EMBEDDING BUILDING INFORMATION MODELING (BIM) COMPETENCIES IN QUANTITY SURVEYING EDUCATION

By

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Pitstop. Not a Milestone.

ABSTRACT

EMBEDDING BUILDING INFORMATION MODELING (BIM) COMPETENCIES IN QUANTITY SURVEYING EDUCATION

Kwong Chin Wei

BIM is now trending in the construction industry. BIM tools is known to be able to assist throughout a project lifecycle from conception to commission and operation. Hence, the supply and demand of the BIM skilled workforce will be an issue in the near future. Higher Education Institutions (HEI) has to act as a vehicle to produce BIM-ready graduates with an attempt to close the gap of demand for graduates with BIM competencies. This study aims to identify the competencies required to embed BIM into the Quantity Surveying education by exploring the knowledge and skills required and recommend BIM competencies to be embedded in the Curriculum Learning Framework of QS undergraduate programme. The scope of this study only focuses on individual competences. From the literature review, three (3) major group of competences are identified: Contextual, Behavioural and Technical competence. 45 BIM competencies obtained from the Initial BIM Learning Outcomes Framework by the Building Academy Forum can be categorised into the three (3) major group of competence, and into 14 groups of BIM Capabilities. Survey questionnaires are distributed to local Quantity Surveyors of various business nature. Factor analysis results indicate that BIM education has to be taught in three (3) stages, namely: Conception Stage, Implementation Stage and Optimisation Stage. BIM competencies that are lack of, also known as the knowledge gap, is identified and sorted into type of competences and stages of education matrix. Further analysis is carried out to pair the competencies found in RICS Assessment of Professional Competence's (APC) and Rules and Syllabuses of the Professional Examinations for Quantity Surveying by Institute of Surveyors Malaysia in view of embedding the BIM competencies into the QS undergraduate programme's Curriculum Learning Framework.

APPROVAL SHEET

This dissertation entitled "**EMBEDDING BUILDING INFORMATION MODELING (BIM) COMPETENCIES IN QUANTITY SURVEYING EDUCATION**" was prepared by KWONG CHIN WEI and submitted as partial fulfillment of the requirements for the degree of Master of Science at Universiti Tunku Abdul Rahman.

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SUBMISSION OF DISSERTATION

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(KWONG CHIN WEI)

DECLARATION

I hereby declare that the dissertation is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Building Information Modelling (BIM) is a construction process that is able to assist throughout a project lifecycle from its conception to commission and moving into the maintenance and operation stage. For example, BIM can be integrated into designing works, cost estimation and budgeting, planning and scheduling, maintenance and operations. Even though BIM has gained its popularity, majority of the firms still opt not to incorporate BIM mainly because they could not afford to purchase the software, in which this was reported in the National BIM Report (2013) that the economy and the lack of funds to invest remained as a barrier to BIM adoption. Another reason may be the construction stakeholders are not aware of the capability of BIM and simply do not know to what extent a BIM tool can assist them in their project. In the National BIM Report (2013), 27% of scepticism exists amongst the practitioners; and from the recent National BIM Report (2018), it is found that there are still 21% of the respondents rather not have BIM adopted.

Several countries have taken initiatives in implementing the BIM process into the construction project. In Singapore, Das et. al (2013) reported that the Building and Construction Authority (BCA) has formulated the BIM Roadmap to steer the industry towards a wider adoption of BIM by year 2015. Das et. al (2013) also reported that the BIM Fund was introduced by BCA to help defray initial investment costs for BIM training, consultancy services and purchase of hardware and software for businesses and projects for the adoption of BIM technology, this initiative is carried out mainly to assist firms in adopting BIM technology into their work processes. While in United Kingdom (UK), professional bodies such as the Royal Institution of Chartered Surveyors (RICS) has added BIM Management into the technical competence of the Quantity Surveying and Construction pathway guide in RICS' Assessment of Professional Competence (APC) (2015); whilst Royal Institute of British Architects (RIBA) (2013) came up with a BIM overlay to the RIBA Plan of Work to suit the changes that has undergone due to the adoption of BIM technology. In Australia, the Australian Government recognises BIM within the built environment. The Built Environment Industry Innovation Council's (BEIIC) Final Report to the Government (2012) made a recommendation to encourage the industry to implement BIM and to consider BIM as a key part of the Government procurement process. Similarly, in Malaysia, the Construction Industry Development Board of Malaysia (CIDB) is also taking initiative in establishing the National BIM Committee in the construction industry. In the Eleventh Malaysia Plan 2016-2020, focus was brought to transforming construction industry through the increase of technology adoption in order to enhance productivity.

1.2 Problem Statement

The construction industry started to implement BIM process in their project lifecycle, they eventually act as the main driver of BIM in the workforce, thus it is foreseeable that the supply of undergraduates with BIM competencies will not be able to meet the demand of the construction industry soon. Therefore, the Higher Education Institutions (HEI) has to act as a vehicle to produce BIM-ready graduates in order to close the gap of demand for graduates with BIM competencies. BIM Academic Forum (BAF) (2013) reported that the HEI in UK are already experiencing the demands for BIM-ready graduates from the industry, hence the need to acquire BIM knowledge and the need for this to be reflected in the graduates' innate skill sets is expected to be critical within the immediate years to come.

1.3 Research Aim

This research aims to identify the competencies required to embed BIM into the Quantity Surveying education, with this, the HEI are able to produce undergraduates that are equipped with the required BIM competencies, in order to meet the demand of BIM-ready graduates in the construction industry.

1.4 Research Objectives

To produce BIM-ready undergraduates, the following objectives are crucial for this research:

1) To explore the knowledge and skills required in the adoption of BIM in the construction industry.
2) To recommend BIM competencies to be embedded in the Curriculum Learning Framework of QS undergraduate programme.

1.5 Research Methodology

This research is based on an inductive approach, whereby the theory only emerges from the data collection and analysing process in order to establish a theoretical framework, in this case this refers to the QS undergraduate programme’s Curriculum Learning Framework. This study falls within the pragmatism paradigm, in which it revolves around quantitative method by collecting data from the distributed survey questionnaires.

A comprehensive literature review started off by giving the reader an introduction on BIM, followed on with the relationship between BIM and QS, by reviewing ways BIM can help to enhance the QS’ professional service and the importance of the HEI in introducing BIM ready QS to meet the demand of the construction industry. A review on the types of competencies and its respective definitions are carried out and subsequently major BIM competences applicable to this study are identified. The 45 competencies narrowed down from the learning outcome statements found in the Initial BIM Learning Outcomes Framework (BAF, 2013) form a major part in the survey questionnaire. Distribution list are merely restricted to QS in various business natures in the construction industry i.e. Developer, Consultant, General Contractor and Specialist Contractor. Respondents' highest qualification ranges from Diploma to Doctorate Degree. Snowball sampling method is selected, in which survey questionnaire were distributed to QS of different positions from various company, and the respondents were then ask to distribute the questionnaire to their colleagues.

Data collected was first analysed using factor analysis, to identify the categorisation of the BIM competencies, the measurable variables are the list of BIM competencies that may be required to be included in QS BIM education. The underlying dimensions were found to be the essential stages to implement BIM competencies in the QS BIM education framework. Subsequently, non-parametric test was conducted to test the significant difference, identify and compare the difference in the respondent's Self-Perceived Maturity Level (SPML) and to analyse their level of BIM understanding

From the data analysed, further steps are taken to identify the knowledge gap and an attempt to match them into the existing RICS Assessment of

Professional Competence's (APC) competencies (RICS, 2015) and Rules and Syllabuses of the Professional Examinations for Quantity Surveying (ISM, 2003).

1.6 Scopes and Limitations

As BIM involves various project stakeholders as follows, but not limited to, project managers, architects, civil & structural engineers, mechanical, electrical and plumbing engineers, QS, contractors, facilities managers; hence in this research the primary focus will be towards the Quantity Surveying profession, that is, to include QS from consultancy firms, developer firms, construction companies, or any other firms that provides quantity surveying services. This research will also focus on QS who works in Malaysia only. The competencies discussed in this study will only be focusing on an individual's competences, hence the data collected from the survey questionnaire is a representation of the individual and does not represent the company they work in.

Another point to note is that, BIM is a popular market trend in the construction industry lately, thus those who understands BIM's function and benefits may only be of a small minority. The collection of survey questionnaire was rather difficult, as prospective respondents that have no knowledge on BIM or have not heard of BIM before refused to answer the questionnaire given.

Therefore, one (1) of the limitations is to reach out to respondents that have no clue about BIM and also to respondents who are new to BIM.

1.7 Research Roadmap

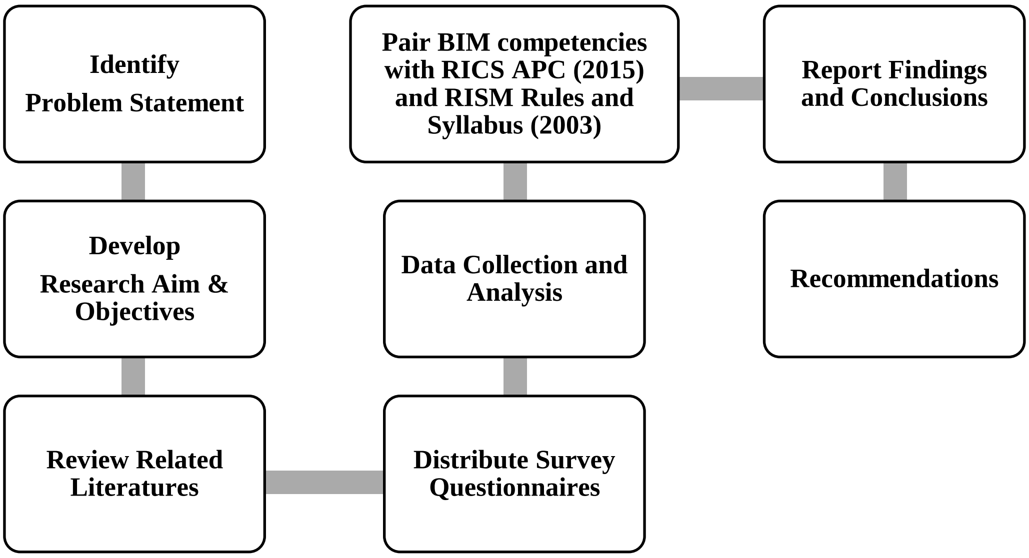

Figure 1.1: Research Roadmap Overview

Chapter one briefly introduces BIM and the changes various Professional Bodies around the globe have done to adapt to the BIM trend. Subsequently, a problem statement is established based on the current issue faced and the research aim and objectives were listed accordingly. A short description on the research methodology was elaborated to give a rough picture on the approach of the research, followed on by the scopes and limitations in carrying out this research. A roadmap of this report as illustrated in Figure 1.1 gives an insight to this research.

Chapter two will be a review of literature on the current issues mentioned in the previous chapter. The definition of BIM were discussed, following by its reported benefits from various firms that employs BIM in their workplace. The relationship of BIM and the QS were discussed by reflecting the benefits of BIM that are able to allow QS to provide a more professional service. Hence to introduce BIM into the QS curricula is essential in order to supply sufficient BIM-skilled graduates to the construction industry. Reviews were also done on the characteristics of BIM to give the readers a better insight on the functions of BIM. This chapter also reviewed the importance of competencies and exploring the type of competences whilst identifying the major three (3) competences to be used in this study. Subsequently the importance of incorporating BIM competencies in the current QS curriculum learning framework.

Chapter three provides an introduction on the research philosophy and approach. The chosen research methodologies and research technique are then described and discussed. An in-depth discussion on how the 45 BIM Competencies are selected, and how the 45 statements are categorised into 14 BIM Capabilities Characteristics and further categorised into the three (3) major competences will be elaborated. The way the survey questionnaire was designed, collected and analysed will also be in this chapter.

Chapter four focuses on the methodology used for analysing the data collected. Factor analysis was conducted to identify the category applicable to BIM education, together with Cronbach's α reliability analysis to further confirm the underlying factors extracted from factor analysis are consistent and reliable. This chapter also explains the type of test used to find out the significant difference between the variables and the newly identified factors, also to identify the trend of the mean ranks between the five (5) levels of BIM proficiency. Subsequently, further test is carried out to identify the statements that are significantly different in the first three (3) Likert scale questions which represents beliefs, knowledge and attitude respectively. Last but not least, competencies known as the knowledge gap will be identified and will be incorporated into the QS undergraduate course.

Chapter five discusses the adequacy of the quantitative data collected from the survey questionnaire. Discussion on the factor analysis results, and the significant differences of the variables is conducted. BIM competencies that are identified as knowledge gaps tabulated into a matrix form to clearly demarcate the relationship of the BIM competencies between the stages of education and the type of competences.

Chapter six concludes the research by reflecting on the aims and objectives set at the beginning of this study. The implications of this study is discussed and this chapter ends with elaborating the limitations of the study and recommendations on ways to improve this study is provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of BIM

Although the general concept and technology behind BIM is approaching its thirtieth anniversary, the industry has only begun to realize the potential benefits of Building Information Models (Quirk, 2012). BIM is defined as the creation and use of coordinated, consistent, computable information about a building project in design-information used for design decision making, production of high-quality construction documents, predicting performance, cost-estimating and construction planning, and, eventually, for managing and operating the facility (Metkari and Attar, 2013).

The information, "I", in BIM must consist of parametric objects. "Parametric object" implies the possibility to reuse object "class" definitions to represent multiple occurrences of similar things; these are termed "instances" of a class and have different attribute values but the same basic structure (Sacks et al., 2004; Eastman et al., 2008). Vandezande et al. (2011) mentioned that these elements share a level of bidirectional associativity, in which, if the elements are changed in a specific place within the model, those changes are visible in all the other views. Weygant (2011) expressed BIM as a technology that allows relevant graphical and topical information related to the built environment to be stored in a relational database for access and management. From these definitions, it can be summed up that BIM is a process of feeding in parametric objects and other relevant information into the related database, and all these inputs are taken as a basis to expedite the construction's project life cycle.

2.2 BIM and the Quantity Surveyors

QS are heavily involved in a wide range of activities from the very beginning to the end of the construction project, which are not limited to the following: preparing cost plans, cost appraisals, estimates, conducting value engineering, brainstorm on design options, advising the client on the suitable procurement methods to be implemented, producing Bill of Quantities (BQ), conducting the tendering process on behalf of the client, administrating contractor's claims, preparing final account and carrying out contract administration works. Throughout the lifecycle of a construction project, the BQ is an important medium for the project stakeholders to have a view on the materials, equipment, system etc. the particular project uses, the granularity of the BQ increases from schematic stage, design development stage, tendering stage.

The past decade has seen a marked rise in the diversification of services into non-traditional areas such as Feasibility Studies, Life Cost Analysis, Programming, Taxation Advice, Arbitration/Mediation, Expert Witness/ Appraisal, Insurance Valuations, Risk Management, Quality Management, Value Management, Project/Construction Management and Facility Management (Smith, 2013)

With the benefits of BIM, the implementation of BIM process will definitely enhance the QS' professional service delivery. As described by Quirk (2012), the BIM workflow is based on the existing building stock and common industry standards and therefore a project which is produced in a BIM platform which emphasizes these tools is likely to reinforce existing paradigms rather than develop new ones. Likewise, BIM assisted cost estimating will not make the role of the estimators obsolete, in the contrary, it can allow them to focus on higher value task than spending most of the time on quantification, hence, giving an increased value to the project processes (Sabol, 2008).

The role of the HEI is to introduce graduates with BIM skills, to fill up the needs of the construction industry (Kymmell, 2008), and to keep the undergraduates on par or ahead of the industry's trend, yet most of the times it is of the opposite pattern whereby the industry acts as a driver to the academic sector. Furthermore, Sacks and Barak (2010) stated BIM-skilled personnel will be in a high demand and currently, the lack of adequately trained personnel is hindering the use and adoption of BIM in the industry. In Singapore, to meet the high demand for skilled BIM manpower, BCA had been working closely with relevant Institutes of Higher Learning, BCA Academy and BIM vendors to incorporate BIM in academic programmes (Teo, 2016). Hence, to keep up with the trend, BIM syllabus has to be introduced to the QS undergraduates in order to narrow down the gap between the supply and demand of BIM ready graduates.

Therefore gap analysis will be used in this study to compare the actual performance with the potential performance. In this research context, potential performance will be referring to the self-perceived maturity level. According to Addagada (2012), in identifying the gap, once the to-be (potential performance) and the as-is (actual performance) models are available, the gaps can be identified. In addition, Addagada (2012) also stated this analysis does not stop with identifying the gaps as one has to draw on the requirements to bridge the gap, estimate the timelines to address them and perform a comprehensive impact analysis.

2.3 Benefits of BIM Implementation

Cartlidge (2011) mentioned that the 1971 RICS report stated that Quantity Surveyor was primarily a producer of Bill of Quantities; and in year 2003, the RICS Quantity Surveying and Construction Professional Group reported that measurement plays an important part to the procurement of buildings. Rundell (2006) stated that quantification requires 50% to 80% of a

Quantity Surveyor’s time on a project. Similarly, RICS Research (2011) found that one of the top three (3) highest workloads in the industry is quantification and costing of construction works. According to Tse et al. (2005), professional opinions on estimating and cash flow management are often characterized by uncertainties, errors, conflicts of interest, omissions and other inadequacies. Similarly, Sabol (2008) stated that, after obtaining the quantities, the process to produce the project cost estimate is usually prone to human error and tends to propagate inaccuracies.

BIM is also able to expedite work, increase accuracy, and also encourage and enhance collaboration among the project stakeholders. It is a platform for the architects’, the civil and structural engineers’ and the mechanical, electrical and plumbing (MEP) engineers’ to sync their data to create a 3D virtual model. After inserting the essential information, the design model will be able to show whether there are any discrepancies in the data given or not. Being able to integrate into a single model, this will shorten time spent on the quantification and measurement process significantly. Therefore, the Bill of Quantities will be able to be generated in a shorter span of time (Rawlinson, 2012).

There is a considerable evidence supporting the rapid adoption of BIM and digital estimating as these approaches promise to positively impact on the future of the construction industry (Olatunji & Sher, 2010). At this juncture, there are already some positive feedbacks on employing BIM in Malaysia. One good example is the Public Works Department's (PWD) BIM pilot project- National Cancer Institute (IKN) in Putrajaya. On December 31, 2011, the project was reported to be 97 days ahead of the schedule (Citizen Journalists Malaysia, 2012), and on a later date, September 19, 2013 it was reported that the hospital was completed on August 16, which is two (2) weeks ahead of its three-year contract completion date (The Star Property, 2013).

According to Latiffi et al. (2013), other BIM pilot projects in Malaysia that are initiated by private agencies are:

1) The Multi-Purpose Hall of Universiti Tun Hussein Onn, Johor;
2) The proposed Educity Sports Complex, which is part of the Newcastle University of Medicine and the Netherlands Maritime Institute of Technology campuses at Johor; and
3) The proposed Hotel Ancasa at Pahang.

Another two (2) pilot projects that will be assisting in the production of families/components of the Revit Families are the Healthcare Centre Project Type 5 (PD 5) at Sri Jaya Maran, Pahang and the Administration Complex MACC Project at Shah Alam, Selangor (PWD, 2013).

The recent National BIM Report (2013) reported that 55% of users found that BIM brought cost efficiencies, 50% agreed that it increases the speed of delivery, and 46% agreed that it increased profitability. According to Sylvester and Dietrich (2010), one of BIM's added value on its estimating methods is that it is able to help estimators visualize real world conditions through a virtual three-dimensional construction of the building. Sabol (2008) adds that BIM offers the capability to generate takeoffs, counts and measurements directly from a model. This provides a process where information stays consistent throughout the project and changes can be readily accommodated. Excelize (n.d.) stated that one of the benefits of BIM is that it is able to achieve an 80% reduction in time to generate estimates. This is further emphasized by ITP (2009) that time issues can be addressed and errors will be eradicated by automating the process. Its benefits are significant for the construction industry, as it does not only provide big savings to the construction cost but is also able to shorten the construction period.

According to one of the case example given by Smith (2006) on the company Mitchell Brandtman, the benefits on employing a BIM software into their workplace was described as: easy to use, short training period for new users, automatically links between drawings and cost planning databases. Another point is that when drawings are changed the revisions are automatically accounted for in the quantities and estimate, thus able to eliminate the previously time consuming task of remeasuring and pricing work when changes are made, and the immediacy of these results where clients can quickly be informed of the cost consequences of proposed changes. This then can enhance the productivity which leads to reduced working hours and better working conditions. Another firm, Turner Townsend Rawlinsons, finds significant time savings on cost plan, estimates and Bill of Quantities (BQ) production. The major benefit was found to be response times for their clients and other project consultants. The ability of the program to quickly calculate the effect of design changes/revisions has changed the landscape in which the firm deals with their clients and raises their services to a much higher professional level. The potential impact of changes can be immediately visualised on the screens in front of the whole team. An added advantage is that the client and project designers are forced into taking ownership of the cost plan/budget and responsibility for design stages.

2.4 BIM Characteristics

Just like any other processes, BIM has its own unique characteristics in which are able to present a holistic view of the project. The characteristics are listed as follows, to give a better view on what BIM is about.

2.4.1 Interoperability

BIM supports the implementation of Integrated Project Delivery (IPD) (Hardin, 2009; Wong et al., 2011). IPD is a project delivery approach which allows the sharing of data between design and construction team, thus it integrates people, systems, and business structures and practices into a collaborative process mainly to reduce waste and optimize efficiency through all phases of the project life cycle (Glick and Guggemos, 2009). Collaboration among project stakeholders is difficult to be achieved at this point as the construction industry is very much fragmented in nature. However, it could be achieved if the various BIM software made for various trades can interoperate at the same digital platform. Therefore, to practice this new approach, one crucial characteristic a software to be considered as ‘BIM’ is - Interoperability.

Interoperability as defined by Institute of Electrical and Electronics Engineers (1990) is the ability of two or more systems or components to exchange information and to use the information that has been exchanged. In a more technical explanation, it can be achieved by mapping parts of each participating application's internal data structure to a universal data model and vice versa (Grilo, & Jardim-Goncalves, 2010). One golden attribute of interoperability is that regardless of the number of times the design changes, or who made the changes, the data remains consistent, coordinated, and more accurate across all stakeholders (Autodesk, 2011). Multiple parties can tap into a BIM project to derive component information for a range of tasks such as environmental compliance, energy analysis, as well as materials take-off and project costing. Sabol (2008) and Maher (2008) added that this feature helps in terms of time saving and improving outcomes through real time communication. Ultimately, according to Marshall-Ponting and Aouad (2005), it can also automate changes, be used and stored not only during design but throughout the project life. Also mentioned by Sabol (2008), this provides a process where information stays consistent throughout the project and changes can be readily accommodated.

According to Eastman et al. (2008) and Sacks et al. (2004), collaboration in design and construction can be described in two ways: internally and externally. In which, “internally” is where multiple users within a single organisation or discipline edit the same model simultaneously, while “externally” is where multiple modellers simultaneously view merged or separate multidiscipline models for design coordination. Whereas in the internal mode objects can be locked to avoid inconsistencies when objects might be edited to produce multiple versions, in the external mode only non-editable representations of the objects are shared, avoiding the problem but enforcing the need for each discipline to modify its own objects separately before checking whether conflicts are resolved.

2.4.2 Visualisation

Visualisation is one of the characteristics that is useful especially to the design team and the clients. With rapid visualization (Manning and Messner, 2008), project stakeholders can gain more insight and have a better picture of their projects (Vandezande et al, 2011); design team members can spot the flaws prior to the construction of the building; clients would be able to get the imagination of the design right by looking at the realistic view generated, hence can make better decisions from it, as decisions according to Vandezande et al.

(2011) indirectly affect the project cost, schedule, and sustainability of the building. Kymmell (2008) mentioned that the BIM approach includes a level of planning that are almost similar with forecasting, which requires a certain level of confidence to be able to carry out this skill. Furthermore, he also emphasised that BIM attracts people who has the tendency and aptitude to observe and plan in enough detail to understand a project's current status so that its future can be better visualised.

2.4.3 Clash Detection

Existing conflicts can be discovered and thus adequate steps can be done to rectify the conflicts during the design and planning phase. Also highlighted by Grilo, & Jardim-Goncalves. (2010), it is far more effective to coordinate these building systems using a visual approach with a 3D model, so that the location and relationships of all the components and their potential conflicts can be resolved during the project's planning phases. By identifying the conflicts, expense on modification of the work together with the inefficiencies of labor, material, and transportation can be avoided (Kraus, Watt & Larson, 2007).

2.4.4 Building Walkthrough/ Realistic View on Construction Design

Project stakeholders will be able to experience a building walkthrough after the construction design is carried out by getting a realistic 3D view. It provides a better marketing strategy; moreover, it is also able to enhance spatial coordination, interior design and building massing (Kraus, Watt & Larson, 2007). Thus, as mentioned by Azhar (2011) it helps project stakeholders by being able to visualize what is to be built in a simulated environment to identify any potential design, construction, or operational issues.

2.4.5 Construction Sequence/ Simulation

Project stakeholders can also visualize the constructability and construction sequences from a complete 3D BIM (Grilo, & Jardim-Goncalves, 2010; Kraus, Watt & Larson, 2007). Kong and Li (2009) and Li et al. (2009) stated that during the coordination process, conflicts can be observed and solutions can be developed respectively, subsequently, alternatives on construction plan can be evaluated, thus, from these features, collaboration techniques and protocol among the project team members can be established. Although this feature has led to considerable increases in human workforce and other costs incurred during the preplanning phase, however all these extra cost incurred prior to the construction are offset by the savings in the aspect of labor, rework and fast completion (Kraus, Watt & Larson, 2007).

By understanding the characteristics, it is shown that BIM has the ability to promote greater transparency and collaboration between members of the construction team and thereby reduce waste throughout all levels of the supply chain (HM Government, 2012). With the construction industry already started implementing BIM in their work; there will be a surge of BIM-ready employees. Hence to cater to the demand, HEI should incorporate BIM into the QS curriculum.

2.5 BIM in the Academic Sector

Education on BIM serves as a huge stepping stone to the construction industry, especially to firms which just started to implement the BIM software, as it does not only reduces the steepness of the learning curve, but also to give a sense of readiness to the industry. Grasping new concepts of BIM is a great challenge; hence, numerous approaches have been adopted to introduce BIM in the curricula (Woo, 2007).

Education on BIM is essential to keep undergraduates on par with the present demand of the industry. BIM has been described to be a reliable tool and is benefiting to the construction industry in many aspects as mentioned earlier. Thus, it would definitely be beneficial for QS to embrace its existence rather than repelling it. Hence, a serious thought to adopt BIM into the QS curriculum should be taken. By implementing BIM, a full curriculum review should be carried out to allow every module to identify changes required for delivery through a BIM model.

Years ago, McKeown and Hopkins (2004) suggested to include sustainable development in the HEI's programme, one should increase the awareness and link it to the existing issues and to have an idea on how to structure and place the topic into the course curriculum. Likewise, for BIM to be included in the undergraduate programme, these steps should be considered to be implemented. Therefore, one must find ways to increase the awareness of both the educational community and the practitioners on what BIM is and what it can achieve, in order to show them that reorienting education towards BIM is essential.

2.6 Competences and BIM Competencies

There are several schools of thoughts on the definition of competence. Boyatzis (1982) are more interested in the individual aspect of competence, in which it refers to the set of skills that an individual must possess in order to be capable of satisfactorily performing a specified job. Hamel and Prahalad (1990) referred competence to an integrated set of core technologies and core skills that provide an organization with its competitive advantage. The competence is more organisationally driven rather than individually focused. Holmes and Joyce (1993) defined competence as action, behaviour or outcome which a person should be able to demonstrate, or the ability to transfer skills and knowledge to new situations within an occupational area. Roggema-van Heusden (2004) defined competence as the ability to perform well in a professional situation that involves the accomplishment of a certain task or the dealing with a problem, in a manner that can be observed and be judged by others. Whilst Caupin et al. (2006) described competence as a collection of knowledge, personal attitudes, skills and relevant experience needed to be successful in a certain function. Succar et al. (2013) explained that competency may be understood by analyzing its component parts. He also deduced that an individual's abilities are the aggregate sum of three (3) components – knowledge, skill and personal traits.

The following discussion is to review the main BIM competency categories that are required to house the competencies. In this literature review, method of categorisation by four (4) individuals/forums will be analysed and compared. The four (4) individuals/forums referred to are Kymmell (2008) in which the skills sets required for creating and managing BIM are categorised into Tool-related, Process-related and Role-related skills; Caupin et. al (2006) has a different range of competencies grouping: Contextual, Behavioural and Technical competency; Building Academic Forum (BAF) (2013) published the initial BIM learning outcome framework in which the framework covers three (3) types of competencies: Strategic, Management and Technical Competency; and Succar et al. (2013) introduced the competencies tiers hierarchy, which consists of three (3) BIM competency tiers: Core, Domain and Execution competency.

Referring to Kymmell (2008) categories of skills, the content of each skill set is described as below:

"(i) The tool-related skill set is typically technical. It involves the ability on visualisation of the modelled objects (and concepts), the accuracy of the represented objects, and the organisation of the model parts.

(ii) The process-related skill set is chiefly conceptual. It involves working with a new form of communication emerged from process based on collaboration work which introduces a certain degree of complexity that requires care; managing of concentration of information which can be space-, location- and time-related information and address the hierarchy of coordination.

(iii) The role-related skill set is primarily psychological and social. In a fully-functioning team, all members will support one another and understand their mutual interdependence."

On the other hand, the categories of competencies grouped by Caupin et al. (2006) in the International Project Management Association Competence Baseline (ICB) are as below:

"(i) The technical competence range: to describe the fundamental project management competence elements. This range covers the project management content, sometimes referred to as the solid elements.

(ii) The behavioural competence range: to describe the personal project management competence elements. This range covers the project managers' attitudes and skills.

(iii) The contextual competence range: to describe the project management competence elements related to the context of the project. This range covers the project manager's competence in managing relations with the line management organisation and the ability to function in a project focused organisation."

Details of the competencies referred to by Succar et al. (2013) are as follows:

(i) Core competency: The personal abilities of individuals enabling them to conduct a measureable activity or deliver a measureable outcome. This competency is further subdivided into four (4) sets of competency, they are:

a. Foundational Traits: refers to the personal attribute inherent in an individual that cannot be acquired through training or education i.e. individual's attitude, behavior, motivation etc

b. Situational Enablers: this refers to the personal attributes related to nationality, language and other criteria which may play a relevant role when delivering a service or product.

c. Qualifications and Licenses: this is related to the existence or sufficiency of academic degrees, scientific publications, professional accreditations, trade/skill certificates or licenses.

d. Historical Indicators: this attributes that are related to employment history, project experiences, roles played and position held.

(ii) Domain competency: The professional abilities of individuals, the means they use to perform multi-task activities and the methods they employ to deliver outcomes with complex requirements. This competency has eight (8) competency sets, they are categorised into two (2) categories:

a. Primary sets:

1. Managerial: This competency is basically referring to the decision-making abilities which drive the long-term strategies and initiatives. Examples of competencies are leadership, strategic planning and organisational management.

2. Functional: This competency is non-technical, it is the overall abilities required to initiate, manage and deliver projects. Examples of competencies are collaboration, facilitation, and project management.

3. Technical: This competency refers to the individual

abilities required to generate project deliverables across disciplines and specialties. Examples of competencies are modelling, drafting and model management.

4. Supportive: This competency refers to the abilities required to maintain information and communication technology (ICT) systems. Examples are ICT support, hardware maintenance and software troubleshooting.

b. Secondary sets:

1. Administration: This competency refers to the activities needed to achieve and maintain the organisational objectives. Competencies such as tendering and procurement, contract management and human resources management are categorised into the administration competency sets.
2. Operation: This competency refers to the practices and efforts required to deliver a project or part/aspect of a project. Example of operational competencies are designing, analysing, simulating and estimating.
3. Implementation: This competency refers to the activities required to introduce transformative concept and tools into an organisation. Examples of this competency include component development, library management and standardisation.
4. Research and Development: This competency refers to

the activities required to evaluate existing processes, investigate new solutions and facilitate their adoption within the organisation or by the larger industry.

(iii) Execution competency: An individual's ability to use specific tools and techniques to conduct an activity or deliver a measureable outcome.

As for BAF (2013), the three (3) categories shown in the Preliminary BIM Learning Outcomes Framework, as attached in Appendix A, were not described in detail. However, the concept is presumed to be similar. The Strategic competency mainly includes leadership, project team partnering, up-skilling, systems and process management etc. With reference of the competencies listed by Succar et al. (2013), the Strategic competency is part of the Managerial and Functional competency sets.

The Management competency from BAF (2013) covers the acquiring of internal resources, developing organisational business plan, managing external requirements, managing technical infrastructure etc. This competency is similar to the Administration, Operation, Implementation, and Research and Development competency sets in regards to Succar et al.'s (2013) Domain competencies.

While the third competency from BAF (2013): Technical, consist of activities on developing design solutions, implementing procurement processes, managing and operating technical information systems etc. which is similar to Succar et al.'s (2013) Technical and Supportive competency sets, and the Execution competency, besides that just like the Management competency, it also falls into the Administration, Operation and Implementation competency sets.

As for the Behavioural competency as described by Caupin et al. (2006) in the International Project Management Association Competence Baseline (ICB), it is described as the personal project management competence elements, which covers the project managers' attitudes and skills. This Behavioural competency can be grouped together with Succar et al.'s (2013) Core competency, which defined as the personal abilities of individuals enabling them to conduct a measureable activity or deliver a measureable outcome. Behavioural competency and Core competency are similar as both of the primary focus is on an individual's personal attributes.

From the various group of competencies discussed above, the competencies are then rearranged according to their definition, with no particular order, as illustrated in the Figure 2.1. As the definition of the competencies are somehow overlapped with one another, the core competencies identified to be used in this research in order to categorised various general and specific competencies are: Contextual, Behavioural and Technical.

The competencies in an undergraduate's curriculum are important to produce competent graduates that are able to practice the skills taught in the course curriculum when they started working in the industry. Not only relevant technical and conceptual skills have to be instilled in the undergraduates, related behavioural skills are also necessary to assist the graduates to react and response towards situation that are out of the book. Hence, in order to produce more BIM educated students for the construction industry; the HEI has to identify the competencies required in order for BIM to be incorporated in the course curriculum.

Apart from fundamental QS technical knowledge, it is important for QS students to acquire soft skills to help them carry out their work in a competent manner (Said, Shafiei, and Omran, 2010). The competencies taught to the graduates have to be consisted of several groups of skills to ensure graduates are competent enough to work in the industry. Hence this brings the importance of BIM competencies in the QS curriculum, as the lack of exposure to the essential BIM workflow and managerial aspects of delivering BIM projects is a major drawback of the existing HEI's BIM curriculum and it undermines students' learning outcomes (Wu and Issa 2013).

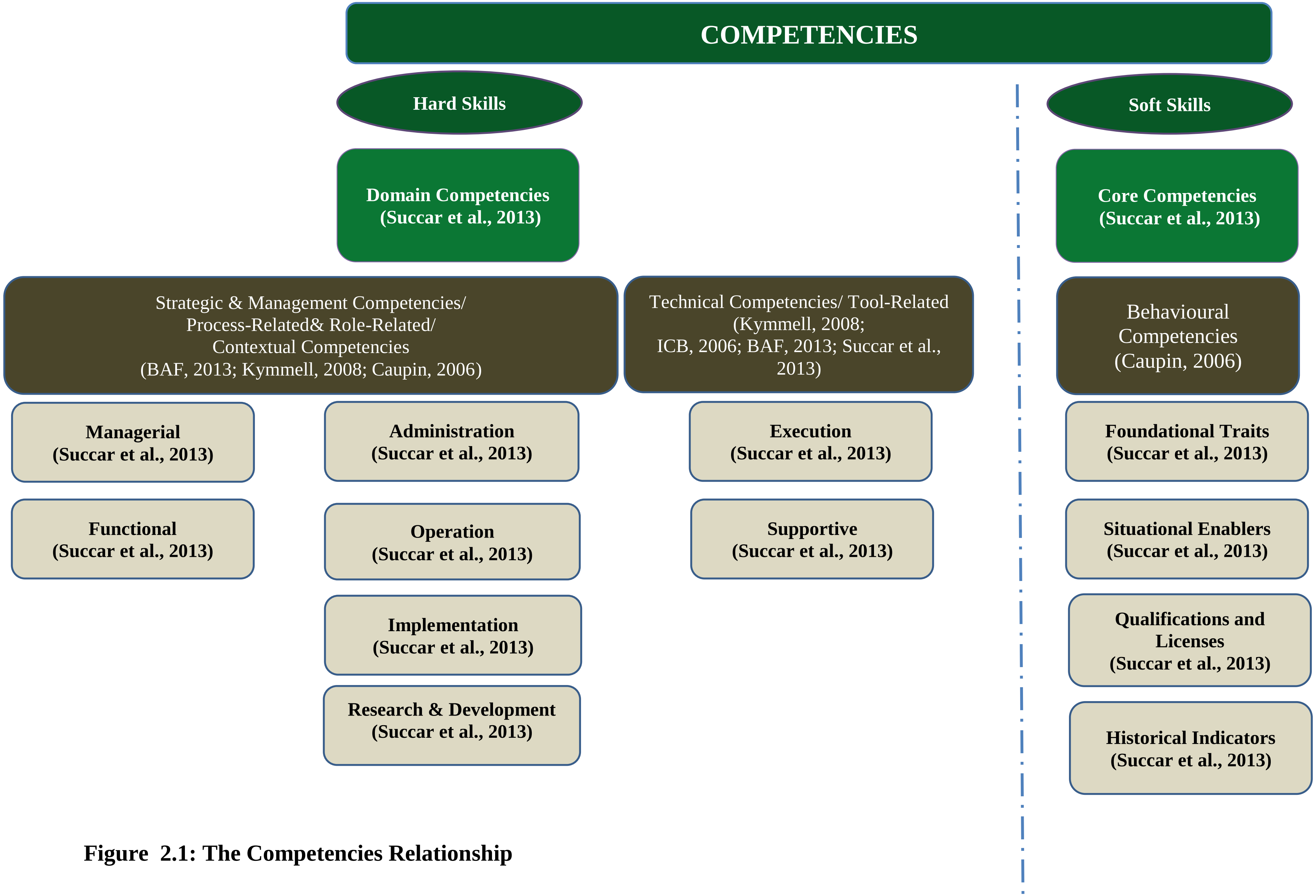

Figure 2.1: The Competencies Relationship

2.7 Summary

No one can stop or unwind the clock and expects the time to stop. As the idiom says ‘time and tide waits for no man’, the technology will keep moving forward, everyday there will be a new system created and new things to learn. Traditional means of education will not be obsolete in future, as students will still need to understand the history and the logic behind conducting a task manually, only by understanding the logic the students will then be able to perform a task knowingly, but unfortunately this will not help the students to adapt to the working environment as fast as before. Hence, to reiterate, HEI should consider embedding BIM competencies into the QS curriculum to supply BIM-ready QS to the construction industry.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the research philosophy selected, research technique and design applied i.e. reviewing literature, distributing questionnaires, sampling method, data analysis and refining the analysed data, in order to achieve the research goal which is to identify the competencies required to embed BIM into the Quantity Surveying education.

3.2 Research Approach

Research philosophy is an important part of research methodology in order to collect data in an effective and appropriate manner (Williams, 2011). According to Creswell (2009), there are four (4) types of philosophy: postpositivism, constructivism, advocacy and pragmatism. These philosophies as described by Creswell (2009) are seen as a general orientation about the world and the nature of research that a researcher holds. This research is more of an inductive approach, whereby the theory only emerges from the data collection and analysing process in order to establish a theoretical framework. Therefore, this study falls within the pragmatism paradigm, in which, according to Patton

(1990) it conveys its importance for focusing attention on the research problem in social science research, thus the study revolves around quantitative method by collecting data from the distributed survey questionnaires.

3.3 Research Technique and Design

As the research philosophy of this study is pragmatism, other than having literature review carried out, the next important research technique is distributing survey questionnaire for data collection, analysing the data collected and further refine the data analysed in order to identify the BIM competencies required to be embedded in the Curriculum Learning Framework of QS undergraduate programme.

3.3.1 Literature Review

The literature review is an on-going exercise, literature review is carried out throughout the process of this research, until it is completed. An elaborated overview on the general concept and definition of BIM was given to provide the reader a brief introduction on BIM. This follows on with reviewing the literature on the relationship of BIM and QS, on how BIM can enhance the QS' professional service and the importance of the HEI in introducing BIM ready QS to cater for the supply and demand of the construction industry. The benefits of BIM implementation in which the experiences by several individuals and firms were listed and the characteristics a BIM tool possesses ie. interoperability, visualisation, clash detection, building walkthrough, construction sequence simulator are reviewed. This leads to the study of the importance of having BIM in the QS curricula and the importance of identifying BIM competencies in order to bridge the gap of the supply and demand of the BIM-skilled personnel in the construction industry. Reviews are also conducted on types of competences, in which it can be grouped into two (2) major skills i.e. Hard skills and Soft skills, can also be called as Domain competencies and Core competencies respectively. Competencies definition and types given by different organisational bodies or authors are generally found to be similar and for the purpose of this research, three (3) types of BIM competencies will be applicable in this study are Contextual, Behavioural and Technical Competences.

3.3.2 Survey Questionnaire

The objective of the distribution of survey questionnaire is to collect sufficient data to identify the BIM competencies that are currently lacked of in the existing HEI's curriculum. Distribution list are merely restricted to QS in various business natures in the construction industry i.e. Developer, Consultant, General Contractor and Specialist Contractor. Respondents' highest qualification ranges from Diploma to Doctorate Degree.

The design of the survey questionnaire consists of three (3) segments: First segment consist of Likert scales on a list of 45 BIM competencies which was filtered and grouped from the 52 BIM competencies listed in the Initial BIM Learning Outcomes Framework by BAF (2013). How the 45 BIM competencies are selected will be explained in the next paragraph. This Likert scales comes in three (3) parts and that is to assess the level of Belief (A1), Knowledge (A2) and Attitude (A3). The first part, A1, consists of the 14 BIM capabilities, which is to assess the level of Belief of the respondent, where respondents are required to rate their awareness on the capabilities, the second part, A2, is to assess the level of Knowledge of the respondent, where respondents are required to rate their competency based on the 45 BIM competencies identified, and third part, A3,of the Likert scale is to test the respondents' attitude towards BIM implementation based on the 45 BIM competencies; Second segment consists of close-ended questions on the respondent's history towards BIM and; Third segment was to obtain the respondent's attributes.

The 52 learning outcome statements found in the Initial BIM Learning Outcomes Framework (BAF, 2013) which are categorised into Strategic, Management and Technical are taken to be as the BIM competencies. The list are subsequently narrowed down into 45 competencies due to some statements appear to be an overview of the learning outcomes, i.e. BIM value proposition, Government requirement from BIM, Industry context of BIM adoption, and Impact to client and supply chain relationship. These statements encompass a range of other listed learning outcomes, thus may not be appropriate to be considered as an individual BIM competency. Similarly, this also applies to the following strategic and management learning outcome, i.e. The role of executive leadership and The need to openly discuss issues associated with BIM adoption respectively, in which the characteristics of this statement can be found across statements like: Engage organisational stakeholders to BIM adoption, Evaluate the impact on internal and external roles posed upon BIM adoption, Engage business stakeholders upon BIM adoption, and Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption. As for the statement Developing the business case that is listed under the Strategic learning outcome, it is merged into developing the business case, investment and return model statement which can be found in the Management list of learning outcomes. This is merged simply due to the findings from the review of the literature that Contextual competency is the same as Strategic and Management competency. To recap, as per Chapter 2 in this study the competency categories will be used are: Contextual, Behavioural and Technical.

The 45 BIM Competencies identified are then grouped into 14 BIM capabilities characteristics as shown in Table 3.1. Figure 3.1 illustrates the workflow from the 52 statements of learning outcomes, narrowed down into 45 BIM competencies and finally categorised into three (3) major competences.

Table 3.1: 14 BIM Capabilities Characteristics and its Competences

No	BIM Capabilities Characteristics and its Competences
	CONTEXTUAL
1	<u>Business case of BIM</u> 1. Develop the business case, investment and return model upon BIM adoption 2. Apply BIM in alignment with organisational goals 3. Gain commitment upon BIM adoption 4. Develop the business goals and plans upon BIM adoption 5. Invest in up-skilling, systems and process management upon BIM adoption
2	<u>Team Engagement</u> 6. Engage organisational stakeholders to BIM adoption 7. Evaluate the impact on internal and external roles posed upon BIM adoption 8. Engage business stakeholders upon BIM adoption 9. Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption
3	<u>Developing BIM Execution Plans</u> 10. Develop frameworks and guidance and execution plan for BIM adoption 11. Consider strategic issues required on BIM adoption
4	<u>Legal Implications</u> 12. Aware of authority requirements posed upon BIM adoption 13. Identify the liability implications posed upon BIM adoption
	BEHAVIORAL
5	<u>Collaboration</u> 14. Collaborate with project teams upon BIM adoption 15. Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption

	TECHNICAL
6	Visualisation 16. Utilise BIM to visualize the project and understand the relationships of the various components to one another 17. Utilise BIM to build 3D models and construct virtual model 18. Utilise BIM to develop the model into an acceptable representation of what is visualized
7	Managing and Reducing Risks (ie QTO) 19. Reduce the project risks with BIM 20. Identify and manage risks upon BIM adoption
8	Facilities Management 21. Utilise BIM to manage project handover and facilities information 22. Utilise BIM to manage the use and maintenance of facilities
9	BIM Information Management 23. Compare examples of successful BIM implementation 24. Define the common language and terminology associated with BIM adoption 25. Implement governance of information and process management with BIM adoption 26. Implement data and process standards upon BIM adoption 27. Identify the project requirements with BIM 28. Utilise BIM to manage design information 29. Utilise BIM to manage and operate technical information systems
10	ICT Management 30. Identify the hardware, software and network infrastructure requirements upon BIM adoption 31. Evaluate and select software and technology upon BIM adoption
11	Scheduling and Estimating 32. Utilise BIM to analyse and plan construction and installation work processes and resources 33. Utilise BIM in scheduling and estimating
12	Constructability and Coordinating Construction 34. Use BIM to assist in achieving productivity and efficiency improvements 35. Communicate the impact of BIM adoption 36. Utilise BIM to assess contextual data affecting potential developments 37. Utilise BIM to develop design solution 38. Utilise BIM to coordinate and control construction and installation operations 39. Utilise BIM to assess the condition of existing assets
13	Whole Life Cycle Costing 40. Use BIM in the whole life inter-disciplinary design 41. Use BIM in achieving sustainable design 42. Utilise BIM to assess the energy performance of buildings
14	Procurement Method/Supply Chain Management 43. Analyse the data deliverables for clients and the supply chain required upon BIM adoption 44. Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption 45. Utilise BIM in procurement processes

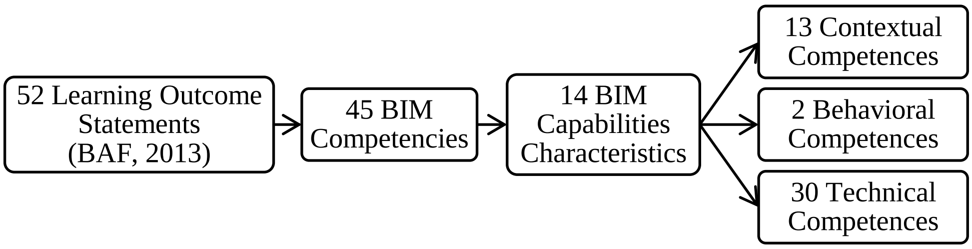

Figure 3.1: Competences Categorisation Process

3.3.3 Sampling Method

The objective of sampling is to provide a practical means of allowing the data collection and processing components of research to be conducted, at the same time ensuring that the sample provides a good representation of the population (Fellows and Liu, 2008).

There are three (3) types of sampling method classified by Fellows and Liu (2008) i.e. random sampling, judgemental sampling, and non-random sampling. Non-random sampling can be further divided into five (5) kinds of sampling method, i.e. systematic sampling, stratified sampling, cluster sampling, convenience sampling, and snowball sampling. Random sampling is carried out using random numbers, either from tables or from computer programs. Judgemental sampling is based on the judgement of the researcher which items of the population should form the sample. Systematic sampling selects a member of the population at a particular interval to form the sample, starting from a random point of the population. Stratified sampling is used when the population occurs in “distinct” groups or strata. The number of samples coming from different stratum is proportioned according to the relative importance of each stratum, while the sampling within each stratum is done randomly. Cluster sampling is appropriate where a population is divided into groups which inter-group differences are small whilst intra-group differences are large. The clusters are selected randomly and the total members of the clusters provide the total sample. Convenience sampling may be used where the nature of the research question(s) and the population do not indicate any particular form of sample and so, the researcher collects data from a sample which can be accessed readily (it is convenient). Snowball sampling is used when data are difficult to access, so the researcher starts with a small number of sources (respondents), and progressively building a sufficient sample by asking the sources to identify further sources.

As there is only a handful of QS in various business nature in the construction industry understands the general concept of BIM and the benefits of it with relations to the QS’ daily routine, and majority of the QS is still being ignorant to the extent of benefits that BIM is capable of, mainly because they fear that their job will be replaced, hence it is anticipated that the response rate will be low due to the nature of this research. In this study, snowball sampling method is selected, in which survey questionnaire were distributed to QS of different positions from various company i.e. the consultant and contractor industry, and the respondents were then ask to distribute the questionnaire to their colleagues.

The targeted respondents are QS from various local company with different business nature, they are not limited to the following developer, consultant, general contractor and specialist contractor. As this research aim is to identify the competencies required to embed BIM into the Quantity Surveying education, thus in order to identify the gap between the QS in the construction industry and the 45 competencies, the respondents can either have knowledge or partial knowledge on BIM or no knowledge at all.

The first batch of survey questionnaire was distributed online via Google form, from 1 August 2016 to 26 December 2016, in which 120 questionnaires were responded. Later in the study, it is decided to further fine tune the results and discussion of this study, hence the second batch of survey questionnaire was distributed via Google form and formally by hand, from 10 January 2018 to 15 March 2018. This round as there were time limitations, the questionnaires are sent to QS at the upper management level, and instructions cascades down to the lower management level to request their employee to participate in the questionnaire, this successfully yields another 130 respondents. This gives a total of 250 respondents received.

A detailed breakdown of the respondents will be provided in the next chapter on analysis of data. Generally, the 250 samples returned are adequate. This is evident in the analysis in Chapter 4 (4.2 Factor Analysis), as the adequacy of the samples are verified with KMO and Bartlett's Test and the results generated from conducting factor analysis.

3.3.4 Data Analysis

Data collected was first analysed using factor analysis. There are two types of factor analysis 1) principal component analysis (PCA) and 2) common factor analysis (CFA). PCA is a data reduction method used to summarize a large set of variables, is applicable when there is a need to accurately report and evaluate a large number of variables using fewer components, while still preserving the dimensions of the data (DeCoster, 1998). As for the latter, the researcher first has to hypodissertatione that there should be a predetermined number of factors, and uses path analysis diagrams to represent variables and factors (Child, 2006). PCA was selected to perform on 250 samples of respondents on the ratings of their proficiency level as PCA is not only a widely used extraction tool, it is also the most suitable to be used for data reduction (Beavers et. al, 2013). In this research, PCA was performed to identify the categorisation of the BIM competencies, the measurable variables are the list of BIM competencies that may be required to be included in QS BIM education. The underlying dimensions were found to be the essential stages to implement BIM competencies in the QS BIM education framework.

Prior to safely considering the application of factor analysis for this research paper, there are a few criteria to be met. The Kaiser-Meyer-Olkin Test (KMO) measures the sampling adequacy and to test if factor analysis is suitable to be performed on the collected data. KMO values between 0.8 and 1.0 are interpreted as "meritorious" and "marvellous" and that the sampling is adequate, whilst KMO values below 0.6 is regarded as "miserable". To further confirm that the variable has patterned relationships, the Bartlett's Test of Sphericity has to show a significant level of $p < 0.05$.

To further verify the sampling adequacy, the diagonal element of the Anti-Correlation matrix has to be above 0.50. Correlation coefficients, $r < 0.30$ shows a lack of patterned relationships, while correlations, $r > 0.90$ indicate that the data may have a multi-collinearity issue. Further to that, to check if the factor model is a good fit, Field (2005) states that the model has to have less than 50% of the non-redundant residuals with absolute values that are greater than 0.05.

Guadagnoli and Velicer (1988) explains that the required sample size depends on the strength of the factors and the items. For instance, if the factors with four or more items with loadings of 0.60 or higher, this will render the sample size irrelevant. If the factors have 10 to 12 items that load 0.40 or higher, then a sample size of 150 or more is needed to be confident in the results. And if factors are defined with few variables and have moderate to low loadings, a sample size of at least 300 is needed. Fabrigar et al. (1999) and MacCallum et al.

(2001), further support that stable solutions can be reached with samples as low as 100 when three to four strong items, factor loadings of 0.70 or greater comprise a factor. These criteria will be analysed in Chapter 4.

Subsequently, non-parametric test was conducted to test the significant difference, identify and compare the difference in the respondent's Self-Perceived Maturity Level (SPML) and to analyse their level of BIM understanding:

1) Kruskal-Wallis test was carried out on the three (3) factors derived from the factor analysis, which refers to the stages to implement BIM competencies in the Curriculum Learning Framework of QS undergraduate programme i.e. Conception Stage, Implementation Stage and Optimization Stage, against the second segment of the questionnaire.
2) Friedman test was carried out by using the 45 statements of potential BIM competencies against the variable: Was BIM part of your course syllabus in the university?

3.3.5 Refining Analysed Data

Gap analysis was conducted to identify the list of competencies that are required in the QS undergraduate programme. After identifying the list of competencies that have the biggest gap, the competencies are then paired with the RICS Quantity Surveying and Construction Assessment of Professional Competence (APC) (RICS, 2015) and the Rules and Syllabuses of the Professional Examinations for Quantity Surveying (ISM, 2003)

3.4 Summary

A brief discussion was carried out on the research philosophy and research approach with the elaboration on the research design to be used in this research study. The next chapter discuss the analysis of data from the questionnaires collected.

CHAPTER 4

RESULTS

4.1 Overview

This chapter presents the results of the analysis conducted on the quantitative data from the survey questionnaire collected. Quantitative analysis carried out in this chapter are as follows: (i) Factor analysis to identify the category applicable to BIM education, together with Cronbach's α reliability analysis to further confirm the underlying factors extracted from factor analysis are consistent and reliable; (ii) Kruskal Wallis Test to find out the significant difference between the variables and the newly identified factors, also to identify the trend of mean ranks; (iii) Kruskal Wallis Test to further identify the statements that are significantly different in question A1, A2, A3 which represents beliefs, knowledge and attitude respectively; (iv) Friedman Test to identify the competences that are required by the graduate in the construction industry.

4.1.1 General Characteristics of Respondents

Questionnaires were only distributed to those practising quantity surveying. There are a total of 250 questionnaires collected. The nature of business the respondents are involved in can be found in Table 4.1. The ratio of developer, consultant, general contractor, specialist contractor and others are 13.6%, 48.8%, 26.8%, 9.2% and 1.6% respectively. In which the other nature of business consist of being in the authority department at 0.8% and in the academic industry at 0.8%. The type of specialist contractor was not provided in detail by the 23 respondents.

Table 4.1: Company's Nature of Business

Company's Nature of Business	Number of Respondents	Ratio (%)
Developer	34	13.6
Consultant	122	48.8
General Contractor	67	26.8
Specialist Contractor	23	9.2
Others:		
Authority department	2	0.8
Academic industry	2	0.8
Total	250	100.0

Respondents' years of working experience, is summarised in Table 4.2. The ratio of respondents with less than 2 years' experience, more than 2 but less than 5 years, more than 5 but less than 10 years, more than 10 but less than 20 years, and more than 20 years are 16.8%, 49.6%, 17.2%, 11.6% and 4.8% respectively.

Table 4.2: Years of Working Experience

Working Experience	Number of Respondents	Ratio (%)
Less than 2 years	42	16.8
More than 2 but less than 5 years	124	49.6
More than 5 but less than 10 years	43	17.2
More than 10 but less than 20 years	29	11.6
More than 20 years	12	4.8
Total	250	100.0

Respondents' highest qualification level is summarised in Table 4.3. The ratio of respondents with a diploma, advance diploma, bachelor degree and master degree qualification are 1.2%, 2.0%, 88.8% and 8.0% respectively.

Table 4.3: Highest Qualification

Highest Qualification	Number of Respondents	Ratio (%)
Diploma	3	1.2
Advance Diploma	5	2.0
Bachelor Degree	222	88.8
Master Degree	20	8.0
Total	250	100.0

Respondents' number of years with current job title is summarised in Table 4.4. The ratio of respondents with less than 2 years' experience, more than

2 but less than 5 years, more than 5 but less than 10 years, more than 10 but less than 20 years, and more than 20 years are 64.4%, 27.6%, 5.6%, 1.6% and 0.8% respectively. Table 4.5 refers the summary of the type of university. The ratio between local university and foreign university is 82.8% and 17.2% respectively. In Table 4.6, it shows that there are 59.6% of respondents whose university do not have BIM as part of their course syllabus, whilst there are 40.4% of respondents who came from university that has BIM as part of their course syllabus. This can be further refined in Table 4.7, in which the ratio of the method BIM was taught or introduced in the university i.e. as a course or individual subject, by inviting guest speaker or guest lecturer, by embedding BIM in the subject and none of the above are 26.0%, 17.2%, 14.8% and 42.0% respectively. In Table 4.8, the ratio on means of knowing or receiving BIM information, i.e. formal education, on-the-job training, professional development and none of the above are 34.8%, 27.6%, 21.2% and 16.4% respectively.

Table 4.4: Number of Years with Current Job Title

Number of Years with Current Job Title	Number of Respondents	Ratio (%)
Less than 2 years	161	64.4
More than 2 but less than 5 years	69	27.6
More than 5 but less than 10 years	14	5.6
More than 10 but less than 20 years	4	1.6
More than 20 years	2	0.8
Total	250	100.0

Table 4.5: Type of University

Type of University	Number of Respondents	Ratio (%)
Local University	207	82.8
Foreign University	43	17.2
Total	250	100.0

Table 4.6: BIM Part of the University Course Syllabus

BIM Part of the University Course Syllabus	Number of Respondents	Ratio (%)
No	149	59.6
Yes	101	40.4
Total	250	100.0

Table 4.7: Method on BIM was taught/introduced in the University

Method on BIM was taught/introduced in the University	Number of Respondents	Ratio (%)
As a course/individual subject	65	26.0
By inviting Guest Speaker/Guest Lecturer	43	17.2
By embedding BIM in the subject(s)	37	14.8
None of the above	105	42.0
Total	250	100.0

Table 4.8: Means of Knowing or Receiving BIM Information

Means of Knowing or Receiving BIM Information	Number of Respondents	Ratio (%)
Formal Education	87	34.8
On-The-Job Training	69	27.6
Professional Development	53	21.2
None of the above	41	16.4
Total	250	100.0

4.2 Factor Analysis

Factor analysis is performed to classify data on several measurable and observable variables into fewer latent variables that share a common variance which are often unobservable (Bartholomew, Knott, & Moustaki, 2011). In this research, the measurable variables are the list of BIM competencies that may be required to be included in QS BIM education.

There are a few criteria to be met prior to safely considering the application of factor analysis for this research. As per the data interpretation of each test described in Chapter 3 (3.3.4 Data Analysis), with reference to Table 4.9, the KMO value is at 0.960, in which the degree of common variance in this case shall be interpreted as “marvellous”. To further confirm that the variable has patterned relationships, the Bartlett’s Test of Sphericity is shown to be significant as $p < 0.001$, hence this provides evidence that the observed correlation matrix is statistically different from a singular matrix, and confirmed that there is a patterned relationship.

Table 4.9: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.960
Bartlett's Test of Sphericity	Approx. Chi-Square	15,663.752
	df	990
	Sig.	0.000

To further verify the sampling adequacy, the diagonal element of the Anti-Correlation matrix has to be above 0.50, in which in this research, the lowest individual diagonal element is: Aware of authority requirements posed upon BIM adoption at 0.578, please refer to Appendix C on the Diagonal Element of the Anti-Correlation Matrix.

Referring to the Coefficient Matrix in Appendix D, the correlation coefficients are between 0.477 and 0.862, thus showing that it has a patterned relationship between the variables. The Total Variance Explained table in Appendix E shows that there are a total of three (3) numbers of underlying factors with eigenvalues greater than 1, which explains 75.1% of the total variance. The Rotated Component Matrix in Appendix F further endorses that there are three (3) numbers of significant factors. Furthermore, majority of the factor loadings of each component as seen in Appendix F are 0.60 and higher, this signifies the sample size of 250 is adequate. From the tests above, it is safe to conclude this research sample size is suitable for PCA to be carried out.

4.2.1 Principal Components Analysis

The collected data was subjected to factor analysis using PCA and Varimax rotation. There are 14 out of 45 variables that load less than 0.60, however from the Correlation Matrix and Bartlett's Test of Sphericity it is shown that they are significantly correlated, hence it is decided that all 45 variables are retained for further interpretation.

From the Rotated Component Matrix in Appendix F the three (3) factors are listed as per Table 4.10. These factors can be seen as categorised into three (3) stages of education. Hence the factors are named as Conception Stage, Implementation Stage and Optimisation Stage respectively, representing the three (3) stages if BIM were to be embedded into the QS BIM education framework.

Table 4.10: Factors Naming

No.	Variables	Factor Loadings
1	Factor 1 – Conception stage	
	Use BIM in the whole life inter-disciplinary design	0.776
	Evaluate and select software and technology upon BIM adoption	0.757
	Utilise BIM to assess the condition of existing assets	0.743
	Utilise BIM in procurement processes	0.727
	Utilise BIM to assess contextual data affecting potential developments	0.723
	Utilise BIM to assess the energy performance of buildings	0.708
	Analyse the data deliverables for clients and the supply chain required upon BIM adoption	0.697
	Utilise BIM to develop design solution	0.693
	Communicate the impact of BIM adoption	0.686
	Utilise BIM to coordinate and control construction and installation operations	0.685
	Use BIM in achieving sustainable design	0.675
	Identify the hardware, software and network infrastructure requirements upon BIM adoption	0.661
	Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption	0.635
	Use BIM to assist in achieving productivity and efficiency improvements	0.624
	Utilise BIM to analyse and plan construction and installation work processes and resources	0.595
	Aware of authority requirements posed upon BIM adoption	0.593
	Identify the project requirements with BIM	0.584
	Define the common language and terminology associated with BIM adoption	0.564
	Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	0.549
	Implement governance of information and process management with BIM adoption	0.537
	Utilise BIM to manage the use and maintenance of facilities	0.533
	Evaluate the impact on internal and external roles posed upon BIM adoption	0.501
2	Factor 2 – Implementation stage	
	Utilise BIM to manage design information	0.757
	Utilise BIM to visualize the project and understand the relationships of the various components to one another	0.725
	Utilise BIM to build 3D models and construct virtual model	0.718
	Utilise BIM to develop the model into an acceptable representation of what is visualized	0.687
	Reduce the project risks with BIM adoption	0.657
	Utilise BIM to manage and operate technical information systems	0.645
	Identify and manage risks upon BIM adoption	0.630
	Utilise BIM in scheduling and estimating	0.605
	Collaborate with project teams upon BIM adoption	0.584
	Utilise BIM to manage project handover and facilities information	0.546
	Implement data and process standards upon BIM adoption	0.497

No.	Variables	Factor Loadings
3	Factor 3 – Optimisation stage	
	Engage organisational stakeholders to BIM adoption	0.751
	Gain commitment upon BIM adoption	0.733
	Develop the business case, investment and return model upon BIM adoption	0.710
	Invest in up-skilling, systems and process management upon BIM adoption	0.708
	Apply BIM in alignment with organisational goals	0.685
	Develop the business goals and plans upon BIM adoption	0.649
	Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption	0.648
	Consider strategic issues required on BIM adoption	0.612
	Identify the liability implications posed upon BIM adoption	0.591
	Engage business stakeholders upon BIM adoption	0.589
	Develop frameworks and guidance and execution plan for BIM adoption	0.573
	Compare examples of successful BIM implementation	0.500

4.2.2 Reliability Analysis on Identified Factors

Cronbach's α reliability analysis is carried out to check on the consistency and reliability of the underlying factors. Table 4.11 shows the Cronbach's α of all three (3) underlying factors are well above 0.9. In Appendix G, all corrected item on total correlations are more than 0.7. All variables Cronbach's α if item deleted are more than the overall Cronbach's α of their corresponding underlying factors. Hence, it shall be concluded that the underlying factors extracted from factor analysis are consistent and reliable.

Table 4.11: Cronbach's α Reliability Analysis

No.	Variables	a[1]
1	Conception Stage	0.982
2	Implementation Stage	0.968
3	Optimisation Stage	0.963

[1]Cronbach's α

4.3 Significant Differences between Variables and the Three Stages of BIM Education

Kruskal-Wallis (KW) test was carried out on the three (3) factors derived: Conception Stage (Cxn), Implementation Stage (Ixn) and Optimisation Stage (Oxn), against the various variables from the questionnaire, in order to test the significant difference.

4.3.1 Item A: Significant Difference between Grouping Variable, "How do you rate your overall BIM understanding?" and the Three Stages of BIM Education

From Table 4.12, all three (3) factors show p-value smaller than 0.05. This test shows that there is a significant difference in all three (3) stages: Conception, Implementation and Optimisation Stage between the respondents' overall understanding of BIM. Refer to Table 4.13, the mean ranks from highest to lowest for all three (3) stages has a similar pattern, in which the statement with the highest mean rank is "Understand what BIM is and able to apply and advise my team in the projects", whilst the lowest is "Aware of what BIM is about, but still unsure of its potential to the construction industry".

Table 4.12: Chi-Square Test on Item A

Chi-Square Test on Item A	**Cxn[1]**	**Ixn[2]**	**Oxn[3]**
Chi-Square	23.632	31.028	20.838
df	4	4	4
Asymp. Sig.	.000	.000	.000

[1]Conception
[2]Implementation
[3]Optimisation

Table 4.13: Kruskal-Wallis Test on Item A

How do you rate your overall BIM understanding?	N	Mean Rank		
		Cxn[1]	Ixn[2]	Oxn[3]
Unaware of what BIM is.	13	131.58	118.92	120.62
Aware of what BIM is about, but still unsure of its potential to the construction industry.	71	105.94	101.68	98.96
Understand what BIM is, and knows its benefit and potential to the construction industry.	108	122.79	120.81	129.86
Understand what BIM is and able to apply it in the projects.	52	143.10	157.31	144.88
Understand what BIM is and able to apply and advise my team in the projects.	6	240.17	230.33	203.83
Total	250			

[1]Conception
[2]Implementation
[3]Optimisation

4.3.2 Item B: Significant Difference between Grouping Variable, "I know most of the information about BIM through Formal Education/On-The-Job Training/Professional Development/None of the Above" and the Three Stages of BIM Education

From Table 4.14, Conception and Optimisation Stage has a significant difference between the different medium that the respondents' knows BIM from.

Table 4.14 Chi-Square Test on Item B

Chi-Square Test on Item B	Cxn[1]	Ixn[2]	Oxn[3]
Chi-Square	8.048	7.134	11.307
df	3	3	3
Asymp. Sig.	.045	.068	.010

[1]Conception
[2]Implementation
[3]Optimisation

4.3.3 Item C: Significant Difference between Grouping Variable, "Was BIM part of your course syllabus in the University?", and the Three Stages of BIM Education

From Table 4.15, all three (3) factors show a p-value lesser than 0.05. This test shows that there is a significant difference in all three (3) stages: Conception, Implementation and Optimisation Stage. From Table 4.16, University that includes BIM as part of their course syllabus has higher mean ranks than those Universities that don't.

Table 4.15: Chi-Square Test on Item C

Chi-Square Test on Item C	Cxn[1]	Ixn[2]	Oxn[3]
Chi-Square	7.208	10.096	11.744
df	1	1	1
Asymp. Sig.	.007	.001	.001

[1]Conception
[2]Implementation
[3]Optimisation

Table 4.16: Kruskal-Wallis Test on Item C

Was BIM part of your course syllabus in the University?	N	Mean Rank		
		Cxn[1]	Ixn[2]	Oxn[3]
No	149	115.40	113.55	112.61
Yes	101	140.41	143.12	144.51
Total	250			

[1]Conception
[2]Implementation
[3]Optimisation

4.3.4 Item D: Significant Difference between Grouping Variable, "How was BIM being taught or introduced in your university?", and the Three Stages of BIM Education

From Table 4.17, all three (3) factor shows p-value lesser than 0.05. This test shows that there is significant difference in Conception, Implementation and Optimisation Stage between the different method BIM was taught or introduced in the respondents' university. From Table 4.18, with BIM being taught as a course/individual subject has the highest mean rank, followed on by the second highest which is having BIM embedded in the subject, then by inviting Guest Speaker/Guest Lecturer and where the selections none of the above as the lowest mean rank.

Table 4.17 Chi-Square Test on Item D

Chi-Square Test on Item D	Cxn[1]	Ixn[2]	Oxn[3]
Chi-Square	10.132	10.824	8.057
df	3	3	3
Asymp. Sig.	.017	.013	.045

[1]Conception
[2]Implementation
[3]Optimisation

Table 4.18: Kruskal-Wallis Test on Item D

How was BIM being taught/introduced in your university?	N	Mean Rank Cxn[1]	Ixn[2]	Oxn[3]
As a course/individual subject	65	148.83	145.02	143.50
By inviting Guest Speaker/Guest Lecturer	43	118.93	122.84	119.51
By embedding BIM in the subject(s)	37	126.77	138.34	135.54
None of the above	105	113.30	109.99	113.27
Total	250			

[1]Conception
[2]Implementation
[3]Optimisation

4.3.5 Item E: Significant Difference between Grouping Variable, "Company's Nature of Business", and the Three Stages of BIM Education

From Table 4.19, Conception Stage has a p-value larger than 0.05. This test shows that there is no significant difference in Conception Stage between the different nature of business of the respondents' company.

Table 4.19 Chi-Square Test on Item E

Chi-Square Test on Item E	Cxn[1]	Ixn[2]	Oxn[3]
Chi-Square	8.013	15.743	13.744
df	5	5	5
Asymp. Sig.	.156	.008	.017

[1]Conception
[2]Implementation
[3]Optimisation

4.3.6 Item F: Significant Difference between Grouping Variable, Working Experience, and the Three Stages of BIM Education

From Table 4.20, Optimisation Stage has a p-value larger than 0.05. This test shows that there is no significant difference in Optimisation Stage between the different years of working experience of the respondents'.

Table 4.20 Chi-Square Test on Item F

Chi-Square Test on Item F	Cxn[1]	Ixn[2]	Oxn[3]
Chi-Square	17.394	9.613	9.048
df	4	4	4
Asymp. Sig.	.002	.047	.060

[1]Conception
[2]Implementation
[3]Optimisation

4.3.7 Item G: Significant Difference between Grouping Variable, Highest Qualification, and the Three Stages of BIM Education

From Table 4.21, all three (3) factor shows p-value larger than 0.05. This test shows that there is no significant difference in Conception, Implementation and Optimisation Stage between the different qualifications of the respondents'.

Table 4.21 Chi-Square Test on Item G

Chi-Square Test on Item G	Cxn[1]	Ixn[2]	Oxn[3]
Chi-Square	2.062	1.087	1.508
df	3	3	3
Asymp. Sig.	.560	.780	.680

[1]Conception
[2]Implementation
[3]Optimisation

4.3.8 Item H: Significant Difference between Grouping Variable, Number of Years with Current Job Title, and the Three Stages of BIM Education

From Table 4.22, all three (3) factor shows p-value larger than 0.05. This test shows that there is no significant difference in Conception, Implementation and Optimisation Stage between the respondents' number of years with the current job title.

Table 4.22 Chi-Square Test on Item H

Chi-Square Test on Item H	Cxn[1]	Ixn[2]	Oxn[3]
Chi-Square	7.864	8.465	6.896
df	4	4	4
Asymp. Sig.	.097	.076	.141

[1]Conception
[2]Implementation
[3]Optimisation

4.3.9 Item J: Significant Difference between Grouping Variable, Type of University, and the Three Stages of BIM Education

From Table 4.23, all three (3) factor shows p-value larger than 0.05. This test shows that there is no significant difference in Conception, Implementation and Optimisation Stage between the type of university the respondents' came from, in terms of local or non-local universities.

Table 4.23 Chi-Square Test on Item J

Chi-Square Test on Item J	Cxn[1]	Ixn[2]	Oxn[3]
Chi-Square	0.681	1.317	0.280
df	1	1	1
Asymp. Sig.	.409	.251	.597

[1]Conception
[2]Implementation
[3]Optimisation

4.3.10 Summary

Chi-Square Test is used to evaluate if two categorical variables are related. At this juncture, it is identified that the variable that has a significant difference to all three (3) stages are: (a) Item A: the overall BIM understanding in which the respondents rate themselves on; (b) Item C: the inclusion of BIM in the respondents' university course syllabus; and (c) Item D: the means on how BIM is taught/introduced in the respondents' university. Item A, C and D will be used to further analyse the collected data.

4.4 Significant Difference between Level of BIM Proficiency and Likelihood of BIM Implementation of Organisation or Team to the Variable: How Do You Rate Your Overall BIM Understanding?

Subsequent step is taken to test the significant difference between the 45 statements from question A2, in which respondents are asked to rate the statements according to their level of BIM proficiency (Please refer to Appendix B on the distributed survey questionnaire), and How do you rate your overall BIM understanding (B1). B1 can be found in the first question at the second segment of the survey questionnaire. B1 represents the respondents' Self-Perceived Maturity Level (SPML), as a benchmark on how the respondents' viewed themselves as. The SPML is represented by the choices of answer to B1 as per Table 4.24.

Table 4.24 Level 1 to 5 of Self-Perceived Maturity Level (SPML)

Maturity Level (ML)	Description
1	Unaware of what BIM is.
2	Aware of what BIM is about, but still unsure of its potential to the construction industry.
3	Understand what BIM is, and knows its benefit and potential to the construction industry.
4	Understand what BIM is and able to apply it in the projects.
5	Understand what BIM is and able to apply and advise my team in the projects.

Table 4.25 shows the mean ranks and average mean ranks in the order of SPML 1 to 5 for the three (3) stages of BIM education. Statements in red indicates that the p-value is more than 0.05. A separate exercise to compare both question A2 and A3's SPML is carried out. This is to have a view on whether or not there are any significant difference on the SPML of the respondents' knowledge as compared to the SPML of the respondents' attitude.

Table 4.25: Mean Ranks and Average Mean Ranks for Self-Perceived Maturity Level (SPML) 1 to 5 On Question A2

	Statements	p	SPML 1	2	3	4	5
	Conception						
1	Use BIM in the whole life inter-disciplinary design	.000	140.31	106.06	120.96	144.90	237.00
2	Evaluate and select software and technology upon BIM adoption	.006	122.73	115.30	121.53	137.70	218.00
3	Utilise BIM to assess the condition of existing assets	.017	131.08	113.43	125.42	130.61	213.50
4	Utilise BIM in procurement processes	.003	129.12	108.49	120.90	149.93	190.00
5	Utilise BIM to assess contextual data affecting potential developments	.000	139.88	109.61	121.30	139.39	237.50
6	Utilise BIM to assess the energy performance of buildings	.003	125.00	115.04	120.33	139.68	220.50
7	Analyse the data deliverables for clients and the supply chain required upon BIM adoption	.000	120.04	108.44	119.49	152.19	216.00
8	Utilise BIM to develop design solution	.101	133.62	114.16	126.31	129.79	190.33
9	Communicate the impact of BIM adoption	.000	146.35	108.37	120.44	143.34	219.50
10	Utilise BIM to coordinate and control construction and installation operations	.001	134.54	113.20	122.91	132.54	237.00
11	Use BIM in achieving sustainable design	.203	118.15	119.77	119.80	144.19	149.83
12	Identify the hardware, software and network infrastructure requirements upon BIM adoption	.001	124.00	108.44	127.18	133.15	234.00
13	Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption	.000	141.12	109.80	119.07	145.76	217.67
14	Use BIM to assist in achieving productivity and efficiency improvements	.004	113.73	109.80	124.46	142.66	206.67
15	Utilise BIM to analyse and plan construction and installation work processes and resources	.000	129.27	110.03	116.86	151.52	230.50
16	Aware of authority requirements posed upon BIM adoption	.004	103.04	114.66	134.69	116.91	211.33
17	Identify the project requirements with BIM	.000	140.19	105.79	121.17	147.45	214.67
18	Define the common language and terminology associated with BIM adoption	.012	131.73	102.68	131.36	137.72	170.67
19	Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	.000	138.62	105.37	125.21	139.33	220.67
20	Implement governance of information and process management with BIM adoption	.000	118.46	99.48	133.60	132.69	240.50
21	Utilise BIM to manage the use and maintenance of facilities	.000	129.19	108.89	122.93	139.91	235.50
22	Evaluate the impact on internal and external roles posed upon BIM adoption	.000	160.54	110.84	119.75	136.06	235.00
	Average mean ranks		**130.49**	**109.89**	**123.44**	**139.43**	**215.74**

	Implementation						
1	Utilise BIM to manage design information	.000	118.92	108.24	119.66	153.61	205.50
2	Utilise BIM to visualize the project and understand the relationships of the various components to one another	.001	116.31	104.75	126.75	144.91	200.33
3	Utilise BIM to build 3D models and construct virtual model	.002	111.00	107.37	123.85	149.87	190.00
4	Utilise BIM to develop the model into an acceptable representation of what is visualized	.000	111.31	103.43	122.38	154.40	223.00
5	Reduce the project risks with BIM adoption	.048	134.92	113.07	121.38	142.49	179.00
6	Utilise BIM to manage and operate technical information systems	.000	115.58	109.68	118.79	150.93	234.50
7	Identify and manage risks upon BIM adoption	.008	138.38	112.26	121.31	139.70	206.50
8	Utilise BIM in scheduling and estimating	.000	120.92	110.96	118.10	150.38	225.00
9	Collaborate with project teams upon BIM adoption	.000	131.81	94.13	125.04	158.57	204.83
10	Utilise BIM to manage project handover and facilities information	.000	133.38	110.77	115.77	156.33	190.67
11	Implement data and process standards upon BIM adoption	.000	102.81	104.08	130.19	140.46	214.00
	Average mean ranks		**121.40**	**107.16**	**122.11**	**149.24**	**206.67**
	Optimisation						
1	Engage organisational stakeholders to BIM adoption	.025	113.31	104.01	134.88	135.96	146.83
2	Gain commitment upon BIM adoption	.001	127.77	100.36	128.03	146.96	186.50
3	Develop the business case, investment and return model upon BIM adoption	.013	148.12	103.06	131.65	132.95	166.67
4	Invest in up-skilling, systems and process management upon BIM adoption	.019	125.58	108.30	124.14	146.85	168.33
5	Apply BIM in alignment with organisational goals	.135	139.96	114.13	124.42	143.00	96.50
6	Develop the business goals and plans upon BIM adoption	.000	112.58	105.92	124.54	147.35	213.17
7	Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption	.225	124.23	112.18	127.88	134.59	164.17
8	Consider strategic issues required on BIM adoption	.000	104.58	107.65	123.56	148.82	214.83
9	Identify the liability implications posed upon BIM adoption	.001	126.73	105.76	128.45	135.27	218.67
10	Engage business stakeholders upon BIM adoption	.000	142.85	100.80	130.19	134.98	213.67
11	Develop frameworks and guidance and execution plan for BIM adoption	.010	132.31	112.78	123.35	135.62	212.33
12	Compare examples of successful BIM implementation	.000	124.69	102.42	136.05	124.86	216.00
	Average mean ranks		**126.89**	**106.45**	**128.10**	**138.93**	**184.81**

Table 4.26: Mean Ranks and Average Mean Ranks for Self-Perceived Maturity Level (SPML) 1 to 5 on Question A3

	Conception	p	SPML				
			1	2	3	4	5
1	Use BIM in the whole life inter-disciplinary design	.001	143.96	100.78	128.94	139.75	192.50
2	Evaluate and select software and technology upon BIM adoption	.000	152.27	96.51	127.29	147.37	188.83
3	Utilise BIM to assess the condition of existing assets	.005	150.04	112.11	119.37	142.23	196.17
4	Utilise BIM in procurement processes	.000	148.27	109.02	123.81	133.47	232.50
5	Utilise BIM to assess contextual data affecting potential developments	.002	155.04	101.00	136.30	124.58	165.00
6	Utilise BIM to assess the energy performance of buildings	.000	181.50	102.25	120.44	143.68	212.67
7	Analyse the data deliverables for clients and the supply chain required upon BIM adoption	.002	162.15	110.58	119.33	142.92	182.67
8	Utilise BIM to develop design solution	.001	167.54	101.73	127.19	138.11	176.00
9	Communicate the impact of BIM adoption	.001	149.81	101.53	129.69	136.58	185.17
10	Utilise BIM to coordinate and control construction and installation operations	.000	173.00	105.27	125.06	132.77	207.00
11	Use BIM in achieving sustainable design	.000	157.38	105.82	121.85	142.64	206.33
12	Identify the hardware, software and network infrastructure requirements upon BIM adoption	.000	133.85	108.28	127.47	130.31	234.00
13	Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption	.009	154.73	105.42	129.71	130.79	178.17
14	Use BIM to assist in achieving productivity and efficiency improvements	.000	143.88	102.15	121.50	152.87	196.67
15	Utilise BIM to analyse and plan construction and installation work processes and resources	.000	170.15	102.04	126.16	135.67	206.33
16	Aware of authority requirements posed upon BIM adoption	.011	126.15	103.32	130.30	145.96	122.83
17	Identify the project requirements with BIM	.016	145.12	106.37	131.88	127.08	180.83
18	Define the common language and terminology associated with BIM adoption	.000	168.81	101.07	134.15	122.84	188.17
19	Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	.003	135.31	103.73	128.11	140.22	187.33
20	Implement governance of information and process management with BIM adoption	.011	154.54	109.19	128.83	126.15	190.00
21	Utilise BIM to manage the use and maintenance of facilities	.000	118.08	99.35	131.22	141.37	210.50
22	Evaluate the impact on internal and external roles posed upon BIM adoption	.004	161.65	103.11	134.07	125.36	159.00
	Average mean ranks		**152.42**	**104.12**	**127.39**	**136.49**	**190.85**

	Implementation						
1	Utilise BIM to manage design information	.000	151.85	95.11	126.38	152.69	176.67
2	Utilise BIM to visualize the project and understand the relationships of the various components to one another	.001	145.08	99.69	129.61	142.29	169.00
3	Utilise BIM to build 3D models and construct virtual model	.029	125.58	109.23	127.78	135.48	190.33
4	Utilise BIM to develop the model into an acceptable representation of what is visualized	.032	119.85	115.02	123.22	137.61	197.83
5	Reduce the project risks with BIM adoption	.000	153.46	98.15	131.01	138.69	175.00
6	Utilise BIM to manage and operate technical information systems	.005	139.85	104.42	128.69	137.70	180.67
7	Identify and manage risks upon BIM adoption	.002	128.46	100.34	132.81	137.71	179.33
8	Utilise BIM in scheduling and estimating	.013	156.38	106.39	126.81	140.16	134.00
9	Collaborate with project teams upon BIM adoption	.000	149.62	97.64	129.00	141.21	203.67
10	Utilise BIM to manage project handover and facilities information	.022	133.88	107.02	128.98	134.67	183.83
11	Implement data and process standards upon BIM adoption	.000	173.46	100.83	129.70	128.90	208.33
	Average mean ranks		**143.41**	**103.08**	**128.55**	**138.83**	**181.70**
	Optimisation						
1	Engage organisational stakeholders to BIM adoption	.006	128.12	104.92	133.06	129.38	193.50
2	Gain commitment upon BIM adoption	.018	135.88	103.32	132.37	135.48	155.33
3	Develop the business case, investment and return model upon BIM adoption	.002	153.54	100.47	128.87	141.91	158.00
4	Invest in up-skilling, systems and process management upon BIM adoption	.001	136.65	99.67	129.62	144.38	169.17
5	Apply BIM in alignment with organisational goals	.063	137.77	106.65	129.85	135.55	156.50
6	Develop the business goals and plans upon BIM adoption	.214	119.19	110.87	132.28	129.98	151.50
7	Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption	.000	141.77	96.32	131.64	144.03	164.50
8	Consider strategic issues required on BIM adoption	.000	131.04	96.45	132.81	142.10	181.83
9	Identify the liability implications posed upon BIM adoption	.000	153.58	95.60	130.06	142.72	187.17
10	Engage business stakeholders upon BIM adoption	.003	116.31	102.68	135.28	143.02	87.67
11	Develop frameworks and guidance and execution plan for BIM adoption	.000	134.15	98.85	131.20	140.79	187.00
12	Compare examples of successful BIM implementation	.001	153.19	100.93	131.28	132.88	188.17
	Average mean ranks		**136.77**	**101.39**	**131.53**	**138.52**	**165.03**

Figures 4.1, 4.2 and 4.3 below illustrate the SPMLs of both A2 and A3 based on the three (3) stages of BIM application respectively. Overall, the trend is observed to be gradually increasing from Level 2 to Level 4 and increases sharply at Level 5, whilst Level 1 SPML is found to be generally higher than Level 3 at charts on Conception and Implementation Stage and higher than Level 2 on Optimisation Stage. From the charts, it is evident that A2 is found to be generally higher than A3. In the Conception chart, Level 1 to 4 are almost similar, however A2 increases dramatically as compared to A3. This similar pattern is also applicable to the Implementation and Optimisation charts, however at Level 1, A3 appears to be higher than A2.

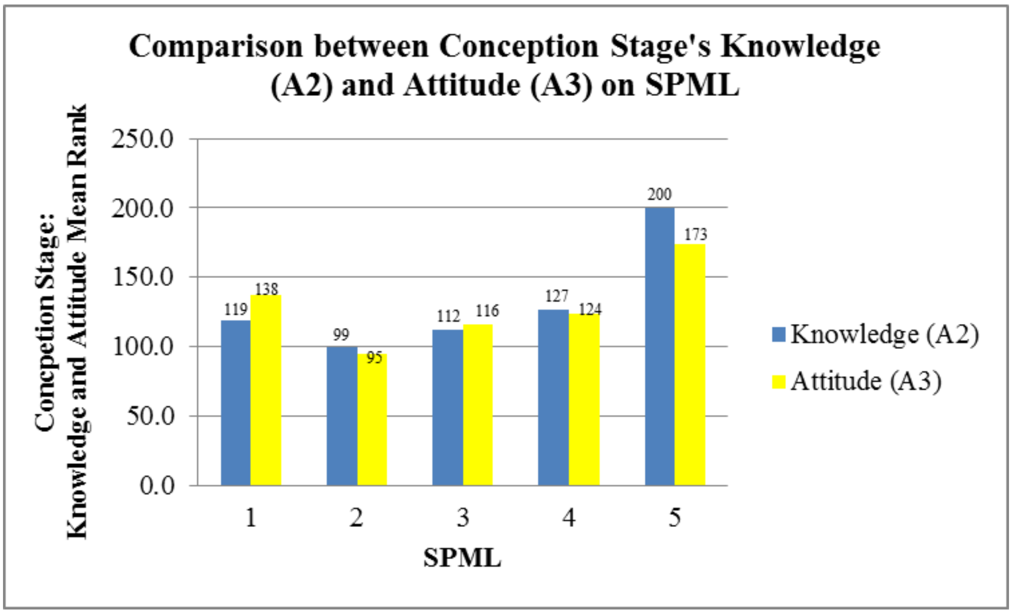

Figure 4.1: Comparison between Conception Stage's Knowledge (A2) and Attitude (A3) on Self-Perceived Maturity Level (SPML)

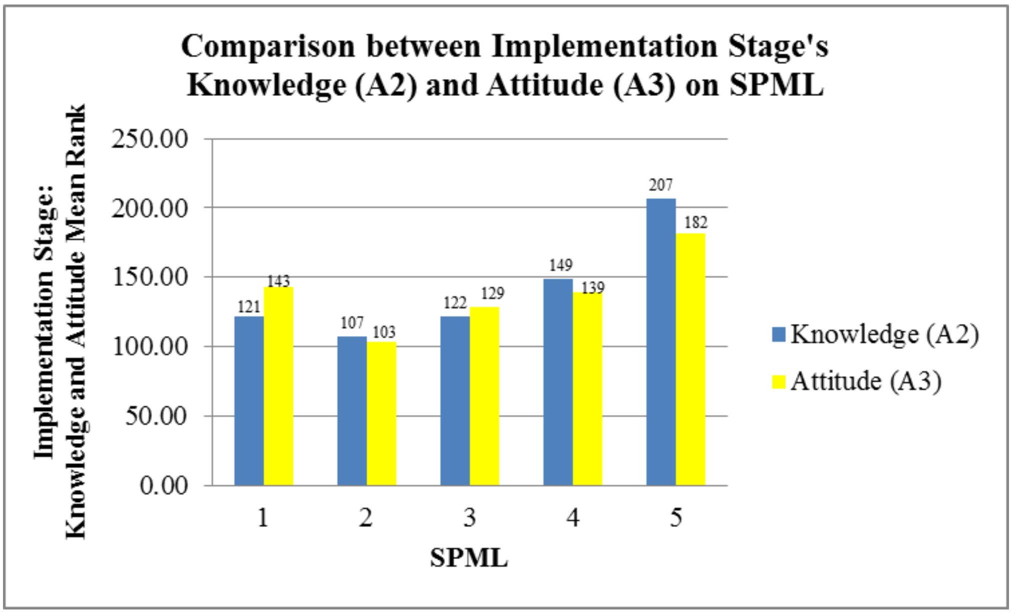

Figure 4.2: Comparison between Implementation Stage's Knowledge (A2) and Attitude (A3) on Self-Perceived Maturity Level (SPML)

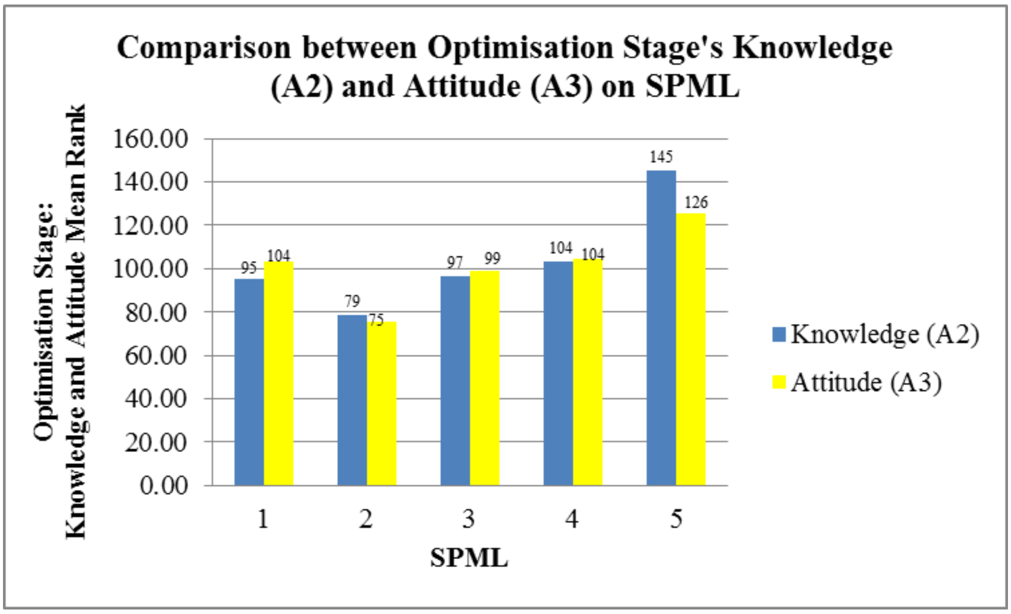

Figure 4.3: Comparison between Optimisation Stage's Knowledge (A2) and Attitude (A3) on Self-Perceived Maturity Level (SPML)

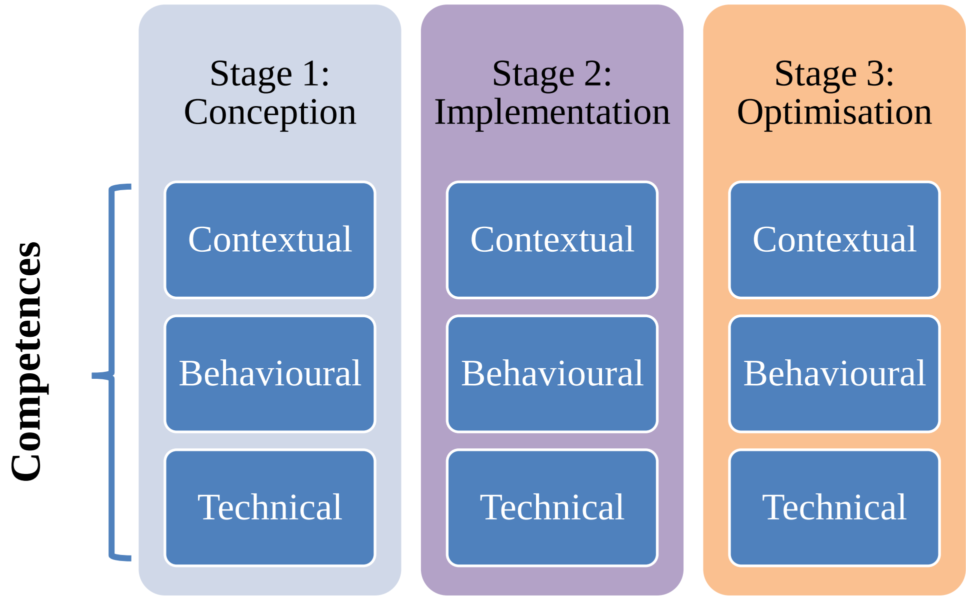

Figure 4.4: The Relationship between Contextual, Behavioural and Technical competences with the Three Stages of BIM Education

As discussed in Chapter 3 where A2 and A3's 45 statements can be grouped into the 14 statements in A1 on the respondents' level of awareness on BIM's capability, that can be further categorised into three (3) types of competences: Contextual, Behavioural and Technical. To recap, A1 represents the respondents' beliefs towards the BIM capability.

A comparison on A1, A2 and A3's SPML is then carried out. A similar trend from Level 1 to Level 5 is observed in Figure 4.5. From Level 2 to 4, A1, A2 and A3 has almost similar statistics. At Level 1, it is evident that the mean ranks are in the sequence from lowest to highest is A2, A1, A3, whilst Level 5 shows the opposite, which in the order from lowest to highest is A1, A3, A2.

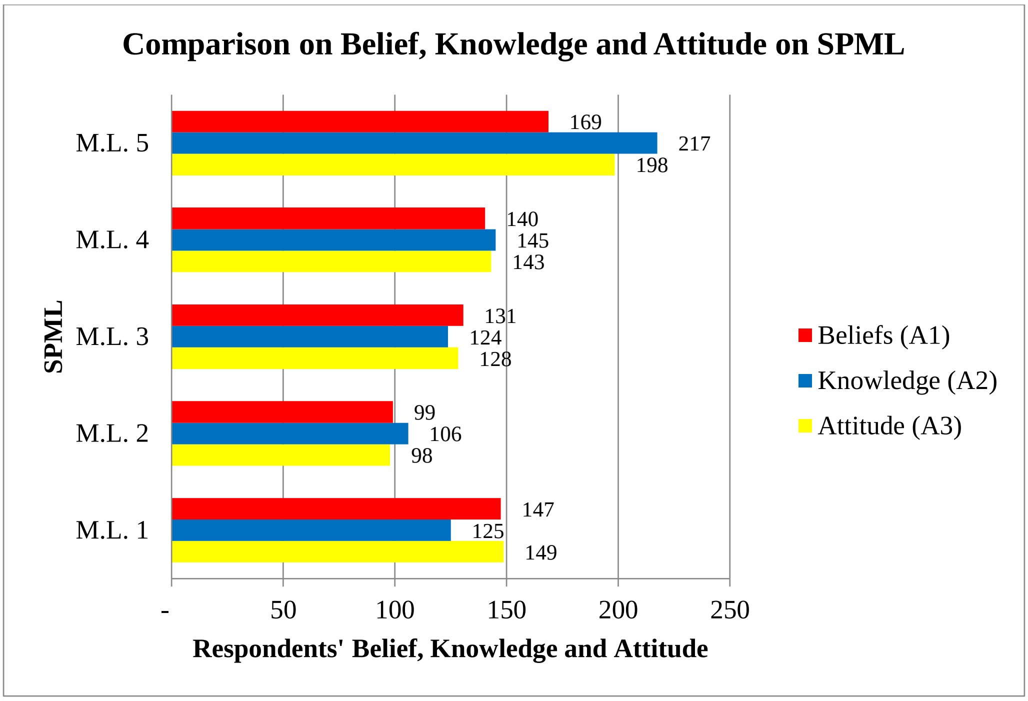

Figure 4.5 Comparison on Belief, Knowledge and Attitude on Self-Perceived Maturity Level (SPML)

4.5 Identifying the Knowledge Gap between Respondents from University With and Without BIM as Part of the Course Syllabus

Friedman Test was carried out on the 45 statements against the variable 'Was BIM part of your course syllabus in the university?'. In Table 4.27, cases of respondents' selecting the option "No" and "Yes" show a p-value smaller than 0.05, hence, it is verified that there is a significant difference whether or not BIM was part of the course syllabus in the university.

Table 4.28 (a) and (b) difference in mean ranks of respondents who selected No and Yes. 24 statements identified has a higher mean ranks in the case which respondents selected the option ‘No’ as compared to respondents who selected the option ‘Yes’, this shows a gap of knowledge that needs to be filled.

Table 4.27: Chi-Square Test on Knowledge Gap

Chi-Square Test on Knowledge Gap	**No**	**Yes**
Chi-Square	279.727	252.744
df	1	1
Asymp. Sig.	.000	.000

Table 4.28(a) Knowledge of respondents when BIM was part of the course syllabus in the University

Statement No.	Statements	No (A)	Yes (B)	B-A
1	Develop the business case, investment and return model upon BIM adoption	18.62	19.87	1.25
2	Apply BIM in alignment with organisational goals	19.80	22.42	2.61
3	Gain commitment upon BIM adoption	22.96	23.44	0.48
4	Develop the business goals and plans upon BIM adoption	22.07	25.84	3.77
7	Evaluate the impact on internal and external roles posed upon BIM adoption	22.43	23.63	1.20
9	Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption	20.70	21.30	0.60
10	Utilise BIM to visualize the project and understand the relationships of the various components to one another	24.82	28.22	3.40
11	Utilise BIM to build 3D models and construct virtual model	27.33	29.15	1.83
12	Utilise BIM to develop the model into an acceptable representation of what is visualized	27.05	28.45	1.40
17	Develop frameworks and guidance and execution plan for BIM adoption	22.05	24.60	2.55
18	Consider strategic issues required on BIM adoption	22.38	23.66	1.28
24	Implement data and process standards upon BIM adoption	22.14	25.36	3.22
25	Identify the project requirements with BIM	22.80	23.40	0.59
26	Utilise BIM to manage design information	25.42	26.51	1.09
33	Utilise BIM in scheduling and estimating	26.20	26.72	0.52
37	Utilise BIM to develop design solution	21.98	24.49	2.51
38	Utilise BIM to coordinate and control construction and installation operations	22.51	24.02	1.51
41	Use BIM in achieving sustainable design	22.23	23.02	0.79
42	Utilise BIM to assess the energy performance of buildings	20.33	21.84	1.52
43	Analyse the data deliverables for clients and the supply chain required upon BIM adoption	21.16	23.81	2.65
44	Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption	21.73	23.29	1.55

Table 4.28(b) Knowledge of respondents when BIM was Not Part of the Course Syllabus in the University

Statement No.	Statements	No (A)	Yes (B)	B-A
5	Invest in up-skilling, systems and process management upon BIM adoption	23.91	23.45	(0.46)
6	Engage organisational stakeholders to BIM adoption	21.08	19.79	(1.29)
8	Engage business stakeholders upon BIM adoption	20.20	18.41	(1.80)
13	Reduce the project risks with BIM adoption	26.26	24.59	(1.66)
14	Identify and manage risks upon BIM adoption	26.03	23.39	(2.64)
15	Utilise BIM to manage project handover and facilities information	23.96	22.69	(1.26)
16	Utilise BIM to manage the use and maintenance of facilities	22.80	20.73	(2.07)
19	Aware of authority requirements posed upon BIM adoption	20.08	18.39	(1.69)
20	Identify the liability implications posed upon BIM adoption	23.08	20.95	(2.13)
21	Compare examples of successful BIM implementation	23.80	21.87	(1.94)
22	Define the common language and terminology associated with BIM adoption	22.41	20.81	(1.61)
23	Implement governance of information and process management with BIM adoption	21.61	19.59	(2.02)
27	Utilise BIM to manage and operate technical information systems	24.57	23.69	(0.88)
28	Collaborate with project teams upon BIM adoption	26.72	25.86	(0.86)
29	Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	23.62	21.01	(2.61)
30	Identify the hardware, software and network infrastructure requirements upon BIM adoption	23.57	21.72	(1.86)
31	Evaluate and select software and technology upon BIM adoption	22.53	20.49	(2.04)
32	Utilise BIM to analyse and plan construction and installation work processes and resources	24.15	23.92	(0.23)
34	Use BIM to assist in achieving productivity and efficiency improvements	25.18	25.10	(0.07)
35	Communicate the impact of BIM adoption	23.20	20.44	(2.77)
36	Utilise BIM to assess contextual data affecting potential developments	22.34	21.91	(0.43)
39	Utilise BIM to assess the condition of existing assets	22.70	20.39	(2.31)
40	Use BIM in the whole life inter-disciplinary design	21.99	21.75	(0.23)
45	Utilise BIM in procurement processes	22.50	21.03	(1.47)

4.6 Summary

The trend of the level of belief, knowledge and attitude against the Self-Perceived Maturity Level (SPML) to all three (3) stages: Conception, Implementation and Optimisation are found to be generally the same, in which there is a gradual increment to the mean ranks from Level 2 to Level 4, and Level 1's mean rank is often found to be between Level 3 to 4's mean rank. Other than that, 24 BIM competencies are identified as a knowledge gap further steps to find out the course syllabus to be embedded into will be carried out in Chapter 5.

CHAPTER 5

DISCUSSION OF RESULTS

5.1 Overview

This chapter starts with analysing the adequacy of the quantitative data collected from the survey questionnaire. Followed on by the discussion on the factor analysis results, the significant differences of the variables against the newly identified stages of education. Discussion on the 24 statements of knowledge gaps are conducted and subsequently tabulated into a matrix form to clearly demarcate the relationship of the 24 statements between the stages of education and the type of competences.

5.2 General Adequacy of Quantitative Data

As BIM promotes interoperability within all stakeholders in the construction industry, survey questionnaires needs to be distributed to QS from different nature of business. There are 250 questionnaires collected which turns out to have a good spread of different groups of respondents within the construction industry. 48.8% are respondents from consultancy firm, whilst a balance of 51.2% respondents are also practising as quantity surveyor however are of a different nature of business, i.e. developer, contractor, personnel from the authority department, and also from the academic industry. There are about 59.6% of respondents claims that BIM was not part of the university course syllabus during their time, this is somewhat similar to the result collected on the respondent's years of working experience, BIM was starting to get popular in the university at about 7 years ago in 2011, respondents who have more than 5 years of experience are at 33.6%. Assuming that not all universities have taken the liberty to introduce BIM, given the balance of 59.6% and 33.6% is at 26%, which is 65 respondents. This could mean that 65 out of 124 respondents, about 52.4% of the respondents who has more than 2 years but less than 5 years working experience do not have BIM as part of the university course syllabus. Hence, this data collected is able to confirm that the respondents that came back with whether or not BIM is included in their course syllabus is in line with the years of experience of the respondents.

5.3 Discussion on Factor Analysis Results

Result of the Factor Analysis, Principal Components Analysis that was conducted on the 45 BIM competencies is identified as the three (3) stages of BIM education i.e. Conception Stage, Implementation Stage and Optimisation Stage. This is found to be aligned with RICS Quantity Surveying and Construction's Assessment of Professional Competence's (APC) (RICS, 2015) three (3) levels of attainment in which Conception Stage is equivalent to RICS

APC Level 1's knowledge and understanding; Implementation Stage is similar to Level 2: Application of knowledge and understanding; and Optimisation Stage is comparable to Level 3's reasoned advice and depth of technical knowledge.

5.4 Discussion on the Significant Differences of the Variables against the Newly Identified Stages of Education

The 45 competencies was grouped into the three (3) stages of education with the purpose of testing the significant difference against the various variables from the questionnaire. Reportedly, the variable that have a significant difference to all three (3) stages are: (a) Item A: the overall BIM understanding in which the respondents rate themselves on; (b) Item C: the inclusion of BIM in the respondents' university course syllabus; and (c) Item D: the means on how BIM is taught/introduced in the respondents' university.

In the result obtained in Item A, refer to Table 4.13, in general all three (3) stages is shown to have gradual increase from Level 2 to Level 5 of BIM understanding. This could be able to translate that the level of BIM understanding is on par with the respondents' years of working experience as shown in Table 4.2. There are a total of 166 respondents with less than 2 years to 5 years of working experience, in which in Table 4.13 it is shown that there are a total of 179 respondents to Level 2 and Level 3 of BIM understanding. The difference between these two (2) may be due to respondents who have more than 5 years' experience have also chosen Level 2 and 3 of BIM understanding. The higher mean rank is in accordance to the level of BIM understanding may imply the respondents' seniority level at exposure to BIM. As for Level 1 of BIM understanding: Unaware of what BIM is, appears to be in between the mean ranks of Level 2 to Level 4. One assumption can be made is that some QS's in different business nature i.e. Specialist Contractor, consist of 23 number of respondents, may not be exposed to BIM as they are from a niche market. This pattern of gradual increase form Level 2 to 5, and Level 1 mean rank found to be in between Level 2 to 4 can be seen repeatedly on the analysed data at Table 4.25, 4.26, Figure 4.2, 4.3 and 4.5.

In the results obtained for Item C, Table 4.16, it is found that 149 respondents selected "No", and 101 selected "Yes" to the question 'Was BIM part of your course syllabus in the University?". This result is also in line with the Years of Working Experience of the respondents, as it can be safely assumed that respondents with less than five (5) years of working experience are somehow introduced to BIM in the university. Other than that, Item D illustrated in Table 4.18 also shows similar pattern as 105 respondents selected 'None of the above' to the question 'How was BIM being taught/introduced in your university?, this is 4 respondents in excess as compared to 101 respondents selected 'No' in Item C. The additional four (4) respondents may have attended webinars conducted by software partners or other external parties.

5.5 Knowledge gaps when BIM was not part of the course syllabus in the Universities

Referring to Chapter 4, Table 4.28(b), there are 24 knowledge gaps identified on the exclusion of BIM in the university course syllabus. They consist of 14 statements at Conception Stage: which made up of one (1) Contextual competence, one (1) Behavioural competence and 12 Technical competences; Five (5) statements at Implementation Stage: which made up of one (1) Behavioural competence and four (4) Technical competences; And, five (5) statements at Optimisation stage: which made up of four (4) Contextual competence and one (1) Technical competence.

In the conception stage, the knowledge gap found in contextual behavioural and technical competence are as follows:

1) Contextual competence:
    - Aware of authority requirements posed upon BIM adoption
2) Behavioural competence:
    - Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption.
3) Technical competence:
    - Utilise BIM to manage the use and maintenance of facilities
    - Define the common language and terminology associated with BIM adoption
    - Implement governance of information and process management with BIM adoption

- Identify the hardware, software and network infrastructure requirements upon BIM adoption
- Evaluate and select software and technology upon BIM adoption
- Utilise BIM to analyse and plan construction and installation work processes and resources
- Use BIM to assist in achieving productivity and efficiency improvements
- Communicate the impact of BIM adoption
- Utilise BIM to assess contextual data affecting potential developments
- Utilise BIM to assess the condition of existing assets
- Use BIM in the whole life inter-disciplinary design
- Utilise BIM in procurement processes

In the implementation stage, there is no knowledge gap found in contextual competence. However, the knowledge gap identified in behavioural and technical competence are:

1) Behavioural competence:
    - Collaborate with project teams upon BIM adoption
2) Technical competence:
    - Reduce the project risks with BIM adoption
    - Identify and manage risks upon BIM adoption
    - Utilise BIM to manage project handover and facilities information

- Utilise BIM to manage and operate technical information systems

In the optimisation stage, only conceptual and technical competence gap is identified:

1) Conceptual competence:
    - Invest in up-skilling, systems and process management upon BIM adoption
    - Engage organisational stakeholders to BIM adoption
    - Engage business stakeholders upon BIM adoption
    - Identify the liability implications posed upon BIM adoption
2) Technical competence
    - Compare examples of successful BIM implementation

This is further summarised in Table 5.1. From Conception to Implementation to Optimisation Stage, it can be seen that the number of contextual competences increases whilst the number of technical competences decrease throughout the stages. This is in line with the view of having the first year students to have hands on experience first, then slowly hone their understanding towards the context of quantity surveying practice in the later years of their undergraduate programme.

Table 5.1 Matrix of Type of Competences and Stages of Education

Type	Contextual	Behavioural	Technical
Conception	1. Aware of authority requirements posed upon BIM adoption	2. Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	3. Utilise BIM to manage the use and maintenance of facilities. 4. Define the common language and terminology associated with BIM adoption. 5. Implement governance of information and process management with BIM adoption 6. Identify the hardware, software and network infrastructure requirements upon BIM adoption 7. Evaluate and select software and technology upon BIM adoption 8. Utilise BIM to analyse and plan construction and installation work processes and resources 9. Use BIM to assist in achieving productivity and efficiency improvements 10. Communicate the impact of BIM adoption 11. Utilise BIM to assess contextual data affecting potential developments. 12. Utilise BIM to assess the condition of existing assets 13. Use BIM in the whole life inter-disciplinary design 14. Utilise BIM in procurement processes

Type	Contextual	Behavioural	Technical
Implementation		1. Collaborate with project teams upon BIM adoption	2. Reduce the project risks with BIM adoption 3. Identify and manage risks upon BIM adoption 4. Utilise BIM to manage project handover and facilities information 5. Utilise BIM to manage and operate technical information systems
Optimisation	1. Invest in up-skilling, systems and process management upon BIM adoption 2. Engage organisational stakeholders to BIM adoption 3. Engage business stakeholders upon BIM adoption 4. Identify the liability implications posed upon BIM adoption		5. Compare examples of successful BIM implementation

The 24 BIM competencies identified are paired with the Rules and Syllabuses of the Professional Examinations for Quantity Surveying (ISM, 2003) and RICS Quantity Surveying and Construction APC (RICS, 2015). The former was selected as it acts as a guideline for local universities to draw up their Quantity Surveying curriculum learning framework, whilst the latter serves as an international standard for local universities to follow.

In the Rules and Syllabuses of the Professional Examinations for Quantity Surveying published by the Royal Institution of Surveyors Malaysia (ISM) (2003), mandatory quantity surveying subjects to be taught by the university are defined in nine (9) subject groups, i.e. measurement, construction technology, building services, management studies, construction economics, legal studies, professional practice, general studies such as information technology, data analysis and land surveying; and applied studies which includes integrated projects and dissertation work. ISM (2013) explains that the topic on Integrated Project will vary from year to year dependent upon the industry support available, whilst dissertation work is conducted

As mentioned previously, in the RICS Quantity Surveying and Construction's APC (RICS, 2015), there are three (3) levels of attainment. In which in this context of the research, Conception Stage is equivalent to RICS APC Level 1's knowledge and understanding; Implementation Stage is similar to Level 2: Application of knowledge and understanding; and Optimisation

Stage is comparable to Level 3’s reasoned advice and depth of technical knowledge.

The pairing of the competencies into the relevant RICS competences and ISM’s syllabus list is tabulated in Table 5.2. The 24 BIM competencies can be adequately allocated into ISM’s nine (9) subject groups that falls under the mandatory Quantity Surveying subjects to be taught by the university. There are some similarities found between ISM’s mandatory Quantity Surveying subject groups and Table 5.2. For instance, in ISM’s list of subjects tabulation, Management Studies and Information Communication Technology (ICT) are to be covered in all three (3) stages of examination i.e. First Examination, Intermediate Examination and Final Examination stage, this is in line with Table 5.2, whereby Management Studies can be found from Conception Stage, Implementation Stage and Optimisation Stage.

However, some subjects paired with the competences are found to be lagged by a stage. For instance, Professional Practice and Construction Technology are to be covered in the Intermediate and Final Examination stage, whereas in Table 5.2, Professional Practice and Construction Technology are found to be in one stage earlier i.e. Conception and Implementation Stage. Other than that, Building Services, Construction Economics is only paired to the competencies in the Conception Stage, as compared to ISM’s examination stage as Building Services can be found in the first two (2) examination stages, whilst

Construction Economics can be found in all three (3) examination stages. This may be because by having BIM embedded in the course syllabus, it is essential for the undergraduates to understand the roles and responsibility of a QS, and how the processes works during the design and construction stage.

Legal Studies are found only in the Optimisation Stage whereas based on ISM's tabulation it should be applied from Foundation Stage, subsequently continuing into Intermediate Examination and Final Examination stages. This may be important to allow undergraduates to understand the general concept of law first, slowly moving into Malaysian Legal System, then Contract and Tort. Once undergraduates have the basic, they will then be introduced with Construction Law and the importance when BIM is implemented.

Similarly, Applied Studies can be found in Optimisation Stage, whereas based on ISM's tabulation it is to be covered in the First and Intermediate Examination Stages. Applied Studies on Integrated Project with the Technical competencies of comparing examples of successful BIM implementation will be able to assist undergraduate to apply thinking skills on the other subjects covered in their first two (2) stages in relation with BIM implementation.

The Measurement subject is found not being paired with any competencies, with the reasoning that measurement is the core in a Quantity

Surveying course, hence with regards to the 24 competencies spread out across Conception, Implementation and Optimisation Stage, the syllabus should be able to assist students to relate the essence of measurement with each subject.

5.6 Summary

The subject "BIM" should not be look at as an individual standalone subject. BIM itself is a definition of interoperability, a platform for exchanges of information to occur. Therefore, in academic wise, BIM should assimilate into the Curriculum Learning Framework of QS undergraduate programme to produce undergraduates that are equipped with the required BIM competencies. This is shown in Table 5.2, whereby the 24 competencies are able to be allocated into the nine (9) core subjects by ISM with its appropriate stages to implement.

Table 5.2 Pairing Competences with Suggested Courses

Stages	Competencies	Suggested Competencies/Courses: RICS Quantity Surveying and Construction APC (RICS, 2015)	Suggested Competencies/Courses: Rules and Syllabuses of the Professional Examinations for Quantity Surveying (ISM, 2003)
Conception	**Contextual**		
	1. Aware of authority requirements posed upon BIM adoption	Due Diligence	Professional Practice
	Behavioural		
	2. Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	BIM Management	Management Studies
	Technical		
	3. Utilise BIM to manage the use and maintenance of facilities	Managing Resources	Building Services
	4. Utilise BIM to assess the condition of existing assets	Due Diligence	Construction Technology
	5. Define the common language and terminology associated with BIM adoption	BIM Management	ICT
	6. Implement governance of information and process management with BIM adoption	Data Management	Management Studies
	7. Identify the hardware, software and network infrastructure requirements upon BIM adoption	BIM Management	ICT
	8. Evaluate and select software and technology upon BIM adoption	BIM Management	ICT
	9. Utilise BIM to analyse and plan construction and installation work processes and resources	Programming and Planning	Construction Technology
	10. Use BIM to assist in achieving productivity and efficiency improvements	Construction Technology and Environmental Services	Construction Technology
	11. Communicate the impact of BIM adoption	Communication and Negotiation	Management Studies
	12. Use BIM in the whole life inter-disciplinary design	Design Economics and Cost Planning	Construction Economics
	13. Utilise BIM to assess contextual data affecting potential developments	Design Economics and Cost Planning	Construction Economics
	14. Utilise BIM in procurement processes	Procurement and Tendering	Professional Practice

Stages	Competencies	Suggested Competencies/Courses: RICS Quantity Surveying and Construction APC (RICS, 2015)	Suggested Competencies/Courses: Rules and Syllabuses of the Professional Examinations for Quantity Surveying (ISM, 2003)
Implementation	**Behavioural**		
	15. Collaborate with project teams upon BIM adoption	Teamworking	Management Studies
	Technical		
	16. Reduce the project risks with BIM adoption	Risk Management	Construction Technology
	17. Identify and manage risks upon BIM adoption	Risk Management	Professional Practice
	18. Utilise BIM to manage project handover and facilities information	Data Management	Management Studies
	19. Utilise BIM to manage and operate technical information systems	Data Management	ICT
Optimisation	**Contextual**		
	20. Invest in up-skilling, systems and process management upon BIM adoption	BIM Management	ICT
	21. Engage organisational stakeholders to BIM adoption	Managing People	Management Studies
	22. Engage business stakeholders upon BIM adoption	Managing People	Management Studies
	23. Identify the liability implications posed upon BIM adoption	Contract Practice	Legal Studies
	Technical		
	24. Compare examples of successful BIM implementation	Communication and Negotiation	Applied Studies on Integrated Project.

CHAPTER 6

CONCLUSION

6.1 Conclusion

It's evident that not only the QS industry, but all stakeholders in the construction industry can reap the benefits of implementing BIM. In order to meet the rising demand of BIM-ready QS graduates, the aim of this research is to identify the competencies required to embed BIM into the Quantity Surveying education, so that the HEI are able to produce undergraduates that are equipped with the required BIM competencies.

To meet the research aim, the first research objectives is to explore the knowledge and skills required in the adoption of BIM in the construction industry. In which this is achieved by identifying 24 BIM competencies as shown in Table 5.1, and subsequently categorised into Contextual, Behavioural and Technical competences and is sorted into three (3) stages of education i.e. Conception, Implementation and Optimisation.

The second research objective is to recommend BIM competencies to be embedded in the Curriculum Learning Framework of QS undergraduate programme. This research objective is achieved as shown in Table 5.2, whereby the 24 BIM competencies are paired with the Rules and Syllabuses of the Professional Examinations for Quantity Surveying (ISM, 2003) and RICS Quantity Surveying and Construction APC (RICS, 2015). This is with the view of recommending the BIM competencies to be embedded in the paired competence or syllabus in the Curriculum Learning Framework of QS undergraduate programme.

With both of the research objectives being met, the research aim is achieved as the competencies required to embed BIM into the Quantity Surveying education are identified.

6.2 Implications

The findings of this research could serve as a useful reference for the Higher Education Institute (HEI), in order for the HEI to embed the competencies into the local universities' current QS curriculum. With this the HEI will be able to bridge the gap of the demand and supply of BIM-ready graduates in the construction industry. Besides that, the findings of this research can serve as a basis for other researchers that would like to explore other aspects of the QS education.

6.3 Limitations

This research is to identify BIM competencies required to embed BIM into the Quantity Surveying education. Thus, in this research the competencies discussed focuses on individual's competences. The target respondents of the survey questionnaire are to QS in Malaysia from consultancy firms, developer firms, construction companies, or any other firms that provides quantity surveying services

BIM is considered to be quite fresh to the Malaysian construction industry, its implementation can be considered as pretty much undeveloped yet. Hence, the respondents' understanding on BIM may differ in future when they understand the full extent of the BIM process. If the questionnaire were to be distributed 10 years later, more knowledge gaps may be identified, as at the current standpoint, the respondents may not know what they do not know yet. Furthermore, in this study, the collection survey questionnaire was difficult, as respondents that have no knowledge on BIM are reluctant to respond to the questionnaire.

6.4 Recommendation

Recommendations to further refine this research can be conducted by working hands in hands with a Quantity Surveying practicing firm on a BIM pilot project. The 24 BIM competencies identified can act as a checker on the pilot project in terms on the stages that the aspects of the BIM competencies is carried out and how elaborate the particular aspects of the BIM competencies are conducted.

Besides that, for validation purposes, a focus group can be conducted with a group of academicians to validate if the 24 BIM competencies that is paired with the mandatory Quantity Surveying subjects by ISM (2003) is appropriate. At the same time, to understand if there are any other barriers that are hindering the HEI to embed BIM into the Quantity Surveying courses.

6.5 Summary

As we are all in a rapidly changing technological world, we should be receptive to changes and prepare ourselves for the best. The 24 BIM competencies categorised into the three (3) main Stages of implementation will act as a start point for HEI to begin with, so that the demand of BIM-ready graduates in the construction industry can be met for the time being. Further refining of Quantity Surveying course syllabus, with the latest competencies required in an individual by the construction industry has to be carried out yearly, so that the HEI does not fall out from the industry current demand.

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APPENDIX A

INITIAL BIM LEARNING OUTCOMES FRAMEWORK (BAF, 2013)

(Please see next page)

PRELIMINARY BIM LEARNING OUTCOMES FRAMEWORK (July 2012)

STRATEGIC

Overview	**In relation to each of the learning outcomes below, as a result of following this course, individuals will be expected to:**
O1	**What is BIM**
	Understand the principles of Building Information Modelling and its application to the whole life inter-disciplinary design, construction and use of building and infrastructure developments
O2	**BIM Value proposition (context relevant, e.g. client and contractor)**
	Understand the value proposition that BIM offers enabling adopters to more efficiently:
	Identify and evaluate stakeholder, user, community and sustainability project requirements
	Prepare project briefs and development programmes
	Assess and manage project risks and opportunities
	Prepare and present project design recommendations
	Assess, plan, estimate and control proposed development energy, whole life and capital costs
	Model and analyse production and installation project design solutions
	Plan and agree detailed project designs
	Analyse and plan project resources and work processes
	Establish project work teams and organisational systems
	Manage project handover guidance, completion and feedback
	Develop and implement property and facilities management plans
O3	**What is the Government requirement from BIM**
	Understand the Government's requirements regarding the adoption of BIM on public projects in order to:
	Identify, assess and agree project requirements and stakeholder preferences
	Establish project team partnering
	Assess and manage project risks and opportunities
	Plan and control proposed capital costs
	Build your organisation's understanding of its market and customers
	Manage business processes and improve performance
O4	**Industry context of BIM adoption (e.g. peer firms)**
	Understand the context in which BIM is being introduced into the industry by being able to:
	Establish project team partnering
	Analyse efficient resource use and work processes
	Map the environment in which the organisation operates
	Identify and resource the research and development of new products and services to meet market needs
	Plan the development of organisational products, services and processes to meet market needs
	Focus resources upon those marketing activities offering the best return
O5	**Impact to client and supply chain relationships (collaborative and coordinated)**
	Understand the impact of BIM on client and supply chain relationships in order to be able to:
	Identify, assess and agree project requirements and stakeholder preferences
	Establish project team partnering
	Implement strategic sourcing partnerships and supply chain arrangements
	Analyse efficient resource use and work processes
	Establish and maintain project organisation and communication systems
	Build your organisation's understanding of its market and customers
	Plan the development of new and innovative operational processes, methods and techniques to meet market needs
Strategic Considerations	
S1	**Strategic issues associated with starting BIM**
	Understand the strategic issues associated with starting to adopt BIM in order to be able to:
	Establish project team partnering
	Implement strategic sourcing partnerships and supply chain arrangements
	Identify and resource the research and development of new products and services to meet market needs
	Plan the development of new and innovative operational processes, methods and techniques to meet market needs
	Lead, plan and implement change
	Manage business processes and organisational performance
S2	**The role of Executive leadership**
	Understand the role of executive leadership in order to be able to:
	Build organisational understanding of its market and customers
	Lead, plan and implement change
	Provide leadership for the organisation
	Promote the use of technology within the organisation
S3	**Information deliverables; impact to procurement conditions and skills demands**
	Understand the changes required by BIM to informatioin deliverables, procurement conditions and skills demands in order to be able to:
	Identify, assess and agree project requirements and stakeholder preferences
	Select and agree a procurement method with stakeholders
	Establish project team partnering
	Establish and monitor project team working methods
	Integrate and evaluate project design information
	Analyse and plan construction project resources and work processes
	Establish and maintain project organisation and communication systems
	Provide information to support use and maintenance planning of property, systems and services
	Manage property and asset use
	Manage business processes
	Establish, implement and monitor human resourcing and skills development policy
S4	**Developing the business case**
	Understand the business case for BIM in order to be able to:
	Plan the development of organisational products, services and processes to meet market needs
	Establish, implement and improve a business plan
	Manage business processes and improve performance
S5	**Investment model (up-skilling, systems and process management)**
	Understand the investment required for BIM up-skilling, systems and process management in order to be able to:
	Plan the development of new and innovative operational processes, methods and techniques to meet market needs
	Plan and implement change
	Establish, implement and improve a business plan
	Allocate organisational budgets for projects
	Manage physical resources
	Manage business processes and improve performance
	Identify collective learning and development needs
	Establish and set up technical information systems
S6	**Organisation stakeholder engagement**
	Understand the need for engagement of organisational stakeholders in the adoption of BIM in order to be able to:
	Build your organisation's understanding of its market and customers
	Develop a customer focused organisation
	Develop the culture of the organisation
	Plan the development of new and innovative operational processes, methods and techniques to meet market needs
	Establish a marketing strategy

PRELIMINARY BIM LEARNING OUTCOMES FRAMEWORK (July 2012)		
MANAGEMENT		
Overview	**In relation to each of the learning outcomes below, as a result of following this course, individuals will be expected to:**	
O1	**What is BIM**	
	Understand the principles of Building Information Modelling and its application to the whole life inter-disciplinary design, construction and use of building and infrastructure developments	
Acquiring internal resources		
A1	**Developing the business case, investment and return model**	
	Understand the business case, investment and return model for BIM in order to be able to	
	Evaluate the benefits and risks of partnership and strategic sourcing	
	Identify and resource the research and development of new products and services to meet market need	
	Identify opportunities to maintain and increase revenue	
	Establish, implement and improve a business plan	
	Allocate organisational budgets for projects	
	Manage physical resources	
	Manage business processes and improve performance	
A2	**Organisation and Project applications, and benefits of BIM**	
	Understand the organisational and project applications and benefits of BIM in order to be able to	
	Identify and evaluate stakeholder, user, community and sustainability project requirements	
	Confirm project energy efficiency and carbon minimisation requirements and strategies	
	Establish arrangements for procurement and management of sustainable projects	
	Prepare project briefs and development programmes	
	Induct and brief a project team	
	Establish and monitor project team working methods	
	Assess and manage project risks and opportunities	
	Select, test and refine sustainable design options	
	Prepare and present project design recommendations	
	Assess and advise on capital, energy, whole life and low carbon costs	
	Model and analyse production and installation project design solutions	
	Prepare and agree production and installation information	
	Agree and implement alignment of systems with partners and supply chains	
	Analyse and plan project resources and work processes	
	Establish and maintain project organisation and communication systems	
	Manage project handover information, completion and feedback	
	Develop and implement property and facilities management plans	
	Monitor and control the use of property and assets	
	Plan the development of organisational products, services and processes to meet market needs	
	Improve organisational performance	
	Target and promote products/services effectively	
	Apply information technology to projects	
	Promote the use of technology within the organisation	
A3	**Visualisation benefits and spatial coordination**	
	Understand the benefits of BIM for visualisation and spatial coordination in order to be able to	
	Establish and monitor project team working methods	
	Analyse and present survey data	
	Assess and present spatial data	
	Select, test and refine sustainable design options	
	Prepare and advise on project design recommendations	
	Model and analyse production and installation project design solutions	
	Plan and agree detailed project designs	
	Advise on and refine integrated conservation solutions	
	Integrate the design of fabric, services and systems	
	Measure quantities from design information	
	Control the assembly of materials, components, systems and finishes to achieve sound construction	
	Provide information to support use and maintenance planning of property, systems and services	
	Allocate space and facilities to meet identified requirements	
	Plan and programme work to existing assets	
A4	**Productivity/Efficiency improvements**	
	Understand the way in which BIM can be adopted to achieve productivity and efficiency improvements by being able to	
	Establish and monitor project team working methods	
	Identify and assess technical, procurement and production factors affecting resources	
	Select, test and refine sustainable design options	
	Model and analyse production and installation project design solutions	
	Integrate the design of fabric, services and systems	
	Evaluate and select work methods	
	Plan work activities and efficient use of resources to meet project work requirements	
	Obtain and evaluate project feedback information and make improvements	

	Monitor and control the use of property and assets	
	Manage and implement work to existing assets	
	Manage business processes and improve performance	
A5	**Sustainable design**	
	Understand the way in which BIM can be adopted to achieve sustainable design by being able to	
	Test the suitability of planning and development strategy and policy options	
	Assess the environmental needs and impacts of resources, policies and proposals	
	Investigate and evaluate sustainable development requirements	
	Establish arrangements for sustainable development	
	Identify and assess technical, procurement and production factors affecting resources	
	Select, test and refine sustainable design options	
	Model and analyse production and installation project design solutions	
A6	**Scheduling, Estimating**	
	Understand the way in which BIM can be adopted for scheduling and estimating in order to be able to	
	Plan and control proposed capital costs	
	Prepare estimates of proposed capital costs	
	Prepare schedules	
	Prepare bills of measured quantities	
	Obtain estimates, bids and tenders	
	Assess and select successful estimates, bids and tenders and negotiate changes	
	Assess the resource requirements and costs within an estimate, bid and tender	
	Finalise and submit an estimate, bid and tender offer	
	Deploy plant and equipment for construction and installation operations	
	Organise, monitor, maintain and improve supplies of materials to meet project requirements	
	Control contract progress against agreed programmes	
	Control contract quantities and costs	
	Prepare and agree interim valuations and final accounts	
	Plan and programme work to existing assets	
	Manage work programmes to existing assets	
A7	**De-risking projects**	
	Understand the way in which BIM can be adopted to de-risk projects by being able to	
	Assess project risks and opportunities	
	Specify and implement methods and procedures to manage project risk	
A8	**Facilities management**	
	Understand the way in which BIM can be adopted for facilities management by being able to	
	Provide information to support use and maintenance planning of property, systems and services	
	Obtain and evaluate project feedback information and make improvements	
	Allocate space and facilities to meet identified requirements	
	Monitor and control the use of property and assets	
	Plan and programme work to existing assets	
	Manage work programmes to existing assets	
	Implement agreed policies and programmes for pre-planned maintenance works	
Developing Organisational Business Plan		
D1	**Engaging business stakeholders**	
	Understand the need for engagement of business stakeholders in the adoption of BIM in order to be able to	
	Build the organisation's understanding of its market and customers	
	Develop a customer focused organisation	
	Build and maintain effective customer relations	
D2	**Developing business goals and plans**	
	Understand the development of business goals and plans for BIM adoption in order to be able to	
	Plan the development of new and innovative operational processes, methods and techniques to meet market need	
	Prepare business plans	
	Allocate organisational budgets for projects	
	Manage business processes and improve performance	
D3	**Gaining commitment**	
	Understand the need for gaining commitment to BIM adoption in order to	
	Develop the culture of the organisation	
	Lead change	
	Plan change	
	Manage business processes and improve performance	
D4	**Execution of plans; referencing examples**	
	Understand the exectioning of plans and referencing of examples for BIM adoption in order to be able to	
	Implement change	
	Establish, implement and improve a business plan	
	Manage business processes and improve performance	

Managing external requirements		
E1	**Legal implications and requirements – FOC's, agreements, appointments, SLA's etc**	
	Understand the legal implications and requirements posed by the adoption of BIM (eg. FOC's, agreements, appointments, SLA's, procuremtn, contacts, briefing etc.) in order to be able to:	
	Identify, assess and agree project requirements and stakeholder preferences	
	Establish arrangements for procurement of sustainable projects	
	Assist clients to meet their legal duties	
	Prepare and present a proposal for a project brief	
	Identify and assess resource use and environmental impact factors	
	Evaluate the benefits and risks of partnership and strategic sourcing	
	Agree and implement alignment of systems with partners and supply chains	
	Implement resource efficient procurement processes	
	Prepare and submit estimates, bids and tenders	
	Prepare, negotiate and secure contracts	
	Identify, monitor and respond to legal and statutory requirements	
E2	**Ownership, IP, copyright, design rights, insurances, PII, etc**	
	Understand the liability implications posed by the adoption of BIM (eg. Ownership, IP, copyright, design rights, insurances, PII, etc.) in order to be able to:	
	Implement strategic sourcing partnerships and supply chain arrangements	
	Prepare, negotiate and secure contracts	
	Identify, monitor and respond to legal and statutory requirements	
E3	**Risk – identifying and managing (risk registers, etc)**	
	Understand the implications of identifying and managing risk in the adoption of BIM in order to be able to	
	Assess and manage project risks and opportunities	
E4	**Data deliverables to supply chain; and to clients**	
	Understand the data deliverables for clients and the supply chain required through the adoption of BIM (eg. COBie, models etc.) in order to be able to:	
	Identify, assess and agree project requirements and stakeholder preferences	
	Prepare and present a proposal for a project brief	
	Induct and brief a project team	
	Establish and monitor project team working methods	
	Select, test and refine sustainable design options	
	Prepare and advise on project design recommendations	
	Plan and control proposed capital costs	
	B53.4 Prepare estimates of proposed capital costs	
	Identify the purpose, methods and techniques for preparing detailed designs	
	Model and analyse production and installation project design solutions	
	Investigate, develop and integrate detailed design solutions	
	Prepare and process applications to secure statutory consents	
	Specify, integrate and control project design information	
	Prepare drawings and associated graphical information	
	Prepare technical specifications	
	Prepare bills of measured quantities	
	Obtain estimates, bids and tenders	
	Assess the resource requirements and costs within an estimate, bid and tender	
	Finalise and submit an estimate, bid and tender offer	
	Analyse and plan project resources and work processes	
	Establish and maintain project organisation and communication systems	
	Coordinate the logistics for work to existing occupied properties	
	Establish and set out dimensional controls	
	Deploy plant and equipment for construction and installation operations	
	Identify and monitor requirements for materials supply	
	Provide information to support use and maintenance planning of property, systems and services	
	Obtain and evaluate project feedback information and make improvements	
	Develop and implement property and facilities management plans	
	Monitor and control the use of property and assets	
	Plan and programme work to existing assets	
	Manage work programmes to existing assets	
	Apply information technology to projects	
managing people		
P1	**Impact to internal and external roles**	
	Understand the impact on internal and external roles posed by the adoption of BIM in order to be able to	
	Establish project team partnering	
	Establish and coordinate the project development teams and processes	
	Integrate the design of fabric, services and systems	
	Integrate and evaluate project design information	
	Implement strategic sourcing partnerships and supply chain arrangements	
	Establish project work teams and organisational systems	
	Map the environment in which your organisation operates	
	Develop the culture of the organisation	

	Establish, implement and monitor human resourcing and skills development policy
	Identify collective learning and development needs
	Manage and operate technical information systems
P2	**Internal stakeholder engagement - strategic, management and technical**
	Understand the need for internal stakeholder engagement at strategic, management and delivery levels in the adoption of BIM within an organisation in order to be able to:
	Develop the culture of the organisation
	Manage business processes and improve performance
	Manage and operate technical information systems
	Provide leadership for your organisation
	Develop productive working relationships with colleagues
	Promote the use of technology within your organisation
P3	**Collaboration – management of people, communication skills, team working, etc**
	Understand the need for collaboration in the management of people, communications and teams in the adoption of BIM within an organisation in order to be able to:
	Establish and coordinate the project development teams and processes
	Prepare and agree production and installation information
	Integrate the design of fabric, services and systems
	Specify, integrate and control project design information
	Agree and implement alignment of systems with partners and supply chains
	Monitor and control arrangements for strategic sourcing and supply chain management
	Establish project work teams and organisational systems
	Coordinate the logistics for work to existing occupied properties
	Co-ordinate site operations
	Provide information to support use and maintenance planning of property, systems and services
	Manage business processes and improve performance
	Allocate and check work in your team
	Allocate and monitor the progress and quality of work in your area of responsibility
	Build and manage teams
	Develop, maintain and enhance productive working relationships
P4	**Communicating the impact and relevance of BIM**
	Understand the need to communicate the impact and relevance of of BIM in its adoption within an organisation in order to be able to:
	Induct and brief a project team
	Establish and monitor project team working methods
	Establish and maintain project organisation and communication systems
	Develop the culture of the organisation
	Plan the development of new and innovative operational processes, methods and techniques to meet market need
	Manage business processes and improve performance
	Provide leadership in the area of responsibility
	Provide leadership for the organisation
	Communicate technical information and advice
	Enable others to learn and benefit from experience
	Use IT systems and software
P5	**Compare examples of successful BIM organisation implementation**
	Understand the need to compare examples of successful BIM implementation in the adoption of BIM within an organisation in order to be able to:
	Build your organisation's understanding of its market and customers
	Develop a customer focused organisation
	Identify, investigate and communicate values and sector and environmental issues which affect the organisation's operations
	Identify and resource the research and development of new products and services to meet market need
	Plan the development of new and innovative operational processes, methods and techniques to meet market need
P6	**Discuss issues associated with starting BIM**
	Understand the need to openly discuss issues associated with the adoption of BIM within an organisation in order to be able to:
	Implement strategic sourcing partnerships and supply chain arrangements
	Plan the development of new and innovative operational processes, methods and techniques to meet market need
	Manage business processes and improve performance
	Establish, implement and monitor human resourcing and skills development policy
	Identify collective learning and development needs
	Manage and operate technical information systems
	Use IT systems and software
Managing process	
R1	**Defining common language; BIM terminology**
	Understand the ned to define the common language and terminology associated with the adoption of BIM within an organisation in order to be able to:
	Identify, assess and agree project requirements and stakeholder preferences
	Establish project team partnering

	Establish and coordinate the project development teams and processes	
	Implement strategic sourcing partnerships and supply chain arrangements	
	Select and form a project work team	
	Provide information to support use and maintenance planning of property, systems and services	
	Plan the development of new and innovative operational processes, methods and techniques to meet market need	
	Manage business processes and improve performance	
	Manage and operate technical information systems	
	Use IT systems and software	
R2	**Governance of information and process management**	
	Understand the requirements for governance of information and process management with the adoption of BIM within an organisation in order to be able to:	
	Identify, assess and agree project requirements and stakeholder preferences	
	Establish project team partnering	
	Establish and coordinate the project development teams and processes	
	Implement strategic sourcing partnerships and supply chain arrangements	
	Select and form a project work team	
	Provide information to support use and maintenance planning of property, systems and services	
	Plan the development of new and innovative operational processes, methods and techniques to meet market need	
	Manage and operate technical information systems	
	Apply information technology to projects	
R3	**Standards (data and process) – knowledge of and implementation**	
	Understand the implementation of data and process standards (eg. BS8541, BS1192.2 & COBie etc.) in the adoption of BIM within an organisation in order to be able to:	
	Establish and monitor project team working methods	
	Agree and implement alignment of systems with partners and supply chains	
	Plan the development of new and innovative operational processes, methods and techniques to meet market need	
	Manage business processes and improve performance	
	Manage and operate technical information systems	
	Apply information technology to projects	
R4	**Developing BIM Execution Plan – frameworks and guidance**	
	Understand the framewoks and guidance involved in developing an execution plan in the use of BIM on projects in order to be able to:	
	Identify, assess and agree project requirements and stakeholder preferences	
	Establish project team partnering	
	Establish and coordinate the project development teams and processes	
	Agree and implement alignment of systems with partners and supply chains	
	Monitor and control arrangements for strategic sourcing and supply chain management	
	Provide information to support use and maintenance planning of property, systems and services	
	Apply information technology to projects	
Managing technical infrastructure		
T1	**Interoperability – adherence to standards, managing compliance**	
	Understand the principles of interoperability in terms of adherence to standards and managing compliance in the adoption of BIM within an organisation in order to be able to:	
	Establish project team partnering	
	Establish and monitor project team working methods	
	Agree and implement alignment of systems with partners and supply chains	
	Monitor and control arrangements for strategic sourcing and supply chain management	
	Provide information to support use and maintenance planning of property, systems and services	
	Manage business processes and improve performance	
	Manage and operate technical information systems	
	Apply information technology to projects	
T2	**Hardware, Software, Network infrastructure requirements (organisation specific)**	
	Understand the hardware, software and network infrastructure requirements in the adoption of BIM within an organisation in order to be able to:	
	Plan the development of new and innovative operational processes, methods and techniques to meet market need	
	Manage physical resources	
	Manage business processes and improve performance	
	Manage and operate technical information systems	
	Apply information technology to projects	
T3	**Software/technology evaluation and selection process**	
	Understand the processes for evaluation and selection of software and technology in the adoption of BIM within an organisation in order to be able to:	
	Agree and implement alignment of systems with partners and supply chains	
	Plan the development of new and innovative operational processes, methods and techniques to meet market need	
	Manage and operate technical information systems	
	Apply information technology to projects	

PRELIMINARY BIM LEARNING OUTCOMES FRAMEWORK (July 2012)	
TECHNICAL	
Overview	**In relation to each of the learning outcomes below, as a result of following this course, individuals will be expected to:**
O1	**What is BIM**
	Understand the principles of Building Information Modelling and its application to the whole life inter-disciplinary design, construction and use of building and infrastructure developments
Tech 1	**Identifying project requirements**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Identify and evaluate stakeholder, user, community and sustainability project requirements
Tech 2	**Assessing contextual data affecting potential developments**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Investigate and assess contextual factors affecting potential project developments
	Identify, assess and take account of resource factors affecting potential sustainable project developments
	Investigate and assess regulatory and legal factors affecting potential developments
Tech 3	**Developing design solutions**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Assess and develop sustainable project design options
	Prepare and advise on project design recommendations
	Assess, plan, estimate and control proposed development energy, whole life and capital costs
	Plan and agree detailed project designs
	Analyse and model environmentally sustainable project design solutions
	Analyse, advise on and support sustainable solutions for historic and heritage assets
	Manage health and safety in design
	Investigate, develop and integrate detailed design solutions
	Prepare applications and appeals to secure statutory consent
Tech 4	**Managing design information**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Specify, integrate and control project design information
	Prepare drawings, graphical information and schedules
	Prepare technical specifications
	Prepare bills of measured quantities
Tech 5	**Implementing procurement processes**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Implement resource efficient procurement processes
	Prepare and submit estimates, bids and tenders
	Prepare, negotiate and secure contracts
Tech 6	**Analysing and planning construction and installation work processes and resources**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Analyse and plan project resources and work processes
	Establish project work teams and organisational systems
Tech 7	**Coordinating and controlling construction and installation operations**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Establish, coordinate and control construction and installation operations and resources to efficiently meet project requirements
	Deploy plant and equipment for construction and installation operations
	Organise, monitor, maintain and improve supplies of materials to meet project requirements
	Establish and maintain systems for managing site health, safety and welfare
	Control project quality, compliance, progress and cost
Tech 8	**Managing project handover and facilities information**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Manage project handover information, completion and feedback
Tech 9	**Assessing the condition of existing assets**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Advise on and refine integrated conservation solutions
	Prepare and present asset condition survey reports and records

Tech 10	**Assessing the energy performance of buildings**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Assess and certify the energy performance of buildings
	Manage, monitor and identify improvements to the energy performance of buildings
Tech 11	**Managing the use and maintenance of facilities**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Coordinate the logistics for work to existing occupied properties
	Develop and implement property and facilities management plans
	Manage property and asset use
	Manage and implement work to existing assets
Tech 12	**Managing and operating technical information systems**
	Understand how to gather, maintain and use BIM data in order to be able to:
	Establish and set up technical information storage systems
	Operate technical information systems
	Apply information technology to projects

APPENDIX B

BUILDING INFORMATION MODELING (BIM) COMPETENCIES IN QUANTITY SURVEYOR PROFESSION

PART A

A1. Please rate the following statements in terms of your level of awareness on BIM's capability.

No.	Statements	Not Aware	Somewhat Aware	Uncertain	Aware	Fully Aware
1	Able to enhance the business case in the organisation	1	2	3	4	5
2	Able to introduce diversity of roles	1	2	3	4	5
3	Able to provide visualisation and spatial coordination	1	2	3	4	5
4	Able to manage and reduce project risks	1	2	3	4	5
5	Able to assist in facilities management	1	2	3	4	5
6	Able to execute plan based on the strategic issues required	1	2	3	4	5
7	Able to identify authority requirements and liability implications upon BIM adoption	1	2	3	4	5
8	Able to manage information to operate technical data	1	2	3	4	5
9	Able to enhance collaboration between project teams	1	2	3	4	5
10	Able to utilise ICT infrastructure to enhance workflow	1	2	3	4	5
11	Able to assist in scheduling, quantifying and estimating	1	2	3	4	5
12	Able to determine constructability and coordinating construction	1	2	3	4	5
13	Able to facilitate whole life cycle costing	1	2	3	4	5
14	Able to improve the procurement method/supply chain management	1	2	3	4	5

A2. Please rate the following statements according to your level of BIM proficiency.

No.	Statements	Not Competent	Somewhat Competent	Uncertain	Competent	Highly Competent
1	Develop the business case, investment and return model upon BIM adoption	1	2	3	4	5
2	Apply BIM in alignment with organisational goals	1	2	3	4	5
3	Gain commitment upon BIM adoption	1	2	3	4	5
4	Develop the business goals and plans upon BIM adoption	1	2	3	4	5
5	Invest in up-skilling, systems and process management upon BIM adoption	1	2	3	4	5
6	Engage organisational stakeholders to BIM adoption	1	2	3	4	5
7	Evaluate the impact on internal and external roles posed upon BIM adoption	1	2	3	4	5
8	Engage business stakeholders upon BIM adoption	1	2	3	4	5
9	Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption	1	2	3	4	5
10	Utilise BIM to visualize the project and understand the relationships of the various components to one another	1	2	3	4	5
11	Utilise BIM to build 3D models and construct virtual model	1	2	3	4	5
12	Utilise BIM to develop the model into an acceptable representation of what is visualized	1	2	3	4	5
13	Reduce the project risks with BIM adoption	1	2	3	4	5
14	Identify and manage risks upon BIM adoption	1	2	3	4	5
15	Utilise BIM to manage project handover and facilities information	1	2	3	4	5
16	Utilise BIM to manage the use and maintenance of facilities	1	2	3	4	5
17	Develop frameworks and guidance and execution plan for BIM adoption	1	2	3	4	5
18	Consider strategic issues required on BIM adoption	1	2	3	4	5
19	Aware of authority requirements posed upon BIM adoption	1	2	3	4	5
20	Identify the liability implications posed upon BIM adoption	1	2	3	4	5
21	Compare examples of successful BIM implementation	1	2	3	4	5
22	Define the common language and terminology associated with BIM adoption	1	2	3	4	5
23	Implement governance of information and process management with BIM adoption	1	2	3	4	5
24	Implement data and process standards upon BIM adoption	1	2	3	4	5

25	Identify the project requirements with BIM	1	2	3	4	5
26	Utilise BIM to manage design information	1	2	3	4	5
27	Utilise BIM to manage and operate technical information systems	1	2	3	4	5
28	Collaborate with project teams upon BIM adoption	1	2	3	4	5
29	Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	1	2	3	4	5
30	Identify the hardware, software and network infrastructure requirements upon BIM adoption	1	2	3	4	5
31	Evaluate and select software and technology upon BIM adoption	1	2	3	4	5
32	Utilise BIM to analyse and plan construction and installation work processes and resources	1	2	3	4	5
33	Utilise BIM in scheduling and estimating	1	2	3	4	5
34	Use BIM to assist in achieving productivity and efficiency improvements	1	2	3	4	5
35	Communicate the impact of BIM adoption	1	2	3	4	5
36	Utilise BIM to assess contextual data affecting potential developments	1	2	3	4	5
37	Utilise BIM to develop design solution	1	2	3	4	5
38	Utilise BIM to coordinate and control construction and installation operations	1	2	3	4	5
39	Utilise BIM to assess the condition of existing assets	1	2	3	4	5
40	Use BIM in the whole life inter-disciplinary design	1	2	3	4	5
41	Use BIM in achieving sustainable design	1	2	3	4	5
42	Utilise BIM to assess the energy performance of buildings	1	2	3	4	5
43	Analyse the data deliverables for clients and the supply chain required upon BIM adoption	1	2	3	4	5
44	Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption	1	2	3	4	5
45	Utilise BIM in procurement processes	1	2	3	4	5

A3. Please rate the following statements that you would likely implement within your organisation or team

No.	Statements	Extremely Unlikely	Unlikely	Neutral	Likely	Extremely Likely
1	Develop the business case, investment and return model upon BIM adoption	1	2	3	4	5
2	Apply BIM in alignment with organisational goals	1	2	3	4	5
3	Gain commitment upon BIM adoption	1	2	3	4	5
4	Develop the business goals and plans upon BIM adoption	1	2	3	4	5
5	Invest in up-skilling, systems and process management upon BIM adoption	1	2	3	4	5
6	Engage organisational stakeholders to BIM adoption	1	2	3	4	5
7	Evaluate the impact on internal and external roles posed upon BIM adoption	1	2	3	4	5
8	Engage business stakeholders upon BIM adoption	1	2	3	4	5
9	Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption	1	2	3	4	5
10	Utilise BIM to visualize the project and understand the relationships of the various components to one another	1	2	3	4	5
11	Utilise BIM to build 3D models and construct virtual model	1	2	3	4	5
12	Utilise BIM to develop the model into an acceptable representation of what is visualized	1	2	3	4	5
13	Reduce the project risks with BIM adoption	1	2	3	4	5
14	Identify and manage risks upon BIM adoption	1	2	3	4	5
15	Utilise BIM to manage project handover and facilities information	1	2	3	4	5
16	Utilise BIM to manage the use and maintenance of facilities	1	2	3	4	5
17	Develop frameworks and guidance and execution plan for BIM adoption	1	2	3	4	5
18	Consider strategic issues required on BIM adoption	1	2	3	4	5
19	Aware of authority requirements posed upon BIM adoption	1	2	3	4	5
20	Identify the liability implications posed upon BIM adoption	1	2	3	4	5
21	Compare examples of successful BIM implementation	1	2	3	4	5
22	Define the common language and terminology associated with BIM adoption	1	2	3	4	5
23	Implement governance of information and process management with BIM adoption	1	2	3	4	5

24	Implement data and process standards upon BIM adoption	1	2	3	4	5
25	Identify the project requirements with BIM	1	2	3	4	5
26	Utilise BIM to manage design information	1	2	3	4	5
27	Utilise BIM to manage and operate technical information systems	1	2	3	4	5
28	Collaborate with project teams upon BIM adoption	1	2	3	4	5
29	Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	1	2	3	4	5
30	Identify the hardware, software and network infrastructure requirements upon BIM adoption	1	2	3	4	5
31	Evaluate and select software and technology upon BIM adoption	1	2	3	4	5
32	Utilise BIM to analyse and plan construction and installation work processes and resources	1	2	3	4	5
33	Utilise BIM in scheduling and estimating	1	2	3	4	5
34	Use BIM to assist in achieving productivity and efficiency improvements	1	2	3	4	5
35	Communicate the impact of BIM adoption	1	2	3	4	5
36	Utilise BIM to assess contextual data affecting potential developments	1	2	3	4	5
37	Utilise BIM to develop design solution	1	2	3	4	5
38	Utilise BIM to coordinate and control construction and installation operations	1	2	3	4	5
39	Utilise BIM to assess the condition of existing assets	1	2	3	4	5
40	Use BIM in the whole life inter-disciplinary design	1	2	3	4	5
41	Use BIM in achieving sustainable design	1	2	3	4	5
42	Utilise BIM to assess the energy performance of buildings	1	2	3	4	5
43	Analyse the data deliverables for clients and the supply chain required upon BIM adoption	1	2	3	4	5
44	Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption	1	2	3	4	5
45	Utilise BIM in procurement processes	1	2	3	4	5

PART B

Please check or fill in the best answer.

1. How do you rate your overall BIM understanding?

- □Unaware of what BIM is.
- □Aware of what BIM is about, but still unsure of its potential to the construction industry.
- □Understand what BIM is, and knows its benefit and potential to the construction industry.
- □Understand what BIM is and able to apply it in the projects.
- □Understand what BIM is and able to apply and advise my team in the projects.

2. I know most of the information about BIM through

- □ Formal Education
- □ On-the-job training
- □ Professional Development
- □ None of the above

3. Was BIM part of your course syllabus in the university?

- □ No
- □ Yes

4. How was BIM being taught/ introduced in your university?

- □ As a course/individual subject
- □ By inviting Guest Speaker/Guest Lecturer
- □ By embedding BIM in the subject(s)
- □ None of the above

5. If your answer was 'By embedding BIM in the subject(s), please list down the subject(s) below.

(a) ____

(b) ____

PART C

Please check or fill in the description that best describes your good self.

1 Company's Nature of Business :

- ☐ Developer
- ☐ Consultant
- ☐ General Contractor
- ☐ Specialist Contractor. Please specify: ______________________________
- ☐ Others, please specify: ______________________________

2 Working Experience

- ☐ Less than 2 years
- ☐ More than 2 but less than 5 years
- ☐ More than 5 but less than 10 years
- ☐ More than 10 but less than 20 years
- ☐ More than 20 years

3 Job Title: ______________________________

4 Number of Years with Current Job Title: ______________________________

5 Highest Qualification

- ☐ Diploma
- ☐ Advance Diploma
- ☐ Bachelor degree
- ☐ Master degree
- ☐ Doctorate degree
- ☐ Others, please specify ____________________

6 Main Functional Role
(Please check all relevant)

- ☐ Assisting in establishing a client requirements
- ☐ Advising on procurement strategy
- ☐ Conduct feasibilities studies
- ☐ Preparing tender and contract documents
- ☐ Preparing, negotiating and analysing the costing for tenders and contracts
- ☐ Undertaking costs analysis for repair and maintenance project work
- ☐ Performing risk and value management and cost control
- ☐ Identifying, analysing and developing responses to commercial risks
- ☐ Allocating work to sub-contractors
- ☐ Providing advice on contractual claims
- ☐ Analysing outcomes and writing detailed progress reports

	☐ Valuing completed work and arranging payments ☐ Maintaining awareness of the different building contracts in current use
7	Name of University in which Higher Education was Pursued ________________________________

Thank you for your participation in this survey!!!

APPENDIX C

Measure of sampling adequacy – Diagonal Element of the Anti-Correlation Matrix

No.	Variables	Diagonal Element of the Anti-Correlation Matrix
A2.1	Develop the business case, investment and return model upon BIM adoption	0.675
A2.2	Apply BIM in alignment with organisational goals	0.679
A2.3	Gain commitment upon BIM adoption	0.771
A2.4	Develop the business goals and plans upon BIM adoption	0.781
A2.5	Invest in up-skilling, systems and process management upon BIM adoption	0.756
A2.6	Engage organisational stakeholders to BIM adoption	0.748
A2.7	Evaluate the impact on internal and external roles posed upon BIM adoption	0.702
A2.8	Engage business stakeholders upon BIM adoption	0.776
A2.9	Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption	0.699
A2.10	Utilise BIM to visualize the project and understand the relationships of the various components to one another	0.804
A2.11	Utilise BIM to build 3D models and construct virtual model	0.830
A2.12	Utilise BIM to develop the model into an acceptable representation of what is visualized	0.839
A2.13	Reduce the project risks with BIM adoption	0.730
A2.14	Identify and manage risks upon BIM adoption	0.719
A2.15	Utilise BIM to manage project handover and facilities information	0.734
A2.16	Utilise BIM to manage the use and maintenance of facilities	0.719
A2.17	Develop frameworks and guidance and execution plan for BIM adoption	0.768
A2.18	Consider strategic issues required on BIM adoption	0.711
A2.19	Aware of authority requirements posed upon BIM adoption	0.578
A2.20	Identify the liability implications posed upon BIM adoption	0.730
A2.21	Compare examples of successful BIM implementation	0.667
A2.22	Define the common language and terminology associated with BIM adoption	0.695
A2.23	Implement governance of information and process management with BIM adoption	0.690
A2.24	Implement data and process standards upon BIM adoption	0.695
A2.25	Identify the project requirements with BIM	0.720
A2.26	Utilise BIM to manage design information	0.855
A2.27	Utilise BIM to manage and operate technical information systems	0.804
A2.28	Collaborate with project teams upon BIM adoption	0.746

No.	Variables	Diagonal Element of the Anti-Correlation Matrix
A2.29	Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	0.695
A2.30	Identify the hardware, software and network infrastructure requirements upon BIM adoption	0.713
A2.31	Evaluate and select software and technology upon BIM adoption	0.810
A2.32	Utilise BIM to analyse and plan construction and installation work processes and resources	0.767
A2.33	Utilise BIM in scheduling and estimating	0.784
A2.34	Use BIM to assist in achieving productivity and efficiency improvements	0.834
A2.35	Communicate the impact of BIM adoption	0.737
A2.36	Utilise BIM to assess contextual data affecting potential developments	0.820
A2.37	Utilise BIM to develop design solution	0.777
A2.38	Utilise BIM to coordinate and control construction and installation operations	0.807
A2.39	Utilise BIM to assess the condition of existing assets	0.764
A2.40	Use BIM in the whole life inter-disciplinary design	0.804
A2.41	Use BIM in achieving sustainable design	0.739
A2.42	Utilise BIM to assess the energy performance of buildings	0.794
A2.43	Analyse the data deliverables for clients and the supply chain required upon BIM adoption	0.808
A2.44	Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption	0.776
A2.45	Utilise BIM in procurement processes	0.738

APPENDIX D

Correlation Matrix, R Matrix

No.	A2.1	A2.2	A2.3	A2.4	A2.5	A2.6	A2.7	A2.8	A2.9	A2.10	A2.11	A2.12	A2.13	A2.14	A2.15	A2.16	A2.17	A2.18	A2.19	A2.20	A2.21	A2.22	A2.23
A2.1	1.000	.731	.707	.679	.641	.637	.552	.647	.583	.551	.619	.611	.499	.506	.600	.624	.621	.640	.539	.600	.663	.536	.607
A2.2	.731	1.000	.742	.703	.687	.664	.619	.639	.639	.610	.651	.636	.610	.593	.660	.585	.631	.596	*.477	.589	.611	.604	.600
A2.3	.707	.742	1.000	.785	.731	.692	.640	.687	.633	.689	.714	.715	.606	.637	.641	.713	.722	.728	.553	.717	.684	.607	.626
A2.4	.679	.703	.785	1.000	.756	.721	.743	.725	.716	.737	.740	.746	.679	.692	.698	.673	.754	.771	.561	.674	.631	.687	.662
A2.5	.641	.687	.731	.756	1.000	.779	.682	.700	.665	.707	.702	.730	.613	.650	.649	.644	.710	.716	.489	.683	.652	.637	.664
A2.6	.637	.664	.692	.721	.779	1.000	.646	.727	.730	.617	.666	.657	.585	.607	.646	.628	.670	.624	.538	.716	.647	.660	.630
A2.7	.552	.619	.640	.743	.682	.646	1.000	.759	.702	.694	.641	.710	.726	.701	.668	.692	.716	.668	.564	.694	.625	.720	.688
A2.8	.647	.639	.687	.725	.700	.727	.759	1.000	.804	.682	.650	.698	.670	.672	.706	.723	.716	.662	.623	.750	.745	.763	.746
A2.9	.583	.639	.633	.716	.665	.730	.702	.804	1.000	.613	.597	.643	.626	.620	.675	.657	.656	.664	.579	.686	.622	.683	.662
A2.10	.551	.610	.689	.737	.707	.617	.694	.682	.613	1.000	.855	.816	.690	.680	.688	.651	.761	.655	.559	.641	.689	.662	.659
A2.11	.619	.651	.714	.740	.702	.666	.641	.650	.597	.855	1.000	.855	.716	.761	.711	.691	.785	.677	.563	.673	.687	.634	.618
A2.12	.611	.636	.715	.746	.730	.657	.710	.698	.643	.816	.855	1.000	.753	.756	.762	.704	.764	.744	.634	.764	.725	.721	.716
A2.13	.499	.610	.606	.679	.613	.585	.726	.670	.626	.690	.716	.753	1.000	.856	.769	.716	.776	.694	.576	.723	.605	.667	.648
A2.14	.506	.593	.637	.692	.650	.607	.701	.672	.620	.680	.761	.756	.856	1.000	.779	.747	.786	.702	.548	.709	.601	.672	.595
A2.15	.600	.660	.641	.698	.649	.646	.668	.706	.675	.688	.711	.762	.769	.779	1.000	.830	.766	.682	.519	.731	.668	.670	.676
A2.16	.624	.585	.713	.673	.644	.628	.692	.723	.657	.651	.691	.704	.716	.747	.830	1.000	.800	.710	.622	.770	.683	.664	.672
A2.17	.621	.631	.722	.754	.710	.670	.716	.716	.656	.761	.785	.764	.776	.786	.766	.800	1.000	.820	.636	.729	.654	.685	.668
A2.18	.640	.596	.728	.771	.716	.624	.668	.662	.664	.655	.677	.744	.694	.702	.682	.710	.820	1.000	.681	.724	.575	.624	.704
A2.19	.539	*.477	.553	.561	.489	.538	.564	.623	.579	.559	.563	.634	.576	.548	.519	.622	.636	.681	1.000	.745	.628	.663	.670
A2.20	.600	.589	.717	.674	.683	.716	.694	.750	.686	.641	.673	.764	.723	.709	.731	.770	.729	.724	.745	1.000	.711	.708	.722
A2.21	.663	.611	.684	.631	.652	.647	.625	.745	.622	.689	.687	.725	.605	.601	.668	.683	.654	.575	.628	.711	1.000	.753	.772
A2.22	.536	.604	.607	.687	.637	.660	.720	.763	.683	.662	.634	.721	.667	.672	.670	.664	.685	.624	.663	.708	.753	1.000	.768
A2.23	.607	.600	.626	.662	.664	.630	.688	.746	.662	.659	.618	.716	.648	.595	.676	.672	.668	.704	.670	.722	.772	.768	1.000
A2.24	.606	.657	.645	.685	.630	.647	.694	.717	.661	.673	.681	.741	.670	.604	.721	.696	.687	.666	.616	.664	.719	.728	.830
A2.25	.537	.591	.632	.724	.644	.596	.734	.734	.664	.688	.676	.695	.690	.645	.754	.714	.671	.676	.584	.653	.664	.679	.758
A2.26	.485	.590	.593	.705	.618	.594	.740	.643	.562	.761	.763	.777	.712	.682	.696	.614	.661	.598	.565	.620	.668	.694	.685
A2.27	.555	.600	.661	.732	.635	.593	.748	.676	.600	.723	.737	.757	.734	.676	.648	.667	.721	.697	.617	.670	.651	.678	.684
A2.28	.578	.684	.697	.731	.647	.554	.710	.701	.629	.712	.675	.754	.693	.692	.715	.660	.689	.706	.586	.681	.711	.740	.726
A2.29	.545	.620	.587	.682	.592	.584	.674	.721	.606	.674	.652	.692	.648	.629	.684	.617	.653	.665	.606	.682	.672	.660	.690
A2.30	.568	.567	.710	.728	.603	.593	.684	.650	.591	.626	.643	.670	.619	.638	.650	.662	.698	.711	.629	.667	.645	.634	.607
A2.31	.573	.567	.691	.676	.612	.612	.693	.762	.658	.588	.592	.664	.619	.618	.674	.770	.687	.653	.659	.721	.681	.716	.675
A2.32	.624	.586	.671	.748	.648	.612	.702	.695	.611	.710	.674	.740	.678	.660	.682	.708	.693	.706	.579	.649	.677	.721	.733
A2.33	.619	.607	.699	.716	.684	.645	.699	.709	.642	.766	.771	.817	.664	.666	.763	.725	.712	.635	.583	.696	.727	.682	.697
A2.34	.583	.624	.658	.679	.670	.594	.724	.722	.640	.743	.754	.805	.717	.719	.755	.714	.703	.637	.656	.689	.726	.744	.719
A2.35	.550	.545	.582	.604	.605	.545	.677	.712	.562	.638	.615	.720	.630	.673	.682	.677	.663	.605	.657	.695	.691	.758	.693
A2.36	.610	.575	.661	.692	.637	.656	.745	.763	.704	.681	.657	.724	.667	.684	.756	.766	.746	.676	.652	.737	.721	.722	.730
A2.37	.581	.585	.570	.610	.584	.555	.675	.685	.651	.639	.654	.724	.655	.634	.732	.699	.653	.604	.610	.665	.666	.670	.696
A2.38	.578	.595	.615	.676	.634	.589	.746	.763	.671	.686	.667	.738	.703	.685	.746	.739	.715	.672	.637	.746	.705	.703	.738
A2.39	.580	.557	.658	.672	.594	.587	.666	.716	.641	.573	.607	.648	.618	.651	.621	.659	.699	.708	.642	.684	.581	.629	.624
A2.40	.571	.569	.654	.675	.596	.617	.699	.719	.627	.568	.572	.642	.622	.610	.667	.717	.658	.694	.592	.665	.625	.697	.649
A2.41	.614	.634	.626	.684	.642	.672	.638	.692	.695	.644	.669	.690	.620	.625	.724	.696	.665	.624	.553	.639	.637	.674	.613
A2.42	.647	.629	.602	.714	.644	.642	.710	.730	.649	.690	.676	.709	.618	.594	.701	.716	.736	.663	.638	.659	.684	.718	.681
A2.43	.646	.642	.636	.732	.649	.638	.714	.719	.637	.688	.687	.703	.675	.667	.732	.715	.723	.679	.625	.672	.691	.714	.705
A2.44	.603	.594	.652	.715	.648	.617	.718	.747	.690	.700	.710	.765	.694	.722	.746	.687	.759	.689	.626	.679	.674	.725	.683
A2.45	.534	.513	.611	.614	.577	.554	.625	.676	.590	.594	.622	.670	.628	.634	.700	.679	.703	.666	.649	.651	.618	.663	.671

No.	A2.24	A2.25	A2.26	A2.27	A2.28	A2.29	A2.30	A2.31	A2.32	A2.33	A2.34	A2.35	A2.36	A2.37	A2.38	A2.39	A2.40	A2.41	A2.42	A2.43	A2.44	A2.45
A2.1	.606	.537	.485	.555	.578	.545	.568	.573	.624	.619	.583	.550	.610	.581	.578	.580	.571	.614	.647	.646	.603	.534
A2.2	.657	.591	.590	.600	.684	.620	.567	.567	.586	.607	.624	.545	.575	.585	.595	.557	.569	.634	.629	.642	.594	.513
A2.3	.645	.632	.593	.661	.697	.587	.710	.691	.671	.699	.658	.582	.661	.570	.615	.658	.654	.626	.602	.636	.652	.611
A2.4	.685	.724	.705	.732	.731	.682	.728	.676	.748	.716	.679	.604	.692	.610	.676	.672	.675	.684	.714	.732	.715	.614
A2.5	.630	.644	.618	.635	.647	.592	.603	.612	.648	.684	.670	.605	.637	.584	.634	.594	.596	.642	.644	.649	.648	.577
A2.6	.647	.596	.594	.593	.554	.584	.593	.612	.612	.645	.594	.545	.656	.555	.589	.587	.617	.672	.642	.638	.617	.554
A2.7	.694	.734	.740	.748	.710	.674	.684	.693	.702	.699	.724	.677	.745	.675	.746	.666	.699	.638	.710	.714	.718	.625
A2.8	.717	.734	.643	.676	.701	.721	.650	.762	.695	.709	.722	.712	.763	.685	.763	.716	.719	.692	.730	.719	.747	.676
A2.9	.661	.664	.562	.600	.629	.606	.591	.658	.611	.642	.640	.562	.704	.651	.671	.641	.627	.695	.649	.637	.690	.590
A2.10	.673	.688	.761	.723	.712	.674	.626	.588	.710	.766	.743	.638	.681	.639	.686	.573	.568	.644	.690	.688	.700	.594
A2.11	.681	.676	.763	.737	.675	.652	.643	.592	.674	.771	.754	.615	.657	.654	.667	.607	.572	.669	.676	.687	.710	.622
A2.12	.741	.695	.777	.757	.754	.692	.670	.664	.740	.817	.805	.720	.724	.724	.738	.648	.642	.690	.709	.703	.765	.670
A2.13	.670	.690	.712	.734	.693	.648	.619	.619	.678	.664	.717	.630	.667	.655	.703	.618	.622	.620	.618	.675	.694	.628
A2.14	.604	.645	.682	.676	.692	.629	.638	.618	.660	.666	.719	.673	.684	.634	.685	.651	.610	.625	.594	.667	.722	.634
A2.15	.721	.754	.696	.648	.715	.684	.650	.674	.682	.763	.755	.682	.756	.732	.746	.621	.667	.724	.701	.732	.746	.700
A2.16	.696	.714	.614	.667	.660	.617	.662	.770	.708	.725	.714	.677	.766	.699	.739	.659	.717	.696	.716	.715	.687	.679
A2.17	.687	.671	.661	.721	.689	.653	.698	.687	.693	.712	.703	.663	.746	.653	.715	.699	.658	.665	.736	.723	.759	.703
A2.18	.666	.676	.598	.697	.706	.665	.711	.653	.706	.635	.637	.605	.676	.604	.672	.708	.694	.624	.663	.679	.689	.666
A2.19	.616	.584	.565	.617	.586	.606	.629	.659	.579	.583	.656	.657	.652	.610	.637	.642	.592	.553	.638	.625	.626	.649
A2.20	.664	.653	.620	.670	.681	.682	.667	.721	.649	.696	.689	.695	.737	.665	.746	.684	.665	.639	.659	.672	.679	.651
A2.21	.719	.664	.668	.651	.711	.672	.645	.681	.677	.727	.726	.691	.721	.666	.705	.581	.625	.637	.684	.691	.674	.618
A2.22	.728	.679	.694	.678	.740	.660	.634	.716	.721	.682	.744	.758	.722	.670	.703	.629	.697	.674	.718	.714	.725	.663
A2.23	.830	.758	.685	.684	.726	.690	.607	.675	.733	.697	.719	.693	.730	.696	.738	.624	.649	.613	.681	.705	.683	.671
A2.24	1.000	.799	.702	.707	.675	.619	.589	.685	.729	.766	.745	.617	.695	.725	.755	.555	.640	.688	.728	.692	.679	.663
A2.25	.799	1.000	.736	.702	.697	.683	.684	.704	.706	.765	.728	.625	.785	.733	.765	.680	.759	.699	.704	.726	.737	.726
A2.26	.702	.736	1.000	.852	.785	.775	.691	.600	.778	.770	.780	.727	.700	.752	.730	.631	.650	.712	.751	.776	.740	.657
A2.27	.707	.702	.852	1.000	.812	.804	.730	.705	.838	.776	.785	.703	.706	.741	.758	.730	.715	.697	.758	.769	.739	.682
A2.28	.675	.697	.785	.812	1.000	.821	.744	.675	.755	.699	.755	.753	.702	.701	.722	.692	.693	.684	.683	.713	.705	.679
A2.29	.619	.683	.775	.804	.821	1.000	.726	.648	.726	.700	.687	.682	.694	.703	.720	.677	.687	.659	.735	.711	.715	.602
A2.30	.589	.684	.691	.730	.744	.726	1.000	.795	.755	.705	.706	.696	.744	.676	.708	.787	.759	.707	.710	.743	.709	.703
A2.31	.685	.704	.600	.705	.675	.648	.795	1.000	.771	.725	.762	.731	.788	.719	.757	.753	.792	.757	.759	.745	.724	.731
A2.32	.729	.706	.778	.838	.755	.726	.755	.771	1.000	.824	.788	.716	.718	.721	.778	.670	.722	.733	.772	.797	.745	.689
A2.33	.766	.765	.770	.776	.699	.700	.705	.725	.824	1.000	.833	.670	.763	.781	.802	.637	.677	.741	.766	.757	.748	.695
A2.34	.745	.728	.780	.785	.755	.687	.706	.762	.788	.833	1.000	.814	.796	.825	.827	.701	.711	.760	.767	.808	.815	.746
A2.35	.617	.625	.727	.703	.753	.682	.696	.731	.716	.670	.814	1.000	.771	.720	.734	.742	.708	.656	.736	.767	.725	.710
A2.36	.695	.785	.700	.706	.702	.694	.744	.788	.718	.763	.796	.771	1.000	.823	.824	.774	.792	.759	.789	.776	.768	.760
A2.37	.725	.733	.752	.741	.701	.703	.676	.719	.721	.781	.825	.720	.823	1.000	.860	.682	.721	.801	.764	.763	.737	.686
A2.38	.755	.765	.730	.758	.722	.720	.708	.757	.778	.802	.827	.734	.824	.860	1.000	.733	.768	.740	.782	.786	.746	.701
A2.39	.555	.680	.631	.730	.692	.677	.787	.753	.670	.637	.701	.742	.774	.682	.733	1.000	.805	.727	.709	.770	.769	.765
A2.40	.640	.759	.650	.715	.693	.687	.759	.792	.722	.677	.711	.708	.792	.721	.768	.805	1.000	.780	.785	.791	.699	.726
A2.41	.688	.699	.712	.697	.684	.659	.707	.757	.733	.741	.760	.656	.759	.801	.740	.727	.780	1.000	.835	.784	.760	.748
A2.42	.728	.704	.751	.758	.683	.735	.710	.759	.772	.766	.767	.736	.789	.764	.782	.709	.785	.835	1.000	**.862	.793	.775
A2.43	.692	.726	.776	.769	.713	.711	.743	.745	.797	.757	.808	.767	.776	.763	.786	.770	.791	.784	**.862	1.000	.843	.764
A2.44	.679	.737	.740	.739	.705	.715	.709	.724	.745	.748	.815	.725	.768	.737	.746	.769	.699	.760	.793	.843	1.000	.827
A2.45	.663	.726	.657	.682	.679	.602	.703	.731	.689	.695	.746	.710	.760	.686	.701	.765	.726	.748	.775	.764	.827	1.000

Notes:

1 *lowest at 0.477

2 **highest at 0.862

APPENDIX E

Total Variance Explained

No.	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	**% of Variance**	**Cumula-tive %**	**Total**	**% of Variance**	**Cumula-tive %**	**Total**	**% of Variance**	**Cumula-tive %**
A2.1	31.1	69.2	69.2	31.1	69.2	69.2	13.5	29.9	29.9
A2.2	1.5	3.3	72.5	1.5	3.3	72.5	10.2	22.6	52.5
A2.3	1.2	2.6	75.1	1.2	2.6	75.1	10.2	22.6	75.1
A2.4	0.9	2.1	77.2						
A2.5	0.9	2.0	79.1						
A2.6	0.8	1.7	80.9						
A2.7	0.7	1.5	82.4						
A2.8	0.6	1.3	83.7						
A2.9	0.6	1.2	84.9						
A2.10	0.5	1.1	86.1						
A2.11	0.5	1.0	87.1						
A2.12	0.4	0.9	88.0						
A2.13	0.4	0.8	88.9						
A2.14	0.4	0.8	89.7						
A2.15	0.4	0.8	90.5						
A2.16	0.3	0.7	91.2						
A2.17	0.3	0.7	91.9						
A2.18	0.3	0.6	92.5						
A2.19	0.3	0.6	93.0						
A2.20	0.2	0.5	93.6						
A2.21	0.2	0.5	94.1						
A2.22	0.2	0.5	94.5						
A2.23	0.2	0.4	95.0						
A2.24	0.2	0.4	95.4						
A2.25	0.2	0.4	95.8						
A2.26	0.2	0.4	96.2						
A2.27	0.2	0.4	96.5						
A2.28	0.2	0.3	96.9						
A2.29	0.1	0.3	97.2						
A2.30	0.1	0.3	97.5						
A2.31	0.1	0.3	97.8						
A2.32	0.1	0.3	98.0						
A2.33	0.1	0.2	98.3						
A2.34	0.1	0.2	98.5						
A2.35	0.1	0.2	98.7						
A2.36	0.1	0.2	98.9						
A2.37	0.1	0.2	99.1						
A2.38	0.1	0.2	99.2						
A2.39	0.1	0.2	99.4						
A2.40	0.1	0.1	99.5						
A2.41	0.1	0.1	99.7						
A2.42	0.0	0.1	99.8						
A2.43	0.0	0.1	99.8						
A2.44	0.0	0.1	99.9						
A2.45	0.0	0.1	100.0						

Extraction Method: Principal Component Analysis.

APPENDIX F

Rotated Component Matrix[a]

Items	Component		
	1	2	3
Use BIM in the whole life inter-disciplinary design	.78		
Evaluate and select software and technology upon BIM adoption	.76		.43
Utilise BIM to assess the condition of existing assets	.74		
Utilise BIM in procurement processes	.73		
Utilise BIM to assess contextual data affecting potential developments	.72		.40
Utilise BIM to assess the energy performance of buildings	.71	.40	
Analyse the data deliverables for clients and the supply chain required upon BIM adoption	.70	.44	
Utilise BIM to develop design solution	.69	.48	
Communicate the impact of BIM adoption	.69	.44	
Utilise BIM to coordinate and control construction and installation operations	.69	.48	
Use BIM in achieving sustainable design	.68		
Identify the hardware, software and network infrastructure requirements upon BIM adoption	.66		
Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption	.64	.48	
Use BIM to assist in achieving productivity and efficiency improvements	.62	.60	
Utilise BIM to analyse and plan construction and installation work processes and resources	.60	.54	
Aware of authority requirements posed upon BIM adoption	.59		.40
Identify the project requirements with BIM	.58	.48	
Define the common language and terminology associated with BIM adoption	.56	.43	.44
Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption	.55	.54	
Implement governance of information and process management with BIM adoption	.54	.43	.47
Utilise BIM to manage the use and maintenance of facilities	.53		.53
Evaluate the impact on internal and external roles posed upon BIM adoption	.50	.50	.45
Utilise BIM to manage design information	.49	.76	
Utilise BIM to visualize the project and understand the relationships of the various components to one another		.73	.44
Utilise BIM to build 3D models and construct virtual model		.72	.50
Utilise BIM to develop the model into an acceptable representation of what is visualized		.69	.47
Reduce the project risks with BIM adoption		.66	.41
Utilise BIM to manage and operate technical information systems	.55	.65	
Identify and manage risks upon BIM adoption		.63	.45
Utilise BIM in scheduling and estimating	.52	.61	
Collaborate with project teams upon BIM adoption	.52	.58	
Utilise BIM to manage project handover and facilities information	.46	.55	.47
Implement data and process standards upon BIM adoption	.48	.50	.47
Engage organisational stakeholders to BIM adoption			.75
Gain commitment upon BIM adoption			.73
Develop the business case, investment and return model upon BIM adoption			.71

Invest in up-skilling, systems and process management upon BIM adoption		.42	.71
Apply BIM in alignment with organisational goals			.69
Develop the business goals and plans upon BIM adoption		.47	.65
Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption	.46		.65
Consider strategic issues required on BIM adoption	.43		.61
Identify the liability implications posed upon BIM adoption	.50		.59
Engage business stakeholders upon BIM adoption	.57		.59
Develop frameworks and guidance and execution plan for BIM adoption	.42	.52	.57
Compare examples of successful BIM implementation	.48	.43	.50

Extraction Method: Principal Component Analysis.

a. Rotation converged in 12 iterations.

APPENDIX G

Total Correlations with Analysed Factor

No.	Variables	a[1]	b[2]	c[3]
1	Conception Stage	0.982		
	Use BIM in the whole life inter-disciplinary design		.857	.981
	Evaluate and select software and technology upon BIM adoption		.862	.981
	Utilise BIM to assess the condition of existing assets		.834	.982
	Utilise BIM in procurement processes		.833	.982
	Utilise BIM to assess contextual data affecting potential developments		.893	.981
	Utilise BIM to assess the energy performance of buildings		.879	.981
	Analyse the data deliverables for clients and the supply chain required upon BIM adoption		.889	.981
	Utilise BIM to develop design solution		.852	.982
	Communicate the impact of BIM adoption		.835	.982
	Utilise BIM to coordinate and control construction and installation operations		.882	.981
	Use BIM in achieving sustainable design		.841	.982
	Identify the hardware, software and network infrastructure requirements upon BIM adoption		.868	.981
	Analyse the changes required to information deliverables, procurement conditions and skills demands upon BIM adoption		.826	.982
	Use BIM to assist in achieving productivity and efficiency improvements		.882	.981
	Utilise BIM to analyse and plan construction and installation work processes and resources		.850	.982
	Aware of authority requirements posed upon BIM adoption		.725	.982
	Identify the project requirements with BIM		.831	.982
	Define the common language and terminology associated with BIM adoption		.813	.982
	Comply with principles of interoperability in terms of adherence to standards and managing compliance upon BIM adoption		.795	.982
	Implement governance of information and process management with BIM adoption		.803	.982
	Utilise BIM to manage the use and maintenance of facilities		.811	.982
	Evaluate the impact on internal and external roles posed upon BIM adoption		.805	.982

2	Implementation Stage	0.968		
	Utilise BIM to manage design information		.860	.965
	Utilise BIM to visualize the project and understand the relationships of the various components to one another		.845	.965
	Utilise BIM to build 3D models and construct virtual model		.865	.965
	Utilise BIM to develop the model into an acceptable representation of what is visualized		.898	.963
	Reduce the project risks with BIM adoption		.830	.966
	Utilise BIM to manage and operate technical information systems		.851	.965
	Identify and manage risks upon BIM adoption		.818	.966
	Utilise BIM in scheduling and estimating		.856	.965
	Collaborate with project teams upon BIM adoption		.824	.966
	Utilise BIM to manage project handover and facilities information		.830	.966
	Implement data and process standards upon BIM adoption		.791	.967
3	Optimisation Stage	0.963		
	Engage organisational stakeholders to BIM adoption		.818	.960
	Gain commitment upon BIM adoption		.845	.959
	Develop the business case, investment and return model upon BIM adoption		.764	.961
	Invest in up-skilling, systems and process management upon BIM adoption		.832	.959
	Apply BIM in alignment with organisational goals		.774	.961
	Develop the business goals and plans upon BIM adoption		.855	.959
	Engage internal stakeholder at strategic, management and delivery levels upon BIM adoption		.792	.960
	Consider strategic issues required on BIM adoption		.811	.960
	Identify the liability implications posed upon BIM adoption		.816	.960
	Engage business stakeholders upon BIM adoption		.840	.959
	Develop frameworks and guidance and execution plan for BIM adoption		.829	.959
	Compare examples of successful BIM implementation		.769	.961

[1]Cronbach's α

[2]Corrected Item – Total correlation

[3]Cronbach's α if item deleted