own procedures for gaining ethical approval

(For example, within a hospital or health centre?)

YES

If YES – what are these and how will you ensure you meet their requirements?

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Provide document as requested by the organisation such as application letter for approval, researcher background information and research information to Senior Director in charge in Public Work Department of Malaysia (Public organisation). In case the Public Work Department of Malaysia agree to participate in this research, a copy of written approval/agreement letter from Public Work Department will be sent to supervisor before commencing with data collection.

7. Are you going to approach individuals to be involved in your research?

YES

If YES – please think about key issues – for example, how you will recruit people? How you will deal with issues of confidentiality / anonymity? Then make notes that cover the key issues linked to your study

The respondents will be contacted by invitation letter. They will be informed on how the data will be treated as confidential.

In terms of the interviews:

- It is estimated that the interviews will take between 30-40 minutes. With the permission of the interviewee, the interview will be tape/ phone recorded. The tapes and information will be used anonymously and only for academic purposes. Information on individuals such as name, gender, and ethnicity and so on will not be appearing on any documentation of the research under any circumstances.
- Senior managers and executives are the main people to be contacted at the first stage to seek the required permission to access the targeted organisations. The participants will be contacted either in person or via email as applicable; but if the candidate respondent suggested different communication method such as phone call, the researcher will respect his/her request.

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- I will only use the records in ways that the interviewee agree to:
- In any use of these records, the interviewee personal information will be treated in confidential.
- The anonymised records can be studied, transcribed and analysed by the interviewer only according to the research aims.
- The anonymised records can be used for scientific publications and meetings.
- The anonymised records can be shown in presentations to scientific or non-scientific groups.
- Cultural issues such as dressing and Islamic manners will be respected as the context requires.
- Interviews will be conducted in a convenient place.
- Records will be kept in secure and locked cabinet with key.
- Any respondent will be given the freedom to withdrawal at any stage and the recorded will be destroyed.
- The research will assure that the ethical issues outlined by the university were dealt with in the manner and the rights of the recruit and the responsibilities of the researcher will be outlined in a consent form (as attach).
- The researcher will discuss and read carefully the Consent Form for each recruit and the requirements of full disclosure fulfilled. Emphasis will be placed on the right of the recruit to withdraw at any time, confidentiality and anonymity. Also, the recruit will be asked to sign the Consent Form to signify their willingness and consent to taking part in the research on the basis of the terms outlined therein.
- The researcher will make interview face-to-face with participants. In the beginning of interview the researcher will explain the aim of interview and the right to the participant to withdraw any time. Then the researcher will ask some of question not in-depth such as demographic about the organisation's background. After that, the researcher will asks some questions in-depth related to aim of research with open-ended questions. At the end of interview, the researcher expected from the participants to answer all the questions and receive any comments related to the questions.
- If the interviewee agrees to conduct this research, he/she will need to sign a consent form. But he/she can withdraw at any time without any affecting to

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him/her.

- Oral and written English or Malay will be used to communicate with all respondents depending on their preference because their name context and language is Malaysian. In case that the respondents prefer to use Malay during interview session, the translation will be completed by the researcher and submit for a proof reading. The researcher will record the translation as anonymised before submission of a proof reading.

In terms of document analysis/ review:

- No document will be analysed without seeking the required permission.
- Photocopied documents will be kept in secure and safe location in a locked personal cabinet.
- Transcript data will be kept in memory stick secured by password.

8. More specifically, how will you ensure you gain informed consent from anyone involved in the study?

- People who will involve will be based on participation volunteer and they are allow to participate or withdraw depending on their willingness. Thus, any information likely to affect a respondent's willingness to participate will be provided by the researcher at the beginning of the interview and give him/her the chance to make the decision toward completing the interview or withdrawal.
- The researcher will aim to ensure that participants would be neither overwhelmed nor inadequately informed by the amount and nature of the information to be provided.

9. How are you going to address any Data Protection issues?

See notes for guidance which outline minimum standards for meeting Data Protection issues

- All the information that collects about respondents during the course of the

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research will be kept strictly confidential. The researcher will not reveal their names, and publish as anonymous in any reports or publications.

- The hard copies data will be safe stored in locked personal cabinet and kept in confidential Electronic data will be stored in a password protected computer.
- Data can only be accessed by the research team (researcher and supervisor).
- All collected data will only be used for the intended purpose and will be destroyed after the study (when project finish).

10. Are there any other ethical issues that need to be considered? For example - research on animals or research involving people under the age of 18.

No

11. (a) Does the project involve the use of ionising or other type of "radiation"

NO

(b) Is the use of radiation in this project over and above what would normally be expected (for example) in diagnostic imaging?

NO

(c) Does the project require the use of hazardous substances?

NO

(d) Does the project carry any risk of injury to the participants?

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NO

(e) Does the project require participants to answer questions that may cause disquiet / or upset to them?

NO

If the answer to any of the questions 11(a)-(e) is YES, a risk assessment of the project is required and must be submitted with your application.

12. How many subjects will be recruited/involved in the study/research? What is the rationale behind this number?

Since BIM is relatively new within the Malaysian construction industry, it was anticipated that acquiring a matured implementation case was a big challenge. 10 companies were identified through the company's website, internal contact and Construction Research Institute of Malaysia (CREAM) networking database. The researcher believes that interviewing at least 6 private organisations and 2 public organisations that consist of 16 executives (2 from each case); can be adequate to meet the aim and the objectives of this research and to answer the research questions.

13. Please state which code of ethics has guided your approach (e.g. from Research Council, Professional Body etc).

Please note that in submitting this form you are confirming that you will comply with the requirements of this code. If not applicable please explain why.

I have reviewed the following documents to complete this form:

1. University of Salford Rules: Ethical approval Notes for Guidance
2. UK Research Integrity Office: Code of Practice for Research

Remember that informed consent from research participants is crucial, therefore all documentation must use language that is readily understood by the target audience.

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Projects that involve NHS patients, patients' records or NHS staff, will require ethical approval by the appropriate NHS Research Ethics Committee. The University College Ethics Panel will require written confirmation that such approval has been granted. Where a project forms part of a larger, already approved, project, the approving REC should be informed about, and approve, the use of an additional co-researcher.

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I certify that the above information is, to the best of my knowledge, accurate and correct. I understand the need to ensure I undertake my research in a manner that reflects good principles of ethical research practice.

Signed by Student 

Print Name abc

Date 5/11/2015

In signing this form I confirm that I have read this form and associated documentation.

***I have discussed and agreed the contents with the student on 3/11/2015
(Please insert date of meeting with student)***



Signed by Supervisor _____

Print Name xyz

Date 3rd November 2015

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**College Ethics Panel:
Application Checklist**

Ref No: Office Use Only

Name of Applicant: abc

Title of Project: Knowledge and information sharing practices in implementing BIM within the Malaysian construction industry.

The checklist below helps you to ensure that you have all the supporting documentation submitted with your ethics application form. This information is necessary for the Panel to be able to review and approve your application. Please complete the relevant boxes to indicate whether a document is enclosed and where appropriate identifying the date and version number allocated to the specific document (*in the header / footer*), Extra boxes can be added to the list if necessary.

Document	Enclosed?			Date	Version No
	(indicate appropriate response)				
Application Form	<u>Mandatory</u>		If not required please give a reason		
Risk Assessment Form		No	Not required for this project	Not involve animals or people under age of 18. This research does not involve risk at any level.	
Participant Invitation Letter	Yes			Yes (included)	
Participant Information Sheet	Yes			Yes (included)	
Participant Consent Form	Yes			Yes (included)	
Participant Recruitment Material – e.g. copies of posters,		No	Not required for this project	This research does not involve such activities	

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newspaper adverts, website, emails						
Organisation Management Consent / Agreement Letter	Yes			In case that the Public Work Department of Malaysia agreed to participate, a copy of agreement letter will be submitted first to supervisor before commencing data collection.		
Research Instrument – e.g. questionnaire		No	Not required for this project	This research does not use questionnaire for data collection		
Draft Interview Guide	Yes		Not required for this project	Draft set of questions have been provided, these subject to change based on pilot study outcomes and it will be discussed with my supervisor		
National Research Ethics Committee consent	Yes		Not required for this project	The following site http://www.nres.nhs.uk/ was reviewed carefully to understand related issues		
Note: If the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and will need to be resubmitted at a later date thus delaying the approval process						

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Participant Invitation Letter

Dear participant:

I am abc studying at the School of the Built Environment | University of Salford, Manchester, United Kingdom. I am conducting a study to ascertain the current practices, policies of knowledge and information sharing, and organisational culture in implementing BIM in the Malaysian Construction Industry. The findings of the study will be used to develop a framework of good practice organisational knowledge and information sharing in implementing BIM within the Malaysian construction industry. You are very important person; you have experienced the work in construction organisations for a period of time. So, I believe you will add a lot to this research by providing your experience and perspectives. I have learned your name and contact details through the list of people provided by your manager in the firm you are working on.

If you agreed to take a part in this research, you will be contacted by me personally bearing in mind that the data will be collected by semi-structured interview.

I can promise you that it will be an enjoyable and meaningful experience. I will take all the required ethical concerns into consideration. You may decide to stop being a part of the research study at any time without explanation. In addition, the data I will collect will not contain any personal information. No one will link the data you provided to the identifying information you supplied. Any other ethical issues related to the research philosophy are considered by the researcher and the University of Salford.

Many thanks,

abc

By signing below, you are agreeing that: (1) you have read and understood the Participant Information Sheet, (2) questions about your participation in this study have been answered satisfactorily, and (3) you are taking part in this research study voluntarily (without coercion).

Participant's Name (Printed)*

Participant's signature*

Date

Participant Information Sheet

PROJECT TITLE:

Knowledge and information sharing practices in implementing BIM within the Malaysian construction industry.

TIME COMMITMENT:

In order to take a part in the interview's session I would not keep you occupied for more than 40 minutes.

PARTICIPANTS' RIGHTS:

You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn/destroyed. You have the right to omit or refuse to answer or respond to any question that is asked of you. You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you can query the researcher before the study begins.

CONFIDENTIALITY/ANONYMITY:

The data I collect do not contain any personal information about you. There will be no link between the data you provided and the personal information you may supply.

FOR FURTHER INFORMATION:

My Supervisor xyz and I will be glad to answer your questions about this study at any time.

You may contact her at xyz@salford.ac.uk .

And me at: abc@edu.salford.ac.uk.

abc, School of Build Environment

The knowledge and information sharing practices in implementing BIM within the Malaysian construction industry

CONFIDENTIALITY STATEMENT

All responses given as part of interviews, and documents will be treated with utmost confidentiality and will be available only to the researcher and supervisor of the project. Excerpts from the interviews, and documents will be used for research publications, but under no circumstances will your name or any identifying characteristics be disclosed in such publications.

This confidentiality statement will be signed by both the participant and the researcher in order to ensure that data obtained will only be used for the above research, and will not be disclosed to any other person, or be used for other purposes.

Name of participant : _____ Name of researcher : abc

Signature : _____ Signature : _____

Date : _____ Date : _____

Thank you for your cooperation

RESEARCH PARTICIPANT CONSENT FORM

The knowledge and information sharing practices in implementing BIM within the Malaysian construction industry.

Name of researcher : abc

Researcher's email address : abc@edu.salford.ac.uk

(Delete as appropriate)

- I confirm that I have read and understood the information sheet for the above study and what my contribution will be.

Yes	No
------------	-----------

- I have been given the opportunity to ask questions (face to face, via telephone and e-mail)

Yes	No
------------	-----------

- I agree to take part in the interview/questionnaire survey

Yes	No	NA
------------	-----------	-----------

- I agree to the interview discussion being tape/ phone recorded

Yes	No	NA
------------	-----------	-----------

- I understand that my participation is voluntary

Yes	No
------------	-----------

- I understand that I can withdraw from the research at any time without giving any reason

Yes	No
------------	-----------

- I understand that if I withdraw from the research, responses given by me will not be used for the study

Yes	No
------------	-----------

The semi-structured interview guideline

Introduction

The main aim of this interview is to understand the interviewee's perspective about issues related to knowledge sharing and organisational culture as well as the interaction between both phenomena in the studied context. Accordingly, there are not right or wrong answers for the upcoming questions rather it is a matter of reflecting the interviewee's experience with the phenomena as they were conceived by him/her.

Your rights

You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn or destroyed. You have the right to omit or refuse to answer or respond to any question that is asked of you. You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you may query the researcher at anytime.

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 What has triggered the BIM implementation by the company?
- 2.5 Could you explain the benefits of BIM?
- 2.6 What are the challenges of BIM implementation, internally and externally?

3.0 Current practices and policies of knowledge and information sharing in implementing BIM

- 3.1 What are the approaches that the company currently uses? Which are the most frequent ways and why? Please explain in detail and give examples.
- 3.2 What are the important sources of information needed? Did the company able to get the information needed? How?
- 3.3 How important that the colleagues respond to the information needs? Why?
- 3.4 What are the management's support and policies to encourage knowledge and information sharing?
- 3.5 Did the company promoted loyalty, integrity, professionalism and commitment in knowledge sharing?

4.0 Organisational culture and knowledge sharing in implementing BIM

- 4.1 Do you think organisational culture can influence knowledge sharing?
- 4.2 How do you think organisational culture influencing knowledge sharing in implementing BIM in your organisation and why?
- 4.3 Who do you think is responsible about setting the culture of organisation and why do you think that?
- 4.4 What are the role of the management in embedding organisational culture that encourage knowledge sharing and why?
- 4.5 How important is the support, commitment and vision of the management and board of directors to encourage knowledge sharing? Please explain in detail and give examples.

5.0 Barriers and enabling factors to improve knowledge and information sharing in implementing BIM

- 5.1 As BIM is a new approach to construction project, some people find BIM transformation challenging. What are the factors that perceived to be barriers in knowledge and information sharing of BIM implementation? and how did the company respond to them?
- 5.2 What are the factors that can improve knowledge and information sharing? Why?

Appendix 2



Science & Technology (CSE, ELS & SOBE) Research, Innovation and Academic Engagement Ethical Approval Panel

Standard Response Form for PGR and Staff Applications

Ref No: ST 15/60

Application Form	Acceptable No changes (please tick)	Minor Change List (please tick)	Major Change List (Please tick)	Comments from the reviewer(s) / Chair of Ethics	Answers to feedback from chair of Ethics/ reviewer(s)
Title	✓				
Focus	✓				
Objectives	✓			Although these are comprehensive some are not summarized enough.	Objectives 2 and 3 have been summarized (Refer page 3).
Research Strategy	✓			The research strategy is comprehensive but requires further work and some proof reading would help.	Will be considered.
Rationale	✓			Just an observation – Double check your documents before submission in future, so you don't send the document with track changes visible - This should be an anonymous submission.	Will always double check before submission. The track changes' format has been off.
Organisational Agreement		✓		Please ensure you submit the written agreement from Public Work Department of Malaysia to your supervisor to confirm back to the ethics commit this is in place before commencing with data collection.	In case the Public Work Department of Malaysia agree to participate in this research, a copy of written approval/agreement letter from Public Work Department will be sent to

Appendix 2

					supervisor before commencing with data collection (Refer page 9).
Approaching individuals	✓				
Informed Consent	✓				
Data protection	✓			Application states all data will be destroyed on complete of research, please be aware that you need to ensure secure destruction to ensure the data is not compromised.	Will be considered.
Other Ethical Issues		✓		If the interviews are conducted in Malay, I have assumed the translation will be completed by the student as they speak both languages. How will the document reviews be facilitated? Will these be publically available documents? If not how will they be sourced and consent for their use, secure storage and return or disposal be achieved?	In case that the respondents prefer to use Malay during interview session, the translation will be completed by the student and submit for a proof reading. The translation will be recorded as anonymised before submission of a proof reading (Refer page 11). The researcher will only use the recorded data in a way that the interviewees agree to (Refer page 10 and 12). The records can only be used as anonymised. All the documents will be kept in secure and safe location in a locked personal cabinet. Transcript data will be kept in a pen drive by password (Refer page 11).
No. Subjects	✓				
Code of ethics used	✓				
Participant info	✓				

Appendix 2

letter					
Consent Form	✓				
Recruitment Material	✓				
Research Instrument	N/A				
Interview Guide	✓			Some questions related with the institutions might be sensitive to the interviewees. Caution and care should be taken here.	Will be considered.
Other Comments					

Recommendation:

Accept – no changes	
Accept subject to minor changes (approved by supervisor if PGR student)	<p>Couple of very minor ethical issues to be clarified:</p> <ul style="list-style-type: none"> • Procedure for translation of Malay into English; • Written agreement from Public Work Department of Malaysia; • Ethical procedures for the use of company documents if they are not in the public domain e.g. contractual documents etc.
Accept subject to changes outlined above (to be approved by committee chair)	
Reject – address changes outlined above and resubmit	

APPENDIX 2: Research Ethics Approval Letter

University of
Salford
MANCHESTER

Research, Innovation and Academic
Engagement Ethical Approval Panel

Research Centres Support Team
G0.3 Joule House
University of Salford
M5 4WT

T +44(0)161 295 5278

www.salford.ac.uk/

6 November 2015

Dear Suria Binti,

RE: ETHICS APPLICATION ST15/60 – Knowledge and information sharing practices in implementing BIM within the Malaysian construction industry.

Based on the information you provided, I am pleased to inform you that your application ST 15/60 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,



Prof Mohammed Arif
Chair of the Science & Technology Research Ethics Panel
Professor of Sustainability and Process Management,
School of Built Environment
University of Salford
Maxwell Building, The Crescent
Greater Manchester, UK M5 4WT
Phone: + 44 161 295 6829
Email: m.arif@salford.ac.uk

APPENDIX 3: Interview Guide used in Pilot Organisation

The semi-structured interview guideline (bilingual)

Pengenalan/ Introduction

Matlamat utama temubual ini adalah untuk memahami perspektif pihak yang ditemubual berkenaan isu-isu yang berkaitan dengan perkongsian pengetahuan dan budaya organisasi beserta hubungan kedua-dua fenomena tersebut dalam konteks kajian (dalam melaksana BIM – salah satu inovasi). Berhubung dengan itu, tiada jawapan yang betul atau salah, tetapi lebih menjurus kepada pengalaman pihak yang ditemubual dengan fenomena yang dihadapi/ dialami sendiri oleh pihak tuan/ puan.

The main aim of this interview is to understand the interviewee's perspective about issues related to knowledge sharing and organisational culture as well as the interaction between both phenomena in the studied context. Accordingly, there are not right or wrong answers for the upcoming questions rather it is a matter of reflecting the interviewee's experience with the phenomena as they were conceived by him/her.

Hak pihak yang ditemubual/ Your rights

Anda berhak untuk berhenti menjadi sebahagian daripada kajian ini pada bila-bila masa tanpa penjelasan. Anda berhak untuk bertanya berkenaan maklumat yang diberikan sehingga tahap ia dimusnahkan. Anda berhak untuk mengelak atau tidak mahu menjawab atau memberi maklum balas kepada mana-mana soalan yang diajukan. Anda berhak untuk bertanya berkenaan prosedur menjawab. Sekiranya anda mempunyai sebarang soalan setelah membaca maklumat yang dinyatakan, anda boleh menyoal pengkaji pada bila-bila masa.

You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn or destroyed. You have the right to omit or refuse to answer or respond to any question that is asked of you. You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you may query the researcher at anytime.

1.0 Latarbelakang organisasi/ Background of the organisation @organisation

1.1 Apakah jenis perniagaan yang organisasi tuan/puan terlibat?

What type of business is your organisation involved in?

1.2 Dalam sektor pembinaan dan bangunan yang manakah, organisasi tuan/ puan paling banyak beroperasi?

In which sector of construction and building does your organisation mostly operate?

1.3 Apakah pulangan tahunan kasar organisasi tuan/ puan?

What is the gross annual revenue of your organisation?

1.4 Berapakah bilangan pekerja dalam organisasi tuan/ puan?

What is the current number of employees in your organisation?

1.5 Apakah jawatan tuan/ puan dalam organisasi tuan/ puan?

What is your position in the organisation?

1.6 Berapakah bilangan tahun pengalaman organisasi dan tuan/ puan dalam sektor pembinaan dan bangunan? dan penglibatan dalam BIM?

How many years of experiences do organisation and you have in construction and building sector? and how many years in BIM?

2.0 Status terkini pelaksanaan BIM/ Current status of BIM implementation

2.1 Apakah perisian BIM yang kini digunakan oleh organisasi? Berapakah lesen yang ada/ dimiliki? Bolehkan tuan terangkan kegunaan perisian yang dinyatakan? Apakah aplikasi perisian yang kini organisasi gunakan?

What is the BIM software that the organisation currently uses? How many licenses are they? Could you discuss the purpose of the aforementioned software? What are the software applications that the organisation is currently using?

2.2 Setakat ini, sehingga tahap manakah BIM digunakan di dalam organisasi? Bagaimana organisasi melibatkan/ menyesuaikan pendekatan BIM di dalam proses rekabentuk/ pembinaan terkini? Apakah jenis skop kerja yang memerlukan pendekatan BIM untuk dilaksanakan?

So far, to what stage has BIM been implemented within the organisation? How does the organisation engaging BIM approach in the current process flow of design? What types of job scope requires BIM approach to be implemented?

2.3 Adakah organisasi mewujudkan peranan dan tanggungjawab baru bagi pelaksanaan BIM? Sekiranya ada, apakah peranan tersebut?

Did the organisation create new roles and responsibilities for BIM implementation? If yes, what are they?

2.4 Apakah yang mencetuskan pelaksanaan BIM oleh organisasi?

What has triggered the BIM implementation by the organisation?

- 2.5 Bolehkan tuan/ puan terangkan manfaat-manfaat BIM?
Could you explain the benefits of BIM?
- 2.6 Apakah cabaran-cabaran dalam pelaksanaan, secara dalaman dan luaran?
What are the challenges of BIM implementation, internally and externally?
- 3.0 Praktis terkini dan polisi perkongsian maklumat dan pengetahuan dalam melaksanakan BIM**
Current practices and policies of knowledge and information sharing in implementing BIM
- 3.1 Apakah pendekatan/ teknik-teknik yang kini organisasi gunakan? Yang manakah kaedah yang paling kerap digunakan dan kenapa? Tolong jelaskan secara terperinci dan berikan contoh-contoh.
What are the approaches that the organisation currently uses? Which are the most frequent ways and why? Please explain in detail and give examples.
- 3.2 Apakah sumber-sumber penting bagi maklumat yang diperlukan? Adakah organisasi mampu mendapatkan maklumat yang diperlukan? Bagaimana?
What are the important sources of information needed? Did the organisation able to get the information needed? How?
- 3.3 Bagaimana pentingnya rakan-rakan sekerja memberi maklum balas kepada maklumat yang diperlukan? Kenapa?
How important that the colleagues respond to the information needs? Why?
- 3.4 Apakah sokongan dan polisi-polisi pihak pengurusan untuk menggalakkan perkongsian maklumat dan pengetahuan?
What are the management's support and policies to encourage knowledge and information sharing?
- 3.5 Adakah organisasi mempromosikan kepercayaan, keterbukaan, kerja berpasukan dan komitmen dalam perkongsian pengetahuan?
Did the organisation promoted trust, openness, teamwork and commitment in knowledge sharing?
- 4.0 Budaya organisasi dan perkongsian pengetahuan dalam melaksana BIM**
Organisational culture and knowledge sharing in implementing BIM
- 4.1 Adakah tuan/ puan fikir yang budaya organisasi boleh memberi kesan kepada perkongsian pengetahuan?
Do you think organisational culture can influence knowledge sharing?
- 4.2 Bagaimana tuan/ puan fikir yang budaya organisasi boleh memberi kesan kepada perkongsian pengetahuan dalam melaksana BIM dan kenapa?

How do you think organisational culture influencing knowledge sharing in implementing BIM in your organisation and why?

- 4.3 Siapakah yang difikirkan bertanggungjawab dalam menentukan budaya organisasi dan kenapa tuan/ puan fikir begitu?

Who do you think is responsible about setting the culture of organisation and why do you think that?

- 4.4 Apakah peranan-peranan pengurusan dalam menanam budaya organisasi untuk menggalakkan perkongsian pengetahuan dan kenapa?

What are the role of the management in embedding organisational culture that encourage knowledge sharing and why?

- 4.5 Bagaimana pentingnya sokongan, komitmen dan visi pengurusan dan lembaga pengarah untuk menggalakkan perkongsian pengetahuan? Tolong jelaskan secara terperinci dan berikan contoh.

How important is the support, commitment and vision of the management and board of directors to encourage knowledge sharing? Please explain in detail and give examples.

- 5.0 Halangan-halang dan faktor-faktor pemangkin untuk meningkatkan perkongsian maklumat dan pengetahuan dalam melaksana BIM

Barriers and enabling factors to improve knowledge and information sharing in implementing BIM

- 5.1 BIM sebagai salah satu pendekatan baru dalam projek pembinaan, sebahagian orang mendapati peralihan/ perubahan kepada BIM adalah mencabar. Apakah factor-faktor yang dianggap/ dikatakan sebagai halangan dalam perkongsian maklumat dan pengetahuan dalam pelaksanaan BIM? Bagaimana organisasi memberi respon terhadap halangan tersebut?

As BIM is a new approach to construction project, some people find BIM transformation challenging. What are the factors that perceived to be barriers in knowledge and information sharing of BIM implementation? and how did the organisation respond to them?

- 5.2 Apakah faktor-faktor yang boleh meningkatkan/ memangkin perkongsian maklumat dan pengetahuan dalam melaksana BIM, secara dalaman dan luaran? Kenapa?

What are the factors that can improve knowledge and information sharing, internally and externally? Why?

APPENDIX 4: Interview Guide used in Exploratory Organisation

The semi-structured interview guideline (bilingual)

Pengenalan/ Introduction

Matlamat utama temubual ini adalah untuk memahami perspektif pihak yang ditemubual berkenaan isu-isu yang berkaitan dengan perkongsian pengetahuan dan budaya organisasi beserta hubungan kedua-dua fenomena tersebut dalam konteks kajian (dalam melaksana BIM – salah satu inovasi). Berhubung dengan itu, tiada jawapan yang betul atau salah, tetapi lebih menjurus kepada pengalaman pihak yang ditemubual dengan fenomena yang dihadapi/ dialami sendiri oleh pihak tuan/ puan.

The main aim of this interview is to understand the interviewee's perspective about issues related to knowledge sharing and organisational culture as well as the interaction between both phenomena in the studied context. Accordingly, there are not right or wrong answers for the upcoming questions rather it is a matter of reflecting the interviewee's experience with the phenomena as they were conceived by him/her.

Hak pihak yang ditemubual/ Your rights

Anda berhak untuk berhenti menjadi sebahagian daripada kajian ini pada bila-bila masa tanpa penjelasan. Anda berhak untuk bertanya berkenaan maklumat yang diberikan sehingga tahap ia dimusnahkan. Anda berhak untuk mengelak atau tidak mahu menjawab atau memberi maklum balas kepada mana-mana soalan yang diajukan. Anda berhak untuk bertanya berkenaan prosedur menjawab. Sekiranya anda mempunyai sebarang soalan setelah membaca maklumat yang dinyatakan, anda boleh menyoal pengkaji pada bila-bila masa.

You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn or destroyed. You have the right to omit or refuse to answer or respond to any question that is asked of you. You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you may query the researcher at anytime.

1.0 Latarbelakang organisasi/ Background of the organisation @organisation

1.1 Apakah jenis perniagaan yang organisasi tuan/puan terlibat?

What type of business is your organisation involved in?

1.2 Dalam sektor pembinaan dan bangunan yang manakah, organisasi tuan/ puan paling banyak beroperasi?

In which sector of construction and building does your organisation mostly operate?

1.3 Apakah pulangan tahunan kasar organisasi tuan/ puan?

What is the gross annual revenue of your organisation?

1.4 Berapakah bilangan pekerja dalam organisasi tuan/ puan?

What is the current number of employees in your organisation?

1.5 Apakah jawatan tuan/ puan dalam organisasi tuan/ puan?

What is your position in the organisation?

1.6 Berapakah bilangan tahun pengalaman organisasi dan tuan/ puan dalam sektor pembinaan dan bangunan? dan penglibatan dalam BIM?

How many years of experiences do organisation and you have in construction and building sector? and how many years in BIM?

2.0 Status terkini pelaksanaan BIM/ Current status of BIM implementation

2.1 Apakah perisian/ perkakasan BIM yang kini digunakan oleh organisasi? Berapakah lesen yang ada/ dimiliki? Bolehkan tuan terangkan kegunaan perisian yang dinyatakan? Apakah aplikasi perisian yang kini organisasi gunakan?

What is the BIM software/ tools that the organisation currently uses? How many licenses are they? Could you discuss the purpose of the aforementioned software? What are the software applications that the organisation is currently using?

2.2 Setakat ini, sehingga tahap manakah BIM digunakan di dalam organisasi? Bagaimana organisasi melibatkan/ menyesuaikan pendekatan BIM di dalam proses rekabentuk/ pembinaan terkini? Apakah jenis skop kerja yang memerlukan pendekatan BIM untuk dilaksanakan?

So far, to what stage has BIM been implemented within the organisation? How does the organisation engaging BIM approach in the current process flow of design? What types of job scope requires BIM approach to be implemented?

2.3 Adakah organisasi mewujudkan peranan dan tanggungjawab baru bagi pelaksanaan BIM? Sekiranya ada, apakah peranan tersebut?

Did the organisation create new roles and responsibilities for BIM implementation? If yes, what are they?

2.4 Apakah yang mencetuskan pelaksanaan BIM oleh organisasi?

What has triggered the BIM implementation by the organisation?

- 2.5 Bolehkan tuan/ puan terangkan manfaat-manfaat BIM?
Could you explain the benefits of BIM?
- 2.6 Apakah cabaran-cabaran dalam pelaksanaan, secara dalaman dan luaran?
What are the challenges of BIM implementation, internally and externally?
- 3.0 Praktis terkini dan polisi perkongsian maklumat dan pengetahuan dalam melaksanakan BIM**
Current practices and policies of knowledge and information sharing in implementing BIM
- 3.1 Apakah pendekatan/ teknik-teknik yang kini organisasi gunakan? Yang manakah kaedah yang paling kerap digunakan dan kenapa? Tolong jelaskan secara terperinci dan berikan contoh-contoh.
What are the approaches that the organisation currently uses? Which are the most frequent ways and why? Please explain in detail and give examples.
- 3.2 Apakah sumber-sumber penting bagi maklumat yang diperlukan? Adakah organisasi mampu mendapatkan maklumat yang diperlukan? Bagaimana?
What are the important sources of information needed? Did the organisation able to get the information needed? How?
- 3.3 Bagaimana pentingnya rakan-rakan sekerja memberi maklum balas kepada maklumat yang diperlukan? Kenapa?
How important that the colleagues respond to the information needs? Why?
- 3.4 Apakah sokongan dan polisi-polisi pihak pengurusan untuk menggalakkan perkongsian maklumat dan pengetahuan?
What are the management's support and policies to encourage knowledge and information sharing?
- 3.5 Adakah organisasi mempromosikan kepercayaan, keterbukaan, kerja berpasukan dan komitmen dalam perkongsian pengetahuan?
Did the organisation promoted trust, openness, teamwork and commitment in knowledge sharing?
- 4.0 Budaya organisasi dan perkongsian pengetahuan dalam melaksana BIM**
Organisational culture and knowledge sharing in implementing BIM
- 4.1 Adakah tuan/ puan fikir yang budaya organisasi boleh memberi kesan kepada perkongsian pengetahuan?
Do you think organisational culture can influence knowledge sharing?
- 4.2 Bagaimana tuan/ puan fikir yang budaya organisasi boleh memberi kesan kepada perkongsian pengetahuan dalam melaksana BIM dan kenapa?

How do you think organisational culture influencing knowledge sharing in implementing BIM in your organisation and why?

- 4.3 Siapakah yang difikirkan bertanggungjawab dalam menentukan budaya organisasi dan kenapa tuan/ puan fikir begitu?

Who do you think is responsible about setting the culture of organisation and why do you think that?

- 4.4 Apakah peranan-peranan pengurusan dalam menanam budaya organisasi untuk menggalakkan perkongsian pengetahuan dan kenapa?

What are the role of the management in embedding organisational culture that encourage knowledge sharing and why?

- 4.5 Bagaimana pentingnya sokongan, komitmen dan visi pengurusan dan lembaga pengarah untuk menggalakkan perkongsian pengetahuan? Tolong jelaskan secara terperinci dan berikan contoh.

How important is the support, commitment and vision of the management and board of directors to encourage knowledge sharing? Please explain in detail and give examples.

- 5.0 Halangan-halang dan faktor-faktor pemangkin untuk meningkatkan perkongsian maklumat dan pengetahuan dalam melaksana BIM**

Barriers and enabling factors to improve knowledge and information sharing in implementing BIM

- 5.1 BIM sebagai salah satu pendekatan baru dalam projek pembinaan, sebahagian orang mendapati peralihan/ perubahan kepada BIM adalah mencabar. Apakah faktor-faktor yang dianggap/ dikatakan sebagai halangan dalam perkongsian maklumat dan pengetahuan dalam pelaksanaan BIM? Bagaimana organisasi memberi respon terhadap halangan tersebut?

As BIM is a new approach to construction project, some people find BIM transformation challenging. What are the factors that perceived to be barriers in knowledge and information sharing of BIM implementation? and how did the organisation respond to them?

- 5.2 Apakah faktor-faktor yang boleh meningkatkan/ memangkin perkongsian maklumat dan pengetahuan dalam melaksana BIM, secara dalaman dan luaran? Kenapa?

What are the factors that can improve knowledge and information sharing, internally and externally? Why?

APPENDIX 5: Invitation Email to Conduct Framework's Validation Interview and Survey Form

Attachment 1 (2/7)

Importance Definition

Within the context of this research, knowledge sharing in implementing BIM is defined as the process that organisation disseminate BIM implementation related knowledge to the members with continuous interactions through various approaches, while BIM is define as a BIM is a modelling technology and associated set of processes to produce, communicate and analyse digital information for construction life-cycle (Construction Industry Development Board Malaysia, 2014). Modelling technology within this context of research is referred to 3D parametric authoring tool, for instance 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.

Attachment 1 (3/7)

SECTION A: PERSONAL INFORMATION

Organisation's Name :
Location :
Email :
Contact Number :

Please provide the following information by circling the appropriate boxes

1.1 Your current position/ job title in your organisation?

1.2 Which of the following discipline does your organisation belongs to?

BIM consultant	Architecture	Design Engineering	Contractor	Developer	Other (please specify)
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1.3 How many employees does your organisation have?

0-10	11-20	21-30	31-40	41-100	More than 100
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1.4 What is your length of experience in the Architectural, Engineering, and Construction industry?

Less than a year	1-5 years	6-10 years	11-15 years	16-20 years	More than 20 years
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1.5 What is your length of experience in the BIM implementation?

Less than a year	1-5 years	6-10 years	11-15 years	16-20 years	More than 20 years
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Please specify the experience in terms of industrial practice years,
and/or research (if any) years.

1.6 Is your organisation currently using BIM tools as part of working process?

YES

NO (Please jump to Section B)

Attachment 1 (4/7)

1.7 What are the BIM tools used by your organisation? (You may choose and specify more than one)

Revit	Bently	Naviswork	ArchiCAD	Civil 3D	Others (Please specify)
				
				

1.8 What is/ are the BIM application/s used by your organisation? (You may choose and specify more than one)

Visualisation	Drawing Automation	Automated Clash Check	Quantity Take Off	Structural Analysis	Others (Please specify)
				
				
				

Attachment 1 (5/7)

SECTION B: KNOWLEDGE SHARING PRACTICES IN IMPLEMENTING BIM

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**

2.1 KNOWLEDGE SHARING (KS) PRACTICES IN IMPLEMENTING BIM - PEOPLE							
ELEMENTS	PRACTICE	COMPONENTS	LEVEL OF IMPORTANCE				
			1	2	3	4	5
PEOPLE	Leadership & Management support	Open and forward thinking					
		Lead with clear and meaningful direction and envision the outcomes					
		Promote trust					
		Reward and recognition					
		Ensure relevant awareness and education on benefits of KS and BIM's knowledge					
		Prepare right software and hardware					
		Provide continuous training					
		Embed KS culture in implementing BIM					
		Active involvement - Top management appearance, demand and support					
		Assure teamwork – Handle the project with the right people and knowledge level					
		Be the BIM champion					
	Team Organisation	Responsive to solve a particular problem or any issues					
		Flexible structure					
		Have skills and experience					
		Trust, open and inclusive involvement					
		Accountability in implementing BIM					
	Individual Attitude & Personality	Positive mind-set and attitude					
		Willingness to learn with positive self-improvement					

Attachment 1 (6/7)

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

2.2 KNOWLEDGE SHARING (KS) PRACTICES IN IMPLEMENTING BIM - PROCESS							
ELEMENTS	PRACTICE	COMPONENTS	LEVEL OF IMPORTANCE				
			1	2	3	4	5
PROCESS	Communication & collaboration	Natural trust relationship					
		Proactive action					
		Coordinate, document and corroborate information					
		Clear interaction					
	Policy	Top-down enforcement					
		Prepare communication platform					
		Sharing information format					
		Rules and government enforcement					
		Work with third party					
	Operational	Embracing change in the organisation					
		Having knowledge on knowledge sharing and BIM					
		Good working condition and culture					

Attachment 1 (7/7)

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

2.3 KNOWLEDGE SHARING (KS) PRACTICES IN IMPLEMENTING BIM - TECHNOLOGY							
ELEMENTS	PRACTICE	COMPONENTS	LEVEL OF IMPORTANCE				
			1	2	3	4	5
TECHNOLOGY	Appropriate tools	Integrated use of techniques: Non-IT base for KS and technologies: IT base for KS					
		Leverage on the existing technology					

Please suggest any other knowledge sharing practices (if any) that is important to the successful of BIM implementation.

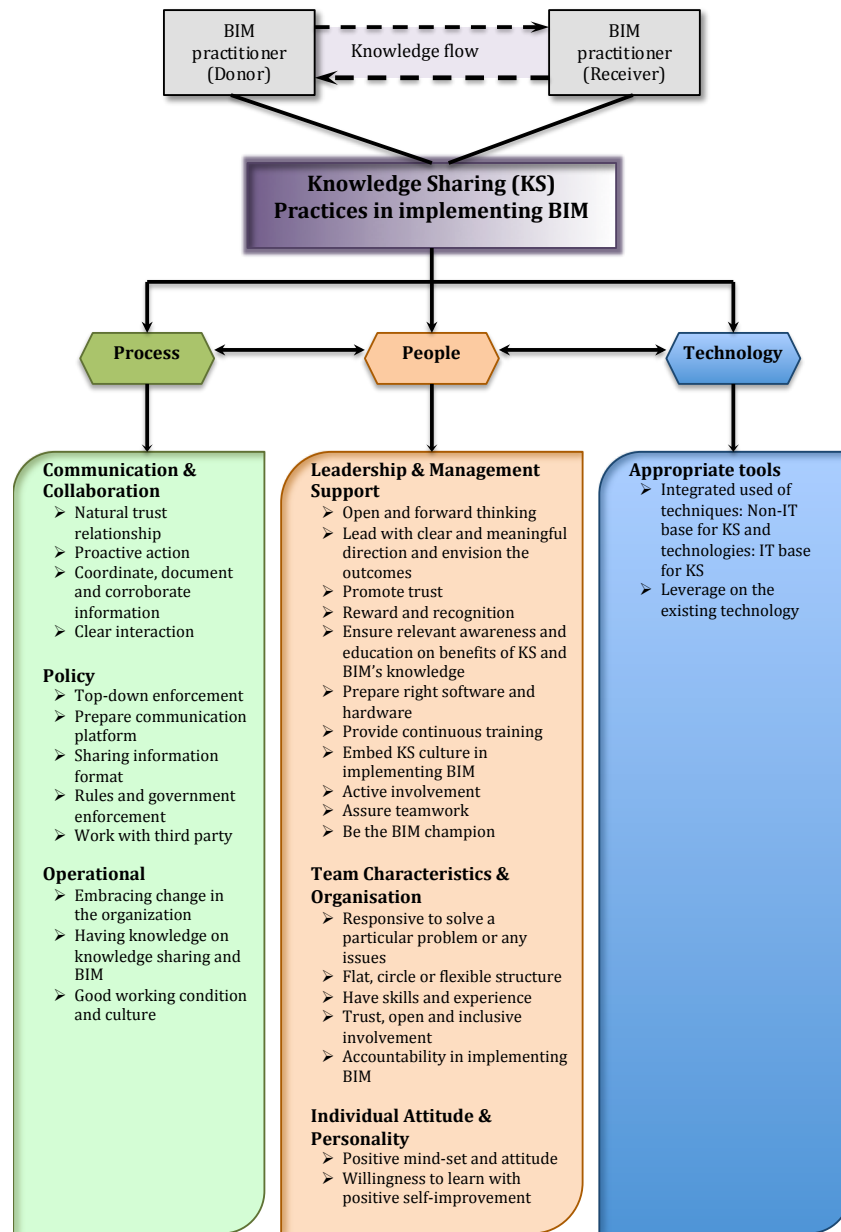
KS PRACTICES	LEVEL OF IMPORTANCE				
	1	2	3	4	5

*** End of question ***

Thank you for your cooperation in completing this questionnaire.

Yours sincerely,

Suria Musa



A draft Framework of Organisational Knowledge Sharing (KS) Practices in Implementing BIM within The Malaysian Construction Industry

Attachment 2 (2/2)

Semi-structured questions for validation's interview

1. What do you think about the clarity of the framework?
2. What do you think about the structure of the framework?
3. From the knowledge sharing (KS) point of view, are the components of knowledge sharing (KS) practices which relate to BIM implementation are appropriate or being included in the framework?
4. Do you think the framework in its current design will help in enhancing the current practice of KS in implementing BIM in construction organisations? How?
5. Do you have any suggestions to improve the framework?

APPENDIX 6: The analysis of knowledge sharing key factors

KEY FACTORS OF KNOWLEDGE SHARING IN IMPLEMENTING BIM			PARTICIPANT'S ANSWER (scale)						FREQUENCY (F) OF ANSWERS LERT SCALE					TOTAL (F*L)
ELEMENT	PRACTICE	COMPONENTS	V1	V2	V3	V4	V5	V6	1	2	3	4	5	
PEOPLE	Leadership & Management Support	L1) Open and forward thinking	4	3	4	5	5	5	0	0	1	2	3	26
		L2) Lead with clear and meaningful direction and envision the outcomes	5	4	4	5	4	4	0	0	0	4	2	26
		L3) Promote trust	4	2	4	4	4	4	0	1	0	5	0	22
		L4) Reward and recognition	1	2	3	4	4	3	1	1	2	2	0	17
		L5) Ensure relevant awareness and education on benefits of KS and BIM's knowledge	4	3	5	5	4	4	0	0	1	3	2	25
		L6) Prepare right software and hardware	4	5	5	5	4	5	0	0	0	2	4	28
		L7) Provide continuous training	4	2	5	5	4	4	0	1	0	3	2	24
		L8) Embed KS in implementing BIM culture	4	4	5	4	5	4	0	0	0	4	2	26
		L9) Active involvement - Top management appearance, demand and support	4	3	5	5	5	4	0	0	1	2	3	26
		L10) Assure teamwork – Handle the project with the right people and knowledge level	4	4	5	5	5	5	0	0	0	2	4	28
		L11) Be the BIM champion	4	3	4	5	5	5	0	0	1	2	3	26
	Team Organisation	T1) Responsive to solve a particular problem or any issues	4	4	5	5	4	5	0	0	0	3	3	27
		T2) Flat, circle or flexible structure	4	3	4	3	3	4	0	0	3	3	0	21
		T3) Have skills and experience	5	5	5	5	3	2	0	1	1	0	4	25
		T4) Trust, open and inclusive involvement	4	3	4	5	4	4	0	0	1	4	1	24
		T5) Accountability in implementing BIM	4	4	5	5	3	4	0	0	1	3	2	25
	Individual Attitude & Personality	I1) Positive mind-set and attitude	5	4	5	5	4	5	0	0	0	2	4	28
I2) Willingness to learn with positive self-improvement		4	4	5	5	4	4	0	0	0	4	2	26	
PROCESS	Communication & collaboration	C1) Natural trust relationship	5	3	5	5	3	4	0	0	2	1	3	25
		C2) Proactive action	4	5	5	5	5	4	0	0	0	4	2	26
		C3) Coordinate, document and corroborate information	4	4	5	5	5	5	0	0	0	4	2	26
		C4) Clear interaction	4	4	5	5	5	4	0	0	0	3	3	27
	Policy	P1) Top-down enforcement	4	3	5	3	5	5	0	0	2	1	3	25
		P2) Prepare communication platform	4	5	5	5	5	4	0	0	0	2	4	28
		P3) Sharing information format	4	4	5	5	5	4	0	0	0	3	3	27
		P4) Rules and government enforcement	5	4	5	5	3	5	0	0	1	1	4	27
		P5) Work with third party	4	3	5	4	4	3	0	0	2	3	1	23
	Operational	O1) Embracing change in the organisation	4	4	4	5	5	4	0	0	0	4	2	26
		O2) Having knowledge on knowledge sharing and BIM implementation	5	5	4	5	4	4	0	0	0	3	3	27
		O3) Good working condition and culture	4	3	4	5	4	4	0	0	1	4	1	24
	TECHNOLOGY	Appropriate tools	A1) Integrated use of techniques: Non-IT base for KS and technologies: IT base for KS	5	3	4	5	5	5	0	0	1	1	4
A2) Leverage on the existing technology			4	4	4	5	5	4	0	0	0	4	2	26

KEY FACTORS OF KNOWLEDGE SHARING IN IMPLEMENTING BIM			AVERAGE INDEX	RANKING
ELEMENT	PRACTICE	COMPONENTS		
PEOPLE	Leadership & Management Support	L1) Facilitate teamwork by handling the project with the right people and knowledge level	4.67	1
		L2) Open and forward thinking	4.33	2
		L3) Lead with clear and meaningful direction and envision the outcomes	4.33	2
		L4) Embed KS in implementing BIM culture	4.33	2
		L5) Active involvement - Top management appearance, demand and support	4.33	2
		L6) Be the BIM champion	4.33	2
		L7) Ensure relevant awareness and education on benefits of KS and BIM's knowledge	4.17	7
		L8) Provide continuous training	4	8
		L9) Promote trust	3.67	9
		L10) Reward and recognition	2.83	10
	Team Organisation	T1) Responsive to solve a particular problem or any issues	4.5	1
		T2) Have skills and experience	4.17	2
		T3) Accountability in implementing BIM	4.17	2
		T4) Trust, open and inclusive involvement	4	4
		T5) Flat, circle or flexible structure	3.5	5
Individual Attitude & Personality	I1) Positive mind-set and attitude	4.67	1	
	I2) Willingness to learn with positive self-improvement	4.33	2	
PROCESS	Communication & collaboration	C1) Clear interaction	4.5	1
		C2) Coordinate, document and corroborate information	4.33	2
		C3) Proactive action	4.33	2
		C4) Natural trust relationship	4.17	4
	Policy	P1) Prepare communication platform	4.67	1
		P2) Sharing information format	4.5	2
		P3) Rules and government enforcement	4.5	2
		P4) Top-down enforcement	4.17	4
		P5) Work with the third party	3.83	5
	Operational	O1) Having understanding on knowledge sharing and BIM implementation	4.5	1
		O2) Embracing change in the organisation	4.33	2
		O3) Good working condition and culture	4	3
TECHNOLOGY	IT Infrastructure	A1) Prepare right software and hardware	4.67	1
	Appropriate Tools	A2: Integrated use of techniques: a Non-IT base for KS and technologies: IT base for KS	4.5	2
		A3) Embracing change in the organisation	4.33	3