

THE ADOPTION OF BUILDING INFORMATION MODELLING IN FACILITIES MANAGEMENT

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**A thesis submitted to the School of the Built Environment in Partial Fulfilment of the
requirements for the degree of Doctor of Philosophy**



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ABSTRACT

Buildings have very long lifespans and decisions made before and during construction have long term consequences. Data and information in paper-based documents are no longer suitable for managing facilities manager's task. With the late delivery of non-digital data, it is challenging for facilities managers to assess the quality of information and whether the information they need is contained in the handover data. Emerging open Building Information Modelling (BIM) standards such as Industry Foundation Classes (IFC) and Construction Operations Building information exchange (COBie) can greatly facilitate the handing over of data and information to the facilities managers in a gradual and structured way. Recent efforts to facilitate the use of COBie have been noted in the British Standards (BS 1192-4: 2014) and Publicly Available Specification (PAS 1192-3: 2014) guide to implement BIM in operation and maintenance stage. However, the adoption open BIM standards and standards guidelines among facilities managers are still low. Therefore, a better understanding on the reluctance of adoption is needed.

A literature review led to a developed conceptual framework that can facilitate the adoption of open BIM standards and standards guidelines. This was used to inform the research design, data collection and analysis. The research was carried out using mixed method approach. The data collections were in-depth interviews and structured online-survey. The data was analysed using NVIVO software to facilitate qualitative analysis, descriptive statistics and correlation analysis using SPSS software. The findings were used to revise the conceptual framework.

The findings identified five key information requirements for BIM-based FM. Moreover, findings of the data concluded that the behaviour intention in adoption of open BIM standards and standard guidelines among facilities managers are influence by several key factors, such as awareness of BIM, cost, classification of BIM data, interoperability, as-built model and up skilling.

This research contributes to literature on the adoption open BIM standards and standards guidelines in FM. The framework is the most important outcome of this research in term of both contribution to knowledge and practice and can be used to support the adoption of open BIM standards and standards guidelines in FM. Furthermore, this study facilitates the understanding and knowledge of open BIM standards i.e. COBie and IFC and standards guidelines in FM.

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DEDICATION

This thesis is dedicated to memory of my father who have been ill and diagnosed with kidney disease and diabetic, Sheikh Said; my mother Aida Hussein, my older brothers, Sheikh Omar Hisham and Sheikh Othman Affan, and a lovely sister, Siti Nabilla.

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CHAPTER 1 INTRODUCTION

1.1 Chapter Overview

The introductory chapter presents the background of the study, stating the rational of the study, followed by the research aim and objectives of the study. Next, the chapter discusses research methodology backing up the importance of the study with the justification towards the Building information modelling (BIM). In the end, the chapter provides the organisation of the study concluded with a summary of the section. **Figure 1.1** outline the organization of Chapter 1.

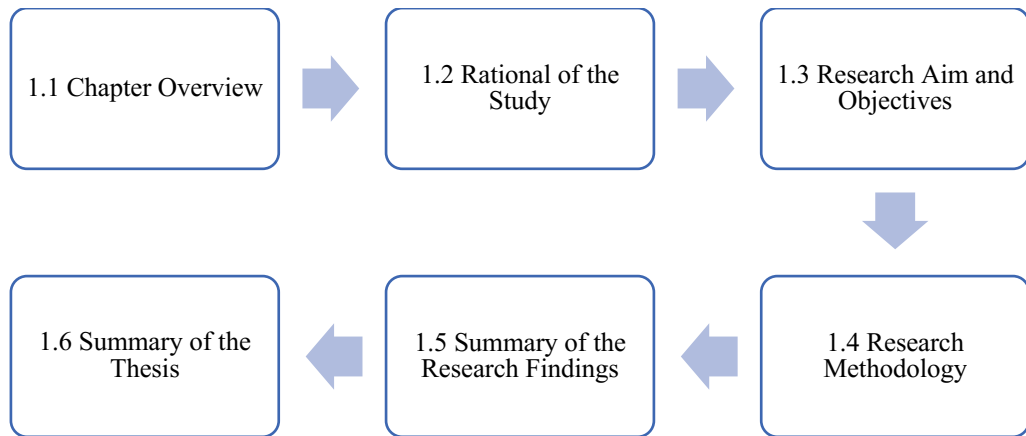


Figure 1.1 Chapter 1 Organisation

1.2 Rational of the Study

This research focuses on the construction industry in the United Kingdom (UK). Building information modelling (BIM) is widely adopted during the architectural, engineering and construction phases, but its uptake has been slow among professionals involved in the facility management (FM) phase. Some of the early definitions of BIM in the literature (Gann et al., 1996; Bjork and Penttila, 1989; Fisher et al., 1997) placed little emphasis on the role of BIM in the whole-of-building life-cycle. Furthermore, the rapid shift of information technology (IT) has significant changes in managing building facilities and performance in delivering service efficiently. IT has been developed to support smarter working and enabler to communicate and transfer information to support user to response every task rapidly (Pearlson et al., 2016). Therefore, it is inevitable that IT has significantly influenced in facilities management (FM) industry (Teicholz, 2013).

Meanwhile, to begin with, the need of IT systems for FM was established in the 1970's which originally developed from operationalising space-planning problems (Lunn and Stephen, 2000; Sanghi, 2016) into an integrated solution not limited to customer service, monitoring planned expenditure against actual performance and real-time information accessibility (Matthews et al., 2015). The common IT systems are Computerised Aided Facilities Management (CAFM), Computerised Maintenance Management System (CMMS) and Building Information Modelling (BIM). CAFM is a system that support and realization of the FM concept throughout the entire life cycle of a real estate property. It was a fusion of Computer Aided Design (CAD) and relational database software that targeted for space management i.e., space data, planning, administering room numbers and areas, and 3D computer aided design (Codinhoto et al, 2013). On the other hand, CMMS is used for preventive/planned maintenance related to building's asset and equipment, and it is also used for scheduling and recording operational tasks of a building (NIBS, 2013). CMMS is specifically used to manage and optimize organization resources (i.e. manpower, equipment, materials and budget) to maintain the operations of building and equipment (NIBS, 2013; Tretten and Karim, 2014). However, Building Information Modelling (BIM) is an emerging digital concept of managing building operation in its entirety that supporting the people, process and technology (Lewis, 2013).

In spite of this, in FM, facilities incurred the largest expenses of organization budgetary other than people (Fraser, 2014) and therefore, the efficient use of organization resources are significantly support the core business and competitiveness of an organisation (Nut, 2000). IT has changed the way how facilities managers manage their organization's resources and this is mainly by monitoring and inspecting assets. Furthermore, the increased use of IT has allowed facilities managers to act proactively and predict changes in an organization's strategic vision and mission in their long-term goals (Sanghi, 2016).

As can be seen, the operational phase of building is the responsibility of the facility manager or building operators to monitored and maintained its function. For some reason, this phase is usually paid a little or no attention by the construction industry, as it tends to focus on the construction of a building. It is crucial, as this phase should have given attention in the early phase of design for the long-term benefits. Kibert (2016) asserts that extensive communication between building design and construction, and maintenance must take place. For example, if a building costs £10 million to construct, then in 20 years the building will

have cost £20 million to operate and maintain. While other (e.g. Hughes et al., 2004) argued that the ratios include 1: 5: 200, i.e. for every £1 spent on design and construction, there are about £5 spent on maintenance and £200 on the running cost of business. This clearly show that the building maintenance cost increase year to year and this unnecessary cost can be significantly reduced, if the design, construction and operators (facilities manager) coordinate their task in a collaborative environment. The potential of adopting BIM in FM during the operational stage of building could significantly improve current practice of FM and reducing the operational cost of a building. Unfortunately, very few studies have examined the practice in BIM and FM related areas, and more research need to be done in order to reduce the facilities cost for long term benefits (Volk, et al., 2014).

In the UK, Hughes et al. (2004) exposed the myth of the 1: 5: 200 ratio relating initial cost, maintenance and staffing costs of office buildings. (Santos & Ferreira, 2013). BIM seems to be promising for long-term benefit but have yet to convince facilities managers to incorporate in their practice because of the lack of evidence that it could be successfully implemented (Gerber et al, 2012; Williams, Shayesteh, et al, 2014). However, the application of BIM can potentially support in many areas of FM, such as locating building components, facilitating real-time data access, visualization and marketing, checking maintainability, creating updating digital assets, space management, refurbishing and renovation works, emergency management, controlling and monitoring energy, and personnel training and development (Gerber et al, 2012). Furthermore, the application of these areas can benefit FM in long-term of building operation in terms of better commissioning and handing over of facility information, enhance management and operation of a facility and integration with FM and operation systems (Kassem et al., 2015, Teicholz, 2013).

According to NIBS (2013), BIM as ‘a digital representation of physical and functional characteristics of a facility, serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward’. Furthermore, BIM also defined as an interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle’ (Succar, 2009). In the context of FM, BIM is viewed as “a process of generating, storing, managing, exchanging and sharing building information in an interoperable and reusable way” and also regarded as collaborating people and information efficiently and effectively through defined processes and technology

(Gerber et al, 2012). Therefore, in order to make use of BIM, the building information is the key to enable facilities manager to exchange information and communicate seamlessly into existing facility management systems to support the operational phase of building.

The BIM4FM survey in 2013 reported that 65% of facilities managers are aware of BIM, but only 26.5% state that they use it within a project. Although recent efforts in UK established standards namely, Publicly Available Specification (PAS 1192-3: 2014), specifies how information can be managed in the operational phase, and British Standards (BS 1192-4: 2014), a methodology for the transfer between parties of structured information relating to facilities, including buildings and infrastructure to facilitate the adoption of BIM in FM, the uptake of these standards found to remain low. A report by the UK National Building Specification revealed that only 26% and 18% of the UK construction professionals surveyed used PAS 1192-3:2014 and BS1192-4: 2014 respectively (NBS, 2015).

Despite the promising benefit that facilities manager could envision, the adoption of BIM poses multiple challenges in the areas of people, process and technologies (Kassem et al., 2015; Parsanezhad and Dimyadi, 2014). The challenges with ‘people’ in adopting BIM is due to cultural barrier, organisation resistance, knowledge gap and lack of real world evidence. Meanwhile ‘process’ challenges are related to roles and responsibilities, data specification, collaboration, and changes in practice in FM. Lastly, technological challenges are related to software tools, interoperability between systems and readiness of software vendors. Not only the adoption of BIM poses multiple challenges as mentioned above, but also the low adoption of these standards can be explained by two main theories that are used in investigating the lack of understanding and reluctance of people in adopting new technologies namely, the Technology Acceptance Model (TAM) (Venkatesh and Bala, 2008; Venkatesh and Davis, 2000) and Innovation Diffusion Theory (IDT) (Rogers, 2003). Therefore, first, this study focuses on the cultural barrier on low adoption of BIM among facilities manager and second, the integration of TAM and IDT employed to establish a framework that can better facilitate the adoption of open BIM standards and standards guidelines in FM.

1.3 Research Aim and Objectives

The aim and objectives of this study is to establish a framework that can better facilitate the adoption of open BIM standards and standards guidelines in FM. The main objectives of the research are:

- RO1: To determine the key information requirements for BIM-driven FM.
- RO2: To identify the key factors that influence the adoption of open BIM standards and standards guidelines.
- RO3: To investigate the extent to which BIM guidelines (i.e. PAS1192-3:2014 and BS1192-4) support the adoption of open BIM standards (COBie and IFC) for FM.
- RO4: To establish a framework that can facilitate the adoption of open BIM standards and standards guidelines in FM.

1.4 Research Methodology

In order to address the research aim and objectives, this study utilised a mix-method approach. The use of both quantitative and qualitative approaches was to better understand the complexity of integrating technology and people in a holistic manner. The complementary of these methods will allow the researcher to gain a great amount of information from participants and vigorous results can be increased. Therefore, a sequential exploratory mixed-method strategy is employed and involves conducting qualitative in-depth interviews and analysis, followed by quantitative structured online-survey and analysis that developed on the input of qualitative analysis. As shown in **Figure 1.2**, six stages were outlined to achieve the research aim and objectives.

The **first stage** was an extensive desk-based literature review on FM, BIM, open BIM standards and BIM standards and guidelines, and also the key information requirement. Technology adoption theories: Technology Acceptance Model (TAM) and Innovation Diffusion Theories (IDT) were used to formulate a conceptual framework for this study. The **second stage** involved conducting in-depth interviews with key BIM experts and FM experts from companies involved with BIM project/s. This investigated the key factors influencing the adoption of open BIM standards and standards guidelines. The qualitative data collected from the interviews are analysed in NVIVO qualitative data analysis software for coding and groups into themes to informed the third stage. The **third stage** investigated the extent to which BIM guidelines supported the adoption of open BIM standards (COBie and IFC) for FM. An online structured-survey that was designed from the input in qualitative analysis, extensive literature review and informal discussion with experts was posted through professional social media LinkedIn groups; BIM4FM, BIM Experts, BSRIA to access wider potential respondents that interested in BIM-FM topics. The quantitative data collected from the structured online-survey are analysed into SPSS statistical software package for calculating frequencies, and producing tables, charts and correlation analysis. The results

from the survey was used to inform the initial conceptual framework. In the **fourth stage**, the analysis of data findings from extensive literature review, in-depth interview and the online structured survey helped to revise the conceptual framework. This was tested as a case study in the next stage. The **fifth stage** was a feedback mechanism where the conceptual framework was validated in follow-up interviews with interview participants and this allowed for further refinement of the framework. Finally, in the **sixth stage**, conclusions were developed from the validation exercise and this informed the subsequent discussion about the study and recommendations for future development.

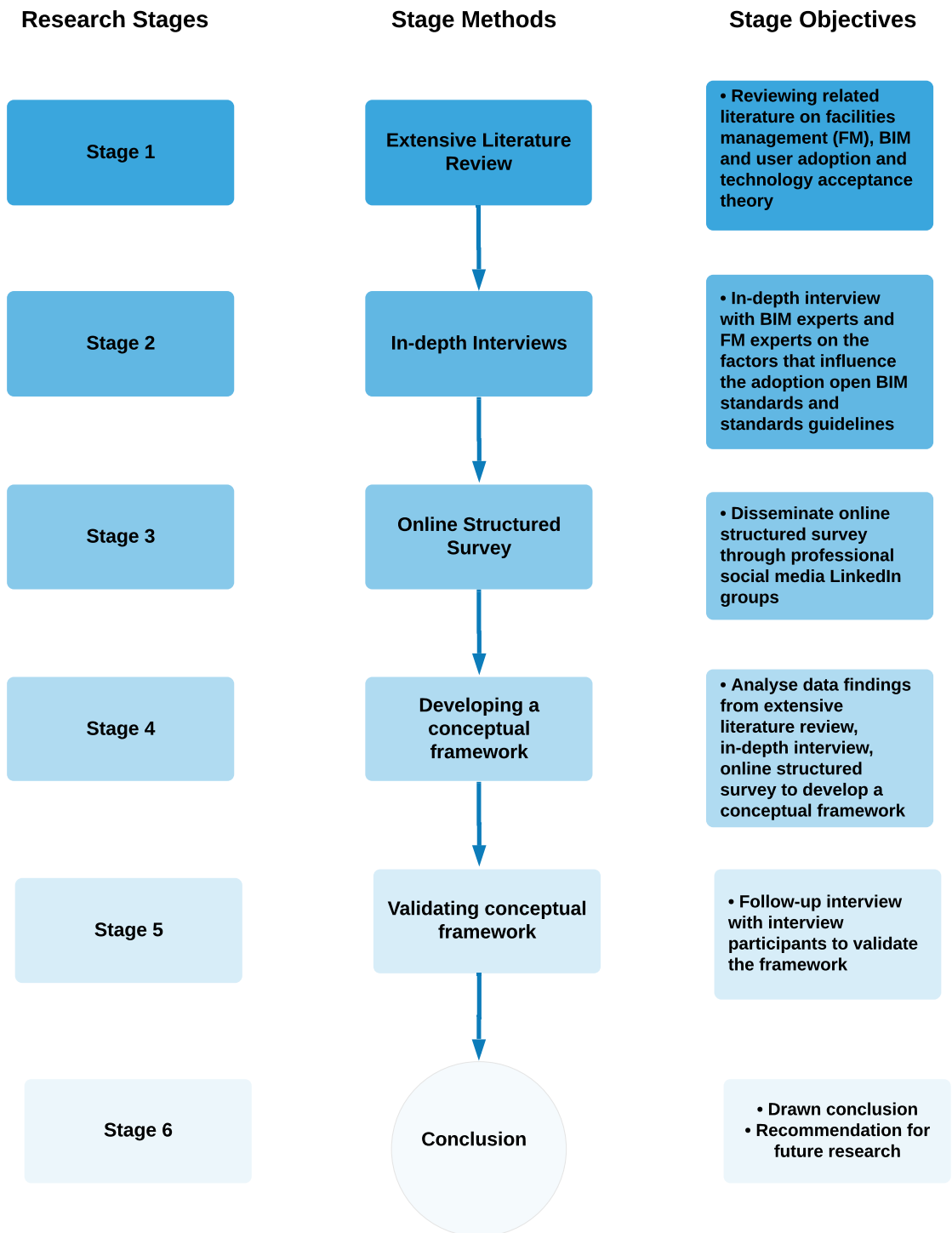


Figure 1.2 Research Methodology

1.5 Summary of Research Findings

The study contributes to the literature on FM specifically from an information technology perspective. This response to the gap of knowledge pointed out in section 1.1 that have been debated by various authors, for instance the reluctance of facilities managers to implement BIM in their practices (Becerik-Gerber et al., 2012; Williams et al., 2014; BIM4FM, 2013). Overall result showed the examined variables—the key factors that can influence the adoption of open BIM standards and standards guidelines in FM. The findings, as discussed in detail in chapter 8 are the following:

Objective 1 evaluates the relevant of key information requirement for BIM-driven FM. The findings suggest that six main categories of key information requirement are substantial in BIM-driven FM tasks, namely, asset information, space information, operation and maintenance information, equipment information, replacement information, miscellaneous information. This is also consistent with the findings qualitative in-depth interviews with similar categories of key information requirement with emerging theme of health and safety information and product information. Similarly, the findings in the quantitative online-survey suggest that a majority of respondents agrees to the key information requirement.

Objective 2 explore the key factors that can influence the adoption of open BIM standards and standards guidelines. The findings in main qualitative in-depth interviews includes; cost, communication in design and construction team, employer information requirement, value of BIM, up-skilling, early stage involvement. However, in quantitative structured survey, several key factors selected from the in-depth interviews and the literature review due to the relativity of adoption open BIM standards (COBie and IFC) and standards guidelines. Therefore, the findings indicate awareness of BIM, compatibility, observability, trialability, perceived usefulness and perceived ease of use has moderate-strong relationship with the behaviour intention in adoption. Meanwhile, the external variables that influence perceived usefulness (PU) i.e as-built model, classification of BIM, cost, data exchange, up-skilling also shows a moderate-strong association with the perceived usefulness (PU) in the behaviour intention in adoption of open BIM standards and standards guidelines.

In **objective 3** assess the extent to which BIM guidelines can support the adoption of open BIM standards. The findings in qualitative in-depth interview suggest lack of understanding in PAS1192-3 and BS1192-4 standard and inadequate standards guidelines for FM impede the willingness to adopt open BIM standards. Meanwhile, the findings in quantitative online

survey found a slight majority of respondents agree that PAS1192-3:2014 clarified BIM process and procedure of information communication with FM system. The proposed framework is the most significant outcome of this study in terms of both contribution to knowledge and practice.

Objective 4 is to establish a framework that can facilitates the adoption of open BIM standards and standards guidelines. The findings confirm the framework can potentially guide researchers examining BIM in FM in the social aspect, whereas practitioners in the field could use the framework to support the adoption of BIM among facilities managers.

1.6 Structure of the Thesis

Chapter one the introduction, sets out the rationale and background to the research, including aim and objectives. It further gives a detailed description of the scope of the research and motivation of the choice of topic. The research methodology is briefly discussed by highlighting the various specific aspects of how the study was conducted. This is elaborated in the fourth chapter.

Chapter two provides a literature review about FM. It discusses definitions and core functions of FM. This enforces the important role of FM in driving the strategic goals and mission of an organization. FM is best positioned in three levels of action; strategic, tactical and operational level in optimizing organization resources. The use of Information Technology (IT) has changed how an organization operates in terms of managing resources. Therefore, the role of IT in FM is also reviewed extensively.

Chapter three is a critical literature review of state-of-the-art of application of building information modelling (BIM) in FM. This addressed the major issues of BIM, which affected the working practice of facility managers in the operational phase of buildings. This review identified the gaps in extant literature.

Chapter four focuses on the theoretical frameworks for technology acceptance. It critically evaluates and integrates two significant models for adoption of BIM in FM. This integration developed a new conceptual model to better understand the key factors that influence the adoption of BIM in FM and can be used for other in-depth studies.

Chapter five explains the reasoning and rationale behind the choices of research strategy, research design and devising the research methods that would achieve the objectives. It provides a detailed discussion about the research methodology by describing the relevant theories that impacted on the choice of research strategy. It also compares several research designs and offers justification for the different choices made for this research. Before the main fieldwork begins, a pilot study is conducted using the selected method to check on clarity and comprehension of interview questions and questionnaire items. The results from pilot study inform the conceptual framework.

Chapter six presents the results of qualitative data collected from the main fieldwork. Qualitative in-depth interviews are conducted with key experts and the transcribed interviews is analysed using the qualitative software NVIVO to identify the key themes, similarities and differences among the interview participants. The results also presented in tables and pie chart to indicate the frequency of interview participants.

Chapter seven presents the results of quantitative data from the main fieldwork. This chapter revealed the demographic characteristics and the characteristics of behaviour intention of adoption of open BIM standards and standards guidelines. The results from the structured online survey are analysed using descriptive analysis to calculate the frequency, mean and median and bivariate analysis that involve finding association and relationships between variables. Both analysis are presented in form of tables and charts via the statistical package software SPSS.

Chapter eight comprehensively discuss the preceding data analysis results. The overall discussion compares the key findings from qualitative and quantitative results as well as previous research to highlight similarities and differences.

Chapter nine concludes this thesis by addressing the aim and objective of this research, the revised conceptual framework, contribution of new knowledge, limitation of this research and finally suggestion for future research.

The following diagram (**Figure 1.3**) is a structure of thesis flow chart that made up from chapter 1 to 9.

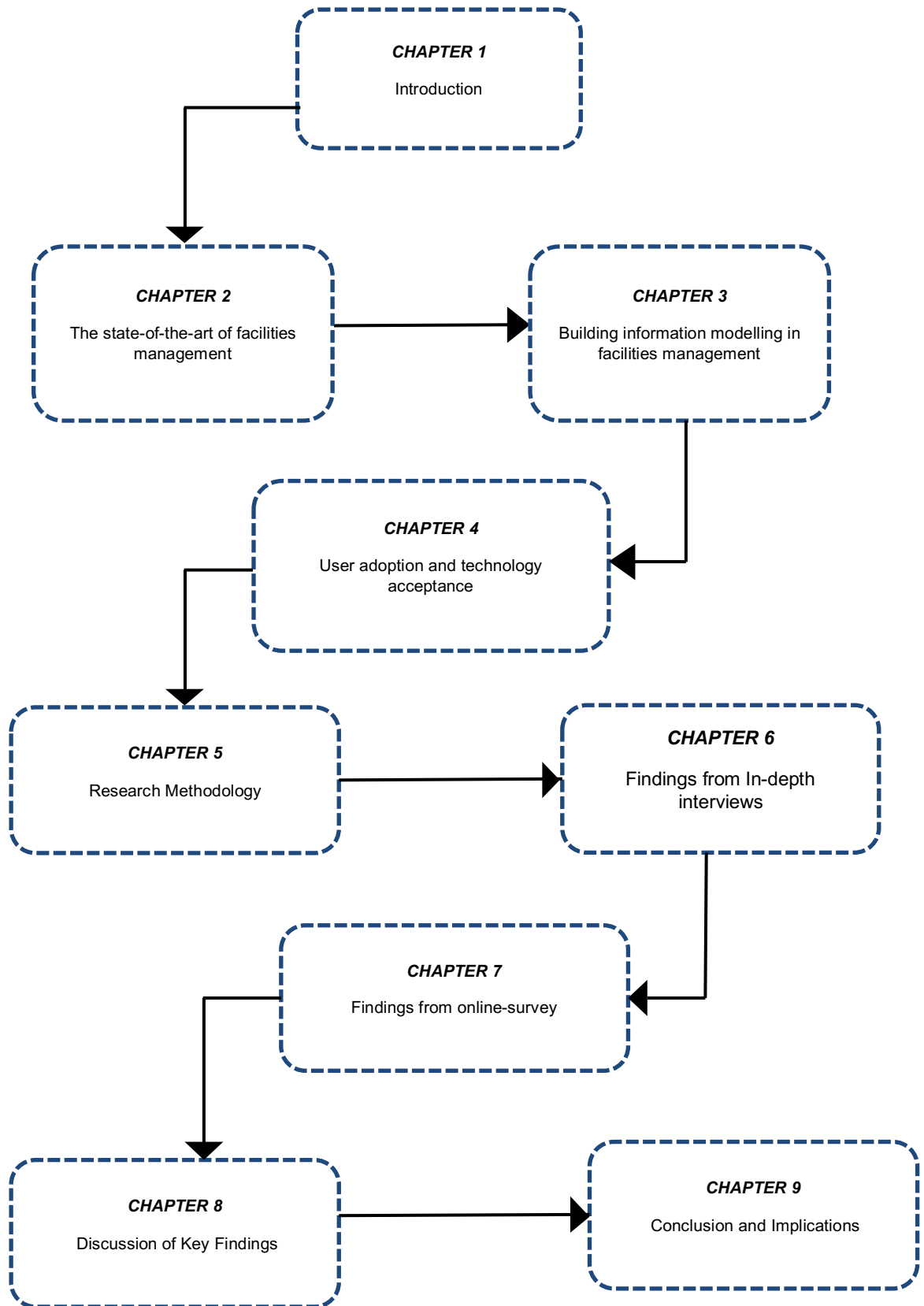


Figure 1.3 Structure of Thesis Flow Chart

CHAPTER 2 FACILITIES MANAGEMENT

2.1 Introduction

Chapter one introduced the research, its, rationale, aims and objectives, research methodology, research findings and structure of the thesis. Subsequently, this chapter provides background information about FM and begins with relevant definitions. The core functions of FM are then examined. The pervasive use of IT has impacted FM and a discussion follows. This chapter concludes by reiterating the importance of FM and the problems about traditional CAFM/ CMMS systems. **Figure 2.1** outline the organization of Chapter 2.

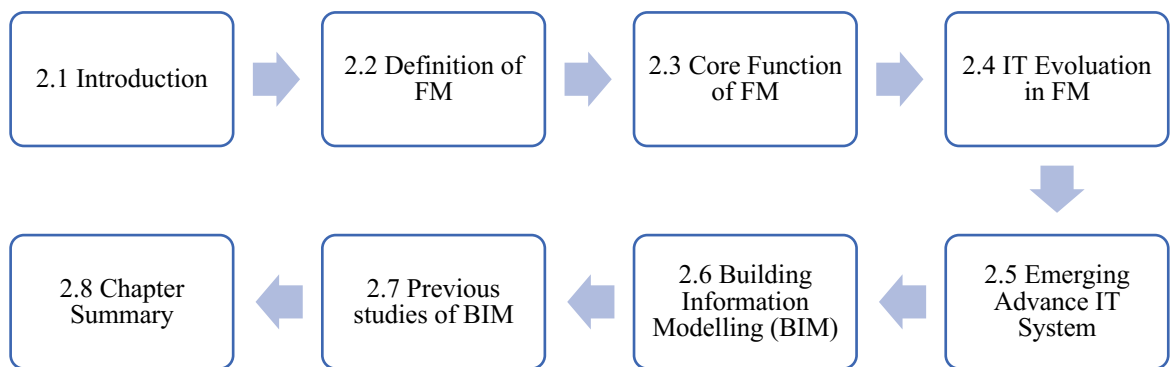


Figure 2.1 Chapter 2 Organisation

2.2 Definition of FM

FM is defined as a profession that includes multiple disciplines to ensure built environment functionality by integrating people, location, process and technology (IFMA, 2017). Meanwhile, in 2016 the British FM Institute (BIFM) coined the terms as "include processes in an organization in order to maintain the services it agreed upon and to enhance the effectiveness of its primary activities.' Pitt and Tucker (2008) alternative definition states that 'the integration of and alignment of non-core services, including those relating to premises, that are necessary to operate. In other words, FM establish to response to support non-core services that related to building management which includes operation and maintenance towards achieving the strategic objective of an organization. **Figure 2.2** illustrate the evolution of FM industry from 1970's to 2000's (Rentokil, 2016).

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(Adapted from: Rentokil, 2016)

Figure 2.2 Evolution of FM Industry

FM is an evolving discipline in the built environment (Atkins and Brooks, 2009). The concern of increasing building stocks has recently in dire need of extending the useful life of building. Large numbers of commercial buildings today are under-utilised, under-maintained and redundant that causes many building-related problems such as overrunning cost, building sick syndrome and dilapidation (Mansfield, 2009). In UK itself, about 1.8 million non-domestic buildings contributed to at least 45% of carbon emission from the use and operation of buildings (Mansfield, 2009; UKGBC, 2007). Historically, prior to FM evolution as a discipline in the last two decades, it was conventionally known as in-house cleaning jobs, repairs and maintenance services and catering services (Atkins and Brooks, 2009). At the turn of millennium, the term FM has been established and integrated with a wide scope of activities that include real estate management, human resource management, space management, financial management, information technology and to name a few (Atkins and Brooks, 2009; Best et al., 2003).

2.3 Core Functions of FM

As FM industry is rapidly growing, the scope and core functions of FM are evolving and supporting many business aspects of every organization (Rentokil, 2016). The recent British Institute of BIFM (2012) report highlights ten core functional areas that identifies the competence of FM. The ten core functional areas are depicted in **Table 2.1**.

Table 2.1 Core Functions of FM

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*Shared common core functional area with IFMA (Adapted from: BIFM, 2014)

Apart of this, BIM Task Group (2012) also shared their description for common core functions of FM as a professional competence within an organisation. The ten-broad core functional areas become the framework and guide to developed the purpose of FM industry. One of the fast-growing core functions in FM is the influence of IT and building automation that has impacted organizations and the business landscape. Furthermore, within an organization, the core functions of FM vary across many different sectors and business organizations such as healthcare, commercial office facilities, engineering facilities, education facilities and others. Each function of FM may involve several different key activities. Codinhoto et al. (2013) identified that facilities managers' function involved several key activities and were required to measure and monitor the performance and

outcome of that specific activities. **Figure 2.3** is reproduced from Codinhoto et al. (2013) to illustrate the scope and importance of a facilities manager role.

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copyright restrictions

(Source: Codinhoto et al., 2013)

Figure 2.3 Key Activities in FM

FM function such as IT services may require several key activities to be conducted that includes monitoring software applications, upgrading IT systems, hardware maintenance and software licence controls. These activities are usually accomplished in the operational level within purview of the FM team. The task conducted in the operational level will be managed in tactical level and eventually reports the strategic level in order to achieve the desired goals and outcome for an organisation. The following section discussed the role of FM in delivering services in operational, tactical and strategic levels.

2.3.1 The Role of FM Organization

Successful FM delivery is about supporting the strategic vision and mission statement of an organization (Lavy et al., 2010, Atkins and Brooks, 2009). The delivery of services involves three main levels of action: strategic, tactical and operation levels (BSI, 2007). According to BSI (2007), **Table 2.2** depicts the role of each level in the FM team to ensure the optimum

level performance in accomplishing various tasks. Strategic level in FM is involved in proposing FM to support the main objectives of an organization in the long-term. The tactical level aims to implement the agreed strategic plans and objectives in the medium term. This involves developing budgets and business plans, service level agreements and, monitoring and auditing the performance of each task conducted. The operational level mainly operates in daily routine and responding to the needs of end-users of the facilities. These roles indicate the relationships that FM has to delivering the operational service, reporting to tactical levels and collecting information for performance evaluation, feedback and demands of end-users.

Table 2.2 Facility Management Objectives Levels

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(Adapted from BSI, 2007)

A fast-paced working environment demands a dynamic way of FM practice. Traditional bureaucratic levels of action may not be the best and effective way in delivering FM task (Barret and Finch, 2014). A better way was advocated by Barret and Finch (2014) whom developed an 'ideal' FM model that interacted between core business and external environment (see **Figure 2.4**). According to Barret and Finch (2014) their model distinguishes between strategic and operational FM. The former involved business planning for future changes, policy framework, and examine the possible development within FM team. While, the latter corresponded to daily routine functions such as maintenance regime, interior planning, benchmarking and other service delivery. It was understood that a facilities manager plays the role of strategic FM in coordinating and planning the duties. All of the tasks are carried out by the 'functional unit' in the FM team and is measured through auditing, post-evaluation occupancy and benchmarking to meet the demand and expectation of end-users/customers and future improvements.

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Figure 2.4 Reproduced Generic Model of 'Ideal' FM (Source: Barret and Finch, 2014)

Facilities incurred the largest expenses of organization budgetary (Fraser, 2014), other than people, therefore, the efficient use of organization resources are significantly support the core business and competitiveness of an organisation (Nut, 2000). IT has changed the way how facilities managers manage their organization's resources. This is mainly by monitoring and inspecting assets. The increased use of IT has allowed facilities managers to act

proactively and predict changes in an organization's strategic vision and mission in their long-term goals (Lunn and Stephenson, 2000).

2.3.2 Role of Information Technology in Facilities Management

In the age of technology advancement, IT has transformed tremendously and impacted all aspect of working practices, routine tasks and also affected business organisations (Avgerou and Walsham, 2017). IT has changed the FM working practice in last two decades by improving productivity and efficiency of operating and maintaining buildings (Ghaffarianhoseini et al., 2017). The pervasive use of IT has inherently become part of important functions of FM now and in the near future (Barret and Finch, 2014). IT in generally is perceived as a broad term across many disciplines. In the context of FM, IT involves computerised systems consisting of hardware (physical computers, laptops), software (Internet search engine, MSWord, Excel), database management systems and, data communication equipment (Barret and Finch, 2014). It involves an infrastructure and facility to function properly (Barret and Finch, 2014). According to Lunn and Stephen (2000), Pintelon et al. (1999) and Davenport and Short (1990), IT has wide key functions in facilitating an organisation and **Figure 2.5** describes in detail the key functions.

Transactional	• Transforming unstructured processes into routine transactions
Geographical	• Making long distances communication
Automation	• Reducing human workload
Analytical	• Using complex analytical methods
Informational	• Process vast information
Sequential	• Multi-tasking
Knowledge Management	• Capturing and disseminating knowledge and expertise to improve the process
Tracking	• Updating status of a task, inputs/outputs
Disintermediation	• Real-time communication between two parties that would otherwise communicate through an intermediary

Figure 2.5 Key Functions of Information Technology in FM

Many of these key functions have become pivotal components informing the development of a simple database program into a comprehensive FM system to improve competitiveness and optimization in buildings operation (Lunn and Stephen, 2000). It was important to note that there are two significant roles of IT. Firstly, it can be used directly as a production technology to improve labour productivity and secondly, it can impact directly as a technology for coordination (Dedrick et al., 2003). However, the common scenario of existing facility management software is underutilized and poorly implemented by the FM during the process of maintaining and operating a facility (Lucas et al., 2013). As a result, there is a tremendous task for information to be populated into the FM system, such as permanent and continued maintenance and updating of information whenever there is a renovation, a change of configuration, equipment or system replaced and/or maintenance job done (East et al, 2013). In addition to that, it was reported in a case study by (Afendizie et al, 2013) that the software system does not entirely support the needs of FM staff which suggests that data population process has to be managed by other different software or even worse, to be manually handled. This can be a deterrent for FM staff to work efficiently which may later lead to poor job performance.

2.4 IT Evolution in Facilities Management

The common IT systems in FM are summarized briefly in the new style and specification of the software / tools that are identified below.

2.4.1 Email Document

Sending and receiving data in the most structured electronic format (Smith and Tardif, 2009) related to email use is deeply rooted in employee communication habits within organizations (Pillet and Carillo, 2016). Email is the powerful IT communication (ICT) to transfer solid information between receiver and sender. People still use email to transfer organizational information. Private email message is the best method of low-cost communication and boundaries (Petrovcic et al., 2016), usually used by private email. Organization created organization account This phenomenon depends on the development of a new technology class, social-collaborative enterprise technology that supports the creation and exchange of user-generated content using blogs, wikis, social networking features, social tagging and microblogging (Pillet and Carillo, 2016). The privacy barriers, of course, when facility managers are unable to view back preservation in personal email. Facility managers would come out with another alternative to use Microsoft Outlook or Agile-based organization email. Another limitation of this type of application occurs when the facility manager is

uncomfortable in the email inbox retrieving the information needed. In terms of negative workplace QOL (Quality of life), email will interact with the organization, workload and civility of stimulus email so that high workload will exacerbate the effect of stimulus email civility on the incivility of email responses (Francis et al., 2015).

2.4.2 Maintenance Management Software

The conventional maintenance management software brands are Computerized Management System (CMMS), C-work, TMA, EAM, etc. Various software brands offered different applications. Each vendor competing to market their process to boost sales. The selection criteria of software must be considered by facility manager depending on user-friendly, budget cost, return on investment (ROI), suit the industry objective such as property, commercial building, factory, etc. Although the vendor offered additional application for this type of tools, the core of the maintenance management software activities included but not limited to (a) creation and maintenance of equipment / asset records; (b) creation and maintenance of equipment / asset records; (c) history of equipment / asset and work order; (d) inventory control; (e) creation, scheduling, execution of work order; Maintenance Management Software is valuable Operational and Maintenance (O&M) information, limiting model visualization. The facility manager is unable to view in precisely and uncomfortable when they are required to perform their task. Some of the commercially available BIM tools supported the import of facility data into a CMMS, but limited data was transferred to graphical spatial information (Akcamete et al., 2010).

2.4.3 Computer Aided Facilities Management (CAFM)

The 'office suite' is usually a combining of word processing, a television chart, visual presentation, an e-mail, a relational database, and desktop publishing applications (Smith and Tardif, 2009) as the most interoperable application. CAFM remains largely based on conventional methods like tabulated data and 2D (two-dimensional) drawings (Gnanarednam and Jayasena, 2013). CAFM is a tool for organizing and managing assets within facilities such as: maintenance and operations, budgeting facilities (Lee et al., 2013) and accounting, construction and project management, space inventory and management, architectural and interior design, space forecasting, telecommunications and cable management, lease and property management, and furniture and equipment management. According to Fernandez, et al. (2003), CAFM is the versatile goal of maintenance management. The limitation 2D visualization or jpeg drawing, however, limited the facility manager to capture the exact maintenance location and the history of modification in the

model. Unlike BIM, visualizing maintenance activities in the context of BIM helps to identify spatial trends for each type of repair activity and spatial relationship between different types of activities and an analytical tool to support FM decision-making (Golabchi and Akula, 2013).

2.4.4 Building Energy Management

BEMS is regularly used to control active systems (HVAC) and to determine their operational times as well, such as heating, ventilation and air-conditioning. The performance of the BEMS is linked in this effort to the energy consumption in buildings and the comfort of the occupants of buildings (Marinakis et al., 2013). In the last decades, BAS has been added to several other domains, including telecommunications, office automation, building computer management, security (Figueiredo and Martins 2010). There are also companies which have been saving electricity consumption, such as Schneider Electric, which introduce electrical waste monitoring and electrical waste monitoring utilities in their customers ' outlets for luminaires linked to ICTs. Facility managers would usually advise the owner to integrate ICTs that link to BAS or the BMS to control mechanical equipment at the office for the huge building. BEMS's complexity can be integrated into BIM and Maintenance Management Systems (CAFM) (Elmualim and Pelumi-Johnson, 2009). The system adopted for more than 30 years is linked with Smart Building (IB), which supports controller, sensor and actuator interoperability (Wang and Xie, 2002).

2.4.5 Agile Software

The Agile Manifesto states that " individuals and interactions over processes and tools, software work through comprehensive documentation, customer collaboration through contract negotiation and reactions to change following a plan" is a priority (Inayat et al., 2015). The industry's most common approach is agile development methodology such as Scrum, Extreme Programming (XP), Kanban and Lean software (Kupiainen et al., 2015). Agile software is necessary in FM to support the technology's business goals. FM is responsible for integrating all services in support of an organization's core business. In combination with ever-growing customer focus, technological development has influenced the industrial practice today greatly (Potes Ruiz et al., 2013). For successful software development (Figure 2) and adoption of agile software, many factors must be taken into account, including internal clients, outside customers, and suppliers (if the adoption is outsourcing). This involves many stakeholders. Agile software's contribution to the FM industry is in reservations, online shopping, external client feedback, etc. The website of

Agile software is called Lazada and Agoda (hotel reservation) (Aziz et al., 2016). Agile software is a unique way for Agile engineers to rely on client demand for the software structures.

2.5 Emerging Advance IT Systems

Both CAFM and CMMS have poor information handling and underutilization of updating status of information. It has been reported that poor information handling causes many problems for systems and users (Jylhä and Suvanto, 2014). In Jylhä and Suvanto (2014) study, they found that people wasted their time searching for irrelevant and incomplete or missing information, whereas Bosch et al. (2014) argued that errors in information occurred when a lack of updates and monitoring of information in the organization were often overlooked. More often than not, information is stored in different systems for different needs and purposes. In addition, inconsistent information management in handling facility operation also resulted in unnecessary cost and inefficient practices (Gyampoh-Vidogah et al., 2003). Emerging advance IT systems has grown interest in FM to help streamlining the exchanging of information. The various advance IT systems for FM can overcome the problem of poor information handling.

Among IT systems that could facilitate and support communication, coordination of information includes Internet of Things (IoT), Geographic Information Systems (GIS) and Building Information Modelling (BIM). IoT is a network of sensors and wireless device that allows interaction and transmission of data (Jaspers and May, 2017). The IoT application includes the use Radio Frequency Identification (RFID), which allows asset tracking, recording inventory items and equipment and with their actual location in the building. On the other hand, GIS allows facilities managers to understand and map data visually in order to find relationships in the forms of maps, globes, reports and charts (Wong et al., 2017). It can be applied to support the FM tasks in space management, visualization and planning, emergency management and others (Wong et al., 2017). Meanwhile, the Building Information Modelling (BIM) is process of creating, exchanging, sharing and managing information between the design and construction, and FM throughout the building lifecycle (Wong et. al, 2017). Based on the above argument on the emerging advanced IT systems, this study had focuses extensively on the application of BIM in FM and following section has discussion in detail the application of BIM.

2.6 Building Information Modelling

BIM is an extremely popular ICT innovation in the life cycle of buildings. The BIM advantage is the rich data from the previous process which in the assembled model can be transferred and re-used in FM phases. In building, contractors can use BIM data to simplify the estimation through automating set-off, carry out collision detection studies to confirm that the design is constructible, and ultimately to minimize errors and change order (Weygant, 2011). In early 2000s, in pilot projects supporting building architects and engineers, BIM modeling was introduced (Volk et al., 2014). Initially, in April 2005, at Sydney Opera House, an exemplary of BIM project in the FM industry was developed and complete in two years. The emerging technology in BIM is more information management that includes the human capital management process and building structure. BIM models may interact with two kinds of expert software, (1) reporting / technical analysis data-providing data applications like structural and energy analyzes or clash detections, or (2) import, data capture and monitoring services, data processing or transformation to the BIM (Volk et al. 2014) data input applications. The following chapter is about BIM in FM.

2.7 Previous Studies of BIM

Many researchers from industrial relations believe that BIM not only improves the patterns of collaboration but also helps the project stakeholders to increase productivity. CIFE 4D CAD was developed at Stanford University (McKinney et al., 1996) and helps facilities managers to directly identify any possible problems at a construction site (Azhar, 2011). The 4D system has attracted the involvement of a large number of leading researchers and practitioners because it displayed promising potential in design, construction and life-cycle management and been expanded from several angles, such as the PROVISO model of Strathclyde University (Adjei-Kumi and Retik, 1997) and nD modelling of the University of Salford (Marshall-Ponting and Aouad, 2005). The University of Salford has already carried out a research project on 3D to nD, which developed a model to integrate the nth number of design dimensions into an integrated 4D and BIM model. The model enables users to visualize the building project process over their entire life cycle and contributes to improving decision-making and construction performance to meet the different project needs (Aouad et al. 2005).

Some researchers from the University of Tsinghua have developed a 4D++ site management model (4DSMM++) (Zhang and Wang, 2003) that enables dynamic management, optimization and 4D simulation of the construction process through an integral system of

information exchange and sharing. Then, 4D BIM-based dynamic resource and real time management building and build-phased design and construction monitoring systems have been developed based on the previous model (Zhang et al. 2011). The integrated construction management system for Wuhan Light Rail Transit projects has been developed by Ding et al (2012) on the basis of multi-dimensional technology. Some scholars at Tongji University (Xudong and Jie, 2006) discussed BIM in various ways as well. A number of studies have analyzed the application of GIS in BIM environments and the development of geo-informational models; the repetitive construction progress of for example a BIM–GIS system has been developed (Elbeltagi and Dawood, 2011). Liu and Issa (2012) studied the feasibility of BIM and GIS integration in order to conduct operational and maintenance work efficiently. A comprehensive BIM–GIS model was presented by Irizarry et al. in 2013, to visualize and monitor the supply chain process.

For the business applications Revit and Civil 3D software products are mainly used for improvement of (informations) management in design and construction by Autodesk Company, Microstation, TriFoma of the Bentley company and archiCAD of the Graphisoft company. These applications are applied only to specific phases of the project life cycle and/or the professional field, and are not fully integrated and informed (Holzer, 2007; Khemlani, 2017). In comparison, current information technology in manufacturing operations can cover customers and suppliers from internal processes. The opportunities and potential benefits of BIM's use in the construction industry have been discussed by researchers and professionals (Campbell, 2007; Chelson, 2010; Kerzner and Kerzner, 2017).

The term BIM application is described by Eastman et al (2008) in the BIM book as a specific use of a building information model for the project team to support a work process or work. The Center for Integrated Facility Engineering (CIFE) at Stanford University is the principal promoter of VDC (Virtual Design Construction) and BIM in construction projects. CIFE recently published a number of valuable insightful comments on the BIM adoption in the American building industry (Fischer et al., 2003). The study of use of VDC and BIM technology in the AEC industry was carried out during 2007 and concluded that... VDC was used and was growing substantially. As this growth progresses, users become more competent and more likely to perceive value and thus make organizational and strategic changes in their activities. FIATECH presents the North American perspective on interoperability of systems in the building industry and has established a roadmap that clearly describes the requirements for IT systems and collaborative technologies for the future of

construction (FIATECH, 2007). In a study by Suermann (2009), the surveys showed significant improvements in cost areas and scheduling. The study also shows that BIM has largely been used by stakeholders as regards better coordination, greater confidence in design and conflict detection.

The American Architectural Institute (AIA) reported in 2006 that roughly 16% of design and construction firms accept and use BIM, although only roughly 60% of architectural firms employing more than 50 people use any kind of BIM (AIA, 2006). The AECBYTES 2007 survey (Khemlani, 2007) supports these findings. Some projects in China such as the Beijing Wasser Cube and the Bird's Nest, the Shanghai Expo pavilions, city rail exchange and the midroad of the South to North Water Diversion project, have sought in order to meet the requirements of special designs and green buildings (Ding et al., 2012). It should be noted that a few case studies and approximately 10 interviews with experts have been completed in the McGraw-Hill 2009 Smart Market Report on BIM adoption in China. In this paper, the parties involved in the project are mainly owners and designers, and BIM technology has been applied only on the stage of architecture, including the Tianjin International Cruise Port and Germany Pavilion collaborative design and collision detection at the Shanghai World Expo (Jones, 2009). In an effort to promote widespread adoption, several researchers have studied and analyzed the obstacle factors for BIM application. According to Ning (2010), BIM technology is very promising in the AEC industry but technical and non-technical barriers exist. Shen et al. (2010) presented a complete overview of AEC / FM system integration and collaboration and proposed that it took a long time to adopt the BIM formal standards. Howard and Bjork (2008) stated that "Nominally supported IFC standards, nobody is against them, only very few are using them fully" and showed that for many, BIM solutions seem too complex. The study revealed that owners are less convinced that BIM in the construction industry is being used to its full value. The research on BIM adoption focused more closely on stakeholders and the people as the main decision makers. The report by CIFE shows that the obstacles to further BIM technology change from technical to personnel (Hartmann and Fischer, 2008).

Suermann (2009) is based on the six key performance indicators (KPIs). Surveys showed that industry stakeholder perceptions, software procurement and training capital, and time are the most critical factors in BIM adoption. Chelson (2010) indicated that the use of BIM increases productivity, and that the success determinants of BIM projects are not technical but human factors. The decision to adopt BIM technology (Tse et al. 2005; Giligan and

Kunz, 2007) was also identified as influencing organisation's support and will reduce the likelihood of adoption if BIM is not supported by the owner and/or the organization. A new report by the Royal Institution of Chartered Surveyors (RICS) (2011) on a 2011 Building Information Modeling Survey shows that most BIM applications are at design and construction phases. Some respondents said that "they did not know if the owners would use the BIM once it was finished." The key conclusion from the survey is that respondents believe that the standards for data exchange are important, but better training and technical support on the use of BIM is urgently needed. Boland et al. (2007) pointed to the importance of communication effectiveness between multiple parties in a building project.

In addition, a number of pioneering research researchers have begun to observe and improve the use of AEC practitioners' BIM technologies in projects that are based on the ethnographic-action research methodological methodology (Aranda-Mena et al., 2008), for example Hartmann and Fischer (2007). In order to understand the accesses and limits of the existing BIM-enabled architectural practice, Abdelmohsen (2012) adopted the ethnographic research method and an interview with AEC staff in interdisciplinary collaborative environments for communicating design intent. The main factors influencing BIM adoption, which could help promote their further adoption to potential and present users and improve the productivity dramatically in the AEC industry, clearly need to be understood. TAM is used to explain the intention of users to use information technology. IDT is a technique to understand the motivators of innovation and how this (motivators) approach develops and leads to eventual adoption and propagation. This study builds on TAM theory and IDT and integrates factors derived from previous BIM research in order to develop and test a relatively comprehensive BIM implementation model. The integration of the theories into a broad proposed framework was discussed in Chapter 4.

2.8 Chapter Summary

This chapter aimed to present an extensive literature on FM, taking into account the definition, core function and role of IT in FM. FM is an umbrella term that encompasses people, process, places and technology. Its main function is to support the non-core business activities of maintenance of building operations within a business organization. This chapter firstly reviewed the concepts of FM and its core functions in the built environment. The growth of FM has received much attention because it is an important factor toward reducing operational costs and improving the useful life of a building. The functions of FM may vary from one organization to another depending on the requirement of owner/client. In this

chapter, the role of IT in FM is often neglected or underappreciated. It was found that although, there were commercial FM systems such as CAFM and CMMS that helped facilities manager to streamline their routine task, these systems were often underutilized and mismanaged which resulted in poor quality of information and information handling. However, BIM is one the solution that could overcome these challenges. This is discussed as a review of literature about BIM in FM.

CHAPTER 3 BUILDING INFORMATION MODELLING

3.1 Introduction

This chapter seeks to provide an in-depth review of Building Information Modelling (BIM) from a FM perspective. The chapter starts with how BIM is defined from different viewpoints. Then, the chapter will discuss briefly on the adoption of BIM in the UK context and traces the evolution of BIM in Architecture, Engineering, Construction and Facilities Management. Subsequently, the application of BIM in FM is discussed and the benefits and challenges of BIM in the context of FM are reviewed. The chapter followed by the discussion of the open BIM standards (i.e COBie and IFC) and standard guidelines (i.e. PAS1192-3 & BS1192-4) for FM. **Figure 3.1** outline the organization of Chapter 3.

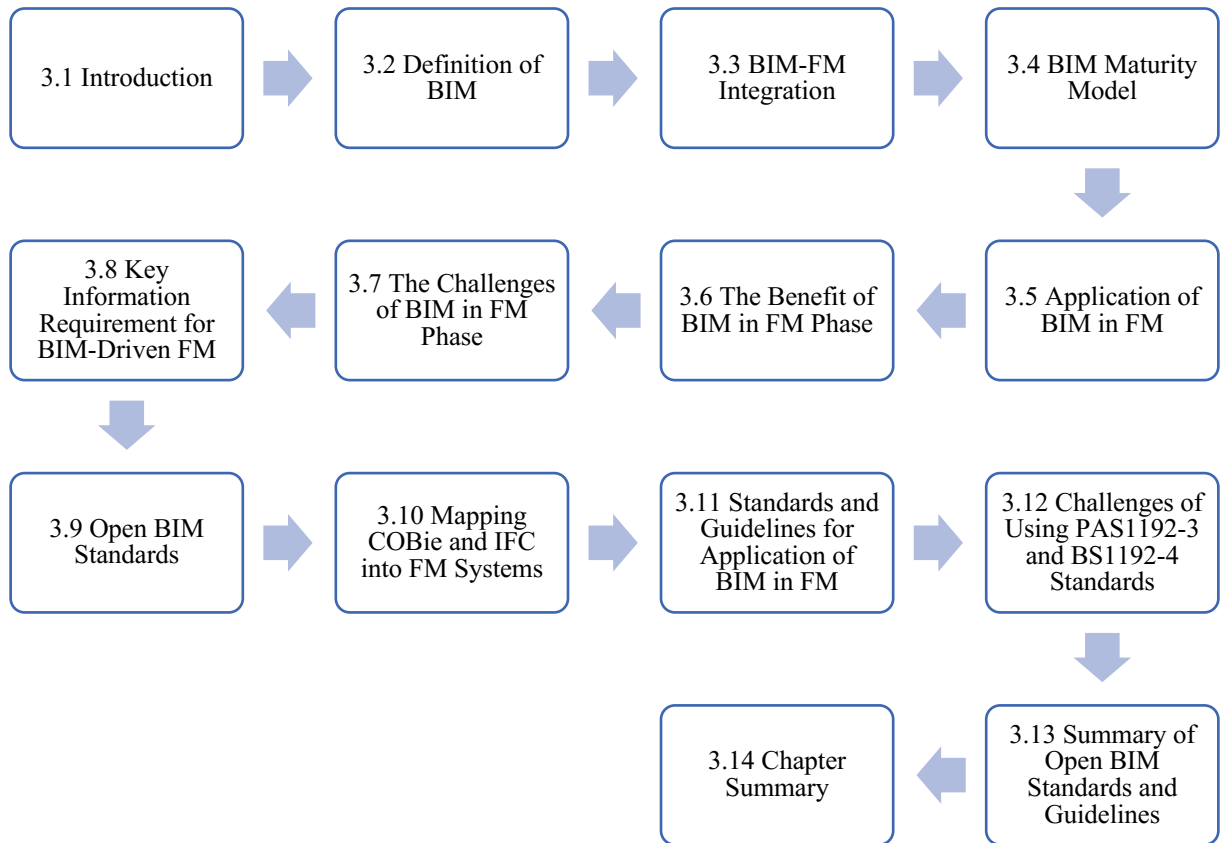


Figure 3.1 Chapter 3 Organisation

3.2 Definition of Building Information Modelling (BIM)

There have been various attempts to describe the expanding domain and meaning of BIM (Succar, 2010). In defining BIM in terms of a physical form, the IFMA (2009) described BIM as:

“a digital representation of physical and functional characteristics of a facility... serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward”.

The UK government has a succinct understanding of BIM and regarded it as

“a collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets. BIM embeds key product and asset data and a 3-dimensional computer model that can be used for effective management of information throughout a project lifecycle – from earliest concept through to operation”

(HM Government, 2012).

The British Institute of Facility Management (BIFM) defined BIM as

“A process involving the generation of digital representations of the physical and functional components of a facility. The resulting building information models become shared knowledge resources to support decision-making about the facility from the conception stage, through design, construction and operational life up to eventual decommissioning”

(BIFM, 2017).

This definition stresses on the process of working and sharing building information models from the entire building lifecycle perspective. However, the dynamic of the BIM definition has evolved from just being a particular technology into “a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle” (Succar, 2009). Specifically, this suggested that BIM has evolved as a new way of construction practice by collaborating with different project members in every stage of a building’s life cycle. In the context of FM, BIM is viewed as “a process of generating, storing, managing, exchanging and sharing building information in an interoperable and reusable way” (Valande et al, 2008). In order to make use of the building information, the use of BIM needed to be able to

exchanged and communicate seamlessly into the existing facility management systems to support the operational phase of building.

BIM represents real buildings with semantic and consistent digital building models virtually throughout the life cycle (Abanda et al, 2017; Ghaffarianhoseini et al., 2017). The BIM consists of parametric objects representing building components and it is created with object-oriented software (Chiabrando et al., 2018). Objects with functional, semantic or topological information may have geometric or non-geometric (Ghaffarianhoseini et al., 2017). For instance, functional attributes may include durations, cost or semantic information store, for example connections, aggregations, information containments or intersections as well as topological attributes.

A narrow, wider perspective is available for BIM (see Figure 3.2). BIM ("Little bim," "tool") in a 'narrow sense' consists only of a digital construction model as a central information management portal or repository and its problems for model development (Toldo 2016). Component bibliography and general functionalities offer integrated data management platforms in business-based BIM (Abanda et al, 2014; Araszkiewicz, 2016). BIMs are widely differentiated in 3D (space quantity starter model), 4D (plus planning) and 5D (plus cost calculation) BIM (Thompson, 2016). The literature extensively discusses further BIM functionality of dominant vendors (Volk et al. 2014). Various new and existing building BIM creation processes. BIM is nevertheless created for new buildings through several LC stages, starting with initiation, briefing, design and project delivery. Since all AEC / FM building stakeholders in LC do not use BIM sometimes, certain people create an isolated BIM for one purpose alone. Depending on the availability of existing BIM in existing buildings.

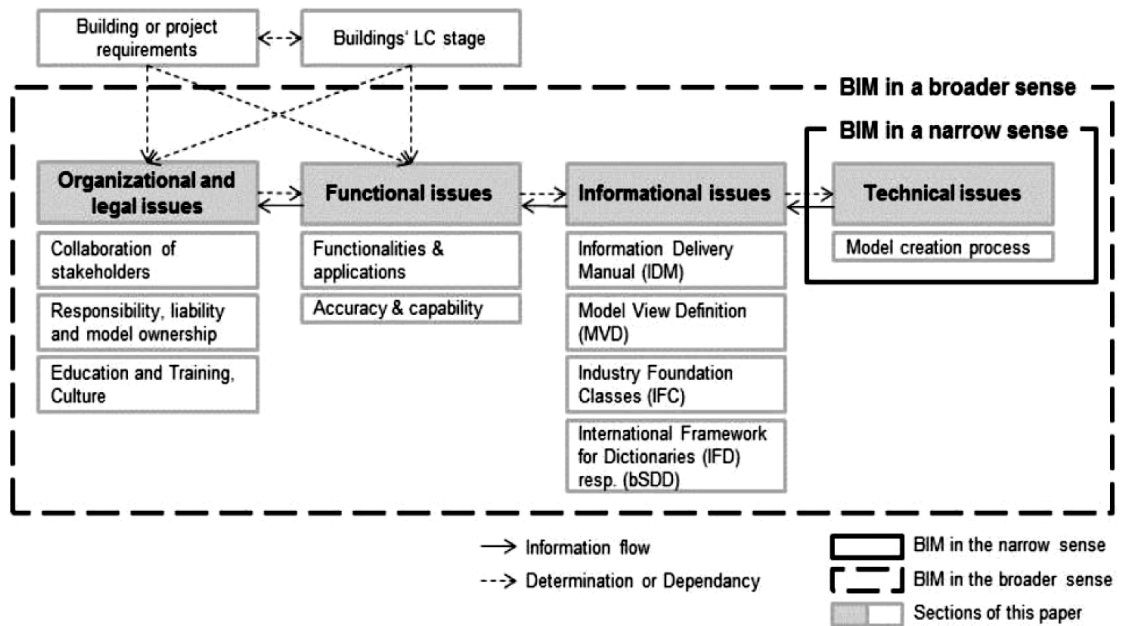


Figure 3.2 Narrow and a Broader Perspective of BIM

Thus costly and mainly manual reverse engineering ("point-to-BIM," "scan-to-BIM") processes are implemented to recapture building information (Dowsett, and Harty, 2013). As shown in figure 3.2, BIM can be broken up into functional, information, technical and organizational / legal interconnected problems. In the broader sense BIM models support and provide expert services in buildings such as energy or environmental analysis according to the requirements of the stakeholders and the project requirements (Dainty et al., 2017). Therefore, the two different types of software experts may interact with a BIM model: (1) data input application that provides importation, data capture and monitoring services, data processing or data transformation into BIM or (2) data output applications that provide reports or technical analysis such as structural or energy analysis or collision detection.

3.3 BIM-FM Integration

In these omnipresent definitions it is essential to be able to use valuable information and data throughout a building's life cycle. In order to promote greater cooperation between stakeholders through the single integrated model throughout the design and construction stages, BIM has orchestrated a paradigm shift in the way information is handled, shared and processed (Zheng et al., 2017). The integrated BIM approach ensures that all stakeholders flow smoothly through information and is defined at development or design levels (Khosrowshahi and Arayici, 2012; Abanda et al., 2015). Design level (LOD) is classified from LOD 100 (conceptual low definition design) up to LOD 500 (high definition model as built). The design level is classified. Models offering LOD500 are rare in practice. BIM and

FM integration may be considered 6-D modeling, which defines nD modeling as the additional information for analysis and simulation purposes to three-dimensional model(s). BIM-FM integration is increasingly being used for the operations of the building and provides various advantages, including: increasing handling of data; enhanced FM data precision (e.g. manufacturer specifications); and enhanced work order performance in order to access and locate data operations (Rezgui et al., 2011). It is recommended that every facility built requires a custom BIM model, similar to the manual of the owner, with a model update mandate that is appropriate for regular repair or refurbishment works (Pishdad-Bozorgi et al., 2018).

In practice, 6D BIM data become the responsibility of the FM, but this can lead to difficulties in other areas. Parn et al (2017), for example, reports litanies of questions such as: incompatible naming arrangements, a multiplicity of specific information requirements for FM, inadequate BIM and CAFM categorization data, poor information synchronization, and lack of existing facility and asset capture approaches. Over 80 percent of an FM's time in O&M is used to find relevant information that designers often do not take into account during pre-construction work (Becerik-Gerber et al. 2011). These data are important for the delivery to building owners of a precise and well-built model for asset management purposes. The Institution of Civil Engineers (ICE, 2015) says it is possible to eliminate these problems by supplying a reliable, BIM source suite of information. The ICE's claim is seriously hindered by a lack of tacit know-how and technical knowledge within the FM. McArthur (2015) claims that identifying the necessary information for informing operational decisions is crucial for the configuration of the data recovery technology during the post-construction phases. However, Motamedi et al. (2013) still has the problem of this task and linking it with the as-built O&M model. Meadati et al. (2010) noted that there is unnecessary expenditure for inconsistencies between demand for and the availability of specific information in an as-built model. Therefore, during the design and development of BIM data, the connection between data and the configuration of recoverable information within the model as constructed for the post-construction period of the project shall be considered.

BIM provides an opportunity for Facilities Management Team (FMT) to manipulate and use 3D object information. However, during the design phase, Lavys et al. (2014) find that participants in a BIM project mainly focus on collision detections and ignore accessibility to maintenance for future protection. The authors point to the potential of BIM to explore background geometry and parametrics and to integrate functions in order to help FMT

anticipate and resolve issues of maintainability. Meadati et al. (2010) and Motawa & Almarshad (2015) are also proposing additional instruments for improving BIM performance in F&M by engaging stakeholders more effectively. Longstreet (2010) adds that, with a project lifecycle developing, the value of implementing BIM increases exponentially. BIM's value in FM is due to improvements to: current manual transmission processes; accuracy of FM data; accessibility of FM data; and increase in efficiency in execution of work orders (Kassem et al., 2015). The participation of the FMT during the BIM development process is therefore vital since all O&M issues can be alerted to the building delivery team. Interestingly, Bosch et al. (2015) conflicts with this position and concludes that, due to a lack of alignment between the provision and demand of FM-related information and the context-driven role of information, the present added value of BIM at the O&M stage is limited. Although it goes against those stated in the broader academic speech, it resonates with Kassem et al. (2015) who admits the major challenge of BIM-FM integration.

3.4 Building Information Modelling (BIM) Maturity Model

The NBS BIM National Report 2015 reported the adoption of BIM in UK has risen in the past few years since the UK government announced the adoption of BIM for all publicly funded projects by 2016 (NBS, 2015). The adoption of BIM required for all construction players to shift their traditional working practices towards a BIM-driven integrated practice. In order to facilitate the implementation of adopting BIM, the concept of 'BIM maturity model' was introduced as a guidance and roadmap in delivering building information throughout a project's lifecycle. An overview is reproduced from Bew and Richard (2008) (See **Figure 3.3**) to demonstrate this.

Figure 3.3 has been removed from this version of the thesis due to copyright restrictions

(Source: Bew-Richard, 2008)

Figure 3.3 UK BIM Maturity Model

The objective of the maturity levels is to categorize types of technological and collaborative task so that the processes, tools and techniques can be described and understood concisely, thus allowing a simple reference to the application of different documents (DBIS 2011).

Level 0 – Computers are used to produce CAD drawings and building documents, which are used as information carriers. The maturity levels can be determined into four levels (DBIS, 2011). Building information is usually available in physical format, like binder and paper drawings.

Level 1 – Information structure permits limited file-based interaction. As 2D and 3D models, the various disciplines in a common data environment can be delivered, but FM systems that carry these files in databases cannot be integrated.

Level 2 – The 3D model has become an object-based model. Level 2 The objects contain attributes and relationship information that allows the integration of various information systems. This means that all information relating to buildings can be reached by the object in the model for facility managers.

Level 3 – Completely integrated information that builds on the prospect of a life cycle and builds on a consistent model of information and standard structures. In the open database,

the information is stored and is linked by web services. The facility manager can set criteria and search for information and data relating to the building.

Level 2 compulsory BIM practice requirements should enable facility managers to receive, seamlessly import object-driven files into their facility management systems (DBIS, 2011). The effort for integration into a Facility Management System between BIM software has however been implemented still. This is due to inconsistencies in building practices, which only favor design and construction phases and appear to exclude the operation phase following completion of the building (Eadie, et al., 2013). This makes it difficult to implement BIM level 2 in facilities management practice.

3.5 The Application of BIM in FM

Several authors have suggested the potential application of BIM in FM (Becerick-Geber et al., 2012; Mohandes et al., 2014) that could enhance the performance of building in the operational stage. The list of application areas are identified to facilitate the task of facilities managers in the following:

3.5.1 Locating Building Components

Locating building components such as equipment and fittings can be a daunting task for facility managers. Typically, facility managers would rely mostly on paper-based documents or on-site observation if they were any faulty situations (East et al., 2013). This practice could be challenging if an emergency happens or when new personnel who is unfamiliar with the site are in need of information. The use of BIM models however, could assist facilities managers to self-locate, search and navigate through relevant information on-site (Su et al., 2011). This could greatly reduce the amount of time and maintenance cost in the long-term period.

3.5.2 Facilitating Real-Time Data Access

The daily routine of facilities managers usually involves handling a lot of building information which is stored in multiple systems that users have to toggle between to locate required data (Wang et al., 2013). Typically, FM systems as previously mentioned CAFM and CMMS are developed for different purposes and separate database; CAFM system assists in spatial information regarding space data, space planning and assigned rooms tagging. While, CMMS perform preventive/planned maintenance related to building's asset and equipment. As a result, building-related information is stored in different database with

access processes that can lead to unproductive practices and difficulty for new configuration. The BIM offers an embedded knowledge integrated data system that can be considered a knowledge management database during building maintenance and operation (Motawa and Almarshad, 2013). This means, in fact, that facility managers can select a target object and capture the necessary information. This technique would allow timely access to information and would also, in the absence of information, avoid unconsidered decisions (Motawa and Almarshad, 2013).

3.5.3 Visualization and Marketing

Visualization of building models has a little or less concerns in different situations in FM phase. The non-graphical data has become a crucial requirement when it comes to the operation and maintenance of a building. A three-dimensional BIM model with the ability to integrate furniture, materials texture, light sources, equipment and more, could potentially allow facility managers to not just perform maintenance of a building but to reuse the BIM models in future renovation and refurbishment. Visualisation also supports decision-making in terms of what if analyses, such as assessment of construction methods and emergency planning (Wetzel and Thabet, 2015). In marketing perspectives, a BIM model could be used as an illustration of interior spaces and furniture to influence the rental process and tenancy contract of a building (Becerik-Gerber, 2012).

3.5.4 Checking Maintainability

Traditional FM systems (i.e. CAFM, CMMS) heavily rely on its users to populate data manually into the system database, however it has been reported/found that sometimes data is inconsistent, easily out-dated and prone to errors (Jylhä and Suvanto, 2014; Bosch et al., 2014). Industrious effort to identify and assess the quality of information is time-consuming and involve high cost in updating the data into the FM systems (Ahn and Chia, 2014). BIM data makes maintenance studies easier for facilities managers in different phases of their building's life cycle to concentrate on the desired performance. The maintainability studies covered the following:

- Accessibility: physical control of equipment on a regular basis, for example for air handling, fire protection systems and clear and quick visual identification of the relevant components; and ample space for removal and replacement of components, according to Becerick-Gerber et al. (2012) and Arayachi et al. (2012a).

- The sustainability of materials: preventive maintenance: selection of components from security criteria such as preventive degradation and failure prevention; and virtual inspection of property of installed and protected components that may require easy repair
- Maintain the sustainability of material, and detect the types of faults that may result from this.

In order to identify spatial relations activities and the trends of each type of repair activity, BIM provides visualizations of maintenance activities (Arayachi et al., 2012a). In this way, facility managers can improve efficiency in working and reduce the cost of monitoring the missing and/or improper information (Ahn and Chia, 2014).

3.5.5 Creating Updating Digital Assets

Handover of project to owners or facility managers requires digital assets to be manually created and loaded into the FM systems (Patacas et al, 2015; East et al., 2013). This process can be lengthy and lead to many errors of data. It is crucial to have imported data in a structured and proper terminology so that it could be easily accessible and reused for future works and inspection. In order to enable the facility manager to record, digitize and transfer necessary data in an more efficient way, the implementation of BIM in facility management should be involved in the early phase of the projects. If the information from diligent project team members is consistent and accurate, the process may be automated and free of manual manipulation. The PAS 1192-3 standards assist facility managers in the management of BIM assets in operations. This process contributes to the acquisition for future works of the Asset Information Model (AiM) for the renovation, refurbishment and demolition (BIFM, 2012). In the following section the standard is discussed in detail.

3.5.6 Space Management

Space management allows facility managers to more effectively evaluate space utilization by increasing end users ' productivity (Atkin and Brooks, 2009). Space management involves the prediction of space requirements, space assignment and simplification of the movement process. This requires facility managers to identify each space's attributes such as space numbers, descriptions, areas, volume, boundaries, intended use and real use. CAD drawings are usually used to manage room, and search to display these attributes, leading to contradicts in naming and elaborate updates of attributes (Bainbridge and Finch, 2009). Space management is often underutilized in FM systems because the information is

inflexible and may not be frequently used when compared to maintenance management, asset management and work order management (Bainbridge and Finch, 2009). Based on the survey conducted by Bainbridge and Finch (2009), it is reported that space management was not frequently used for conducting FM operational activities in CAFM systems. Hence, the challenge of flexibility of spatial information in CAFM systems can be addressed using BIM model. A BIM model can help visualize space and attributes through the identification of unutilized spaces, space requirements, space analytical simplification, movement management and comparison of space use actual and expected (Becerick-Geber et al., 2012; Kassem et al., 2015). The information may be manipulated in many ways for example in order to accurately identify spaces and their various purposes, to compile and maintain office schedules efficiently and to detect assets through multiple moves over time (Becerick-Geber et al. 2012).

3.5.7 Planning and Feasibility for Non-Capital Construction

A building's lifespan usually depends on its value and need for change (Mansfield, 2009). Thus, it is the task of facility managers to assess value and such change if a building undergoes a refurbishment, renovation or demolition works (Iltter and Ergen, 2015). Refurbishment and renovation works could improve the condition of facilities both physically and economically. However, the decision of conducting these works is limited due to insufficient information provided to contractors which may lead to excessive cost in assessing the existing condition of buildings (Chau et al., 2003). It is difficult to conduct refurbishing works when information is stored and scattered in different FM systems and when data is inflexible when needed to be reused for budgeting and decision-making.

A BIM model could assist in planning, designing, analysing, simulation of renovation and refurbishment works (Iltter and Ergen, 2015). The model could present visual characteristics of exterior and interior works, the dimension of scaled components, the estimation of building materials and identification of equipment (Iltter and Ergen, 2015; Volk et al., 2014). Furthermore, historic data such as materials labour and cost of designing and constructing existing buildings could be used as estimation and decision-making (Araiichi et al., 2012; Iltter and Ergen, 2015; Volk et al., 2014). Several studies investigated using BIM model for existing buildings, refurbishment and renovation project during the operation and maintenance phase (Iltter and Ergen, 2015; Volk et al., 2014). Araiichi et al. (2012) provided a case study using BIM in relocation and refurbishment project in Mediacity, UK. Their findings suggest that a BIM model not only helps a facility manager/owner in navigating a

walkthrough in a virtual model, but it can also be used in automating quantification and scheduling that sets the amount of time and cost for budgeting and decision-making (Arayichi et al., 2012).

3.5.8 Emergency Management

In a situation of emergency, it is critical for occupants of building to be aware of the information of an evacuation plan and the way out of the premise (Lee et al., 2013). This information should be clear and easily accessible through a logical wayfinding structure. Traditional FM systems often focus on mainly operational and maintenance aspects of a facility, which is limited to real-time monitoring information and visualization in evaluating damages in physical conditions of buildings (Lee et al., 2013). As a result, glitches in the facility could risk losing human life and property damage due to the unnecessary delay in retrieving emergency-related information and decision-making for taking appropriate measures of urgency (Lee et al., 2013).

A BIM model can help provide in-house access data for potential emergency issues and identify hidden links between the routing position of evacuation and environmental risks (Rueppel and Stuebbe, 2008). This model could be employed by facility managers to identify fire hydrants, electrical panels, hazardous materials, and building floor plans while residents are on an emergency exit. It would also help facility managers to be better prepared for emergencies and to help evaluate damage estimates by simultaneously developing and testing the response plans for emergencies before an emergency occurrence is undertaken (Becerik-Gerber et al. 2012).

3.5.9 Controlling and Monitoring Energy

Assessing buildings ' energy use is one of the core functions in the management of buildings (Al-Shalabi and Turkan, 2015). Controlling and monitoring the energy utilization of a building through energy management systems is usually the responsibility of facility managers. The background to these systems is that when new floor plans are built, interconnectivity is lacking (Zhang et al, 2018). The transformation of these floor plans into energy management systems takes a long time. This is because the visualisation of new appliances and components should be different from other building characteristics and construction users (Lee et al., 2016).

BIM's graphical interface can be linked to building sensors, meters and sub-meters that make real time surveillance and automated control possible. In the context of energy saving measures, Xu et al. (2014) indicate what if multi-state setup scenarios could be simulated. A BIM model could also control the energy consumption of a building by remotely turned off lights in unoccupied rooms and provide historically useful data on the energy consumption, on energy budgeting and on conservation activities (Al-Shalabi and Turkan, 2015). This would allow us to control the building's energy consumption.

3.5.10 Personnel Training and Development

Newly hired facility managers may require familiarization with the process and procedure of handling new building or renovated facilities. Usually, training is provided through slides presentations, site visits, hands-on demonstration, and self-study, all of which is time consuming in its preparation and is heavily dependent on an experience trainer (Becerik-Gerber, 2012). With BIM, trainees are able to walk-through the facilities in a virtual model to inspect building spaces, components and equipment, and review the related information. Through this approach, trainees would have better understanding of the building systems and able to perform their task more efficiently (Knutt, 2015). A post-training of BIM can be conducted to test the knowledge and skills of trainees for their ability to remotely locate building parts, search information for equipment that needed to be fixed, responding to work orders for maintenance and generating new maintenance reports (Becerik-Gerber, 2012). However, despite these attributes, the adoption of BIM is not pervasive among facilities managers due to the lack of training and involvement in BIM projects which in turn, creates uncertainty in using open BIM standards (Palos et al., 2014).

3.6 The Benefits of BIM in FM Phase

The utilisation of BIM promises many benefits in the longer term of a building's life cycle. Although research and studies suggested many potential benefits of BIM, most focused on the operational phase of a building because these studies investigated the post-construction phase of a facility. Kassem et al. (2015), Teicholz (2013) and Eastman et al. (2011) described several benefits of using BIM during the operational phase of a building:

3.6.1 Improved Commissioning and Handing

Different project members individually manage each phase of the construction process. This results in a small exchange of information through spreadsheets, word materials and 2D drawings (Vanlande et al., 2008). The accumulated information may be completely or

partially lost during building stages when move from stage to stage. BIM can link data generated by virtual BIM models during construction. Such information may be transferred to the facility to be used for management.

3.6.2 Enhanced Management and Operation

A building's operating phase is the longest life cycle (Teicholz, 2013). Information on assets and facilities is critical to building maintenance and operations for owners and facility managers (Teicholz, 2013). Adequate and accessible information is therefore a key challenge before maintenance begins. BIM software can extend its use to facilities and maintenance management by facilitating the easy collection, access, exchange and updating of information.

3.6.3 Integration of FM and Operation Systems

Software systems can only be integrated if they communicate. Due to poor interoperability problems in capturing the necessary data to conduct building maintenance activities, owners and managers of facilities have been subject to significant costs (Teicholz, 2013). BIM software and FM systems can be connected to facility-related information for effective management and reporting. BIM also could provide accurate as-built information for maintenance, as during construction, the BIM virtual model has been validated.

3.7 The Challenges of BIM in FM Phase

The current adoption of BIM poses many challenges in FM industry. According to literature, these challenges are divided into three categories; people, process and technology. A depiction of this understanding is provided in **Table 3.1** below which summarizes the challenges reported by Kassem et al. (2015), Patacas et al. (2015), Parsanezhad and Dimyadi (2014), Gnanarednam and Jayasena (2013) and Becerik-Gerber et al. (2012). Below table were grouped into three major categories namely; people, process and technology.

Table 3.1 Challenges in implementing BIM in FM

BIM in FM	Challenges	Authors
People	• Cultural barrier toward adopting new technology; • Organization-wide resistance: need for investment in infrastructure, training, and new software tools • Undefined fee structures for additional scope	Kassem et al., 2015; Becerik-Gerber et al., 2012 Becerik-Gerber et al., 2012 Gnanarednam & Jayasena, 2013; Becerik-Gerber et al., 2012

	• Lack of sufficient legal framework for integrating owners' view in design and construction • Lack of real-world cases and proof of positive return for investment • Unclear how to use BIM for FM • Lack of knowledge to evaluate BIM • Lack of best practice and guidelines • Lack of evidence in operational savings (FM need evidence before engaging/ adoption of BIM depends on owners) • Coping with non-consistent terminologies and taxonomies used by different actors • Identifying which information and what level of detail is desired by the FM teams	Kassem et al., 2015; Williams et al., 2013; Becerik-Gerber et al., 2012 Kassem et al., 2015; Becerik-Gerber et al., 2012 Kassem et al., 2015; Becerik-Gerber et al., 2012 Kassem et al., 2015; Patacas et al., 2015; Parsanezhad & Dimyadi, 2014; Williams et al., 2013 Williams et al., 2013 Williams et al., 2013 Parsanezhad & Dimyadi, 2014 Parsanezhad & Dimyadi, 2014
Process	• Unclear roles and responsibilities for loading data into the model or databases and maintaining the model • Challenge in data specification • Lack of collaboration between design, construction and FM • Lack of methodologies to demonstrate the tangible benefits of BIM in FM • Lack of overall architecture and functionalities of different components of integrated BIM FM system • Changes in practice and use of information	Kassem et al., 2015 Williams et al., 2013 Gnanarednam & Jayasena, 2013 Kassem et al., 2015; Williams et al., 2013; Becerik-Gerber et al., 2012 Williams et al., 2013; Gnanarednam & Jayasena, 2013
Technology	• Diversity in BIM and FM software tools, and interoperability issues • Necessity yet difficulty in software vendor's involvement, including fragmentation among different vendors, competition, and lack of common interests. • Lack of efficient technologies for capturing BIM models of existing facilities • Poor cloud computing facilities	Kassem et al., 2015; Gnanarednam & Jayasena, 2013; Williams et al., 2013 Becerik-Gerber et al., 2012 Parsanezhad & Dimyadi, 2014 Gnanarednam & Jayasena, 2013

The first group identifies 'people' as a challenge in adopting BIM in FM due to cultural barrier, organisation resistance, knowledge gap and lack of real world evidence. The second category is classifying 'process' challenges that are related to roles and responsibilities, data specification, collaboration, and changes in practice in FM. The last category perceives as technological challenges that related to software tools, interoperability between systems and

readiness of software vendors. In the broader term, the application of BIM in FM appears inconsistent and slow with the current practice. Many arising issues are still unsolved and questionable to facilities managers. First of all, the adoption of BIM is considered rather new in the FM industry (Patacas et al., 2015; Becerik-Gerber et al., 2012). Most BIM projects were utilised on the design and construction stage, with little or no consideration in the operational stage (Patacas et al., 2015). This prevents facilities managers from efficiently monitoring a building (Kassem et al., 2015).

Secondly, incompetency in handling BIM information may due to lack of technical knowledge regarding BIM. For example, BIM file formats of IFC, XML and HTML are foreign to most facilities managers who have little or no IT skills (Kassem et al., 2015; William et al., 2013). This is exacerbated when the lack of interoperability arises from compatibility shortcomings with an IFC file format (Gnanarednam and Jayasena , 2013; Parsanezhad and Dimyadi, 2014). The third issue is related to the BIM processes. Exchanging information using BIM is still uncommon because of the lack of collaboration among project team members when providing relevant information for FM (Gnanarednam and Jayasena, 2013). Interaction becomes inefficient and ineffective. Fourthly, there are problems with defining relevant information needs for operational use which is crucial when monitoring a building operation. This is because BIM carries both graphical and non-graphical information in design and construction phases, where it is the non-graphical information that is the most important to FM task (Becerick-Gerber et al., 2012; Patacas et al., 2015). Non-graphical information consists manufacture data, operation instruction, procedure, spare parts and maintenance specification, warranty information and other related information. This information are usually missing or incomplete and requires effort to collect and collate. Therefore, defining the extent of the key information required for FM plays an important role in adoption of BIM.

3.8 Key Information Requirements for BIM-Driven FM

Identifying the key information requirements to perform a building operation is one of the most problematic tasks for facilities managers. Information can be both non-digital and digital information which gradually are delivered in large volumes. The practice of organising this information is time consuming, takes a lot of effort to check and requires double processing due to the low-reliability of information delivery, low validity of information content and incomplete information (Jylhä and Suvanto, 2014). Using BIM may further exacerbate this challenge if BIM is not adopted properly; as information exchange

needs to be checked and validates for its completeness and usefulness of types of information delivered (Patacas et al, 2015). Not all information comes from BIM is useful to FM; this will need to be filtered and identified before it could be imported to the facility management system. However, the key information that is relevant and suitable for FM has yet to be identified (Patacas et al, 2015; Parsanezhad and Dimyadi, 2014). From these findings, it is evident that the relevance of information determines the usefulness of exchanging information from BIM platform to FM systems.

Several official reports and studies have outlined the information requirements for FM during the operational phase of building (RICS, 2015; Becerick-Geber, 2012, RICS, 2011). **Figure 3.4** presents the categories and types of information requirements for FM use in operating and maintaining the building in the FM systems. This list was adapter/sourced from (RICS, 2015; Becerick-Geber, 2012, RICS, 2011).

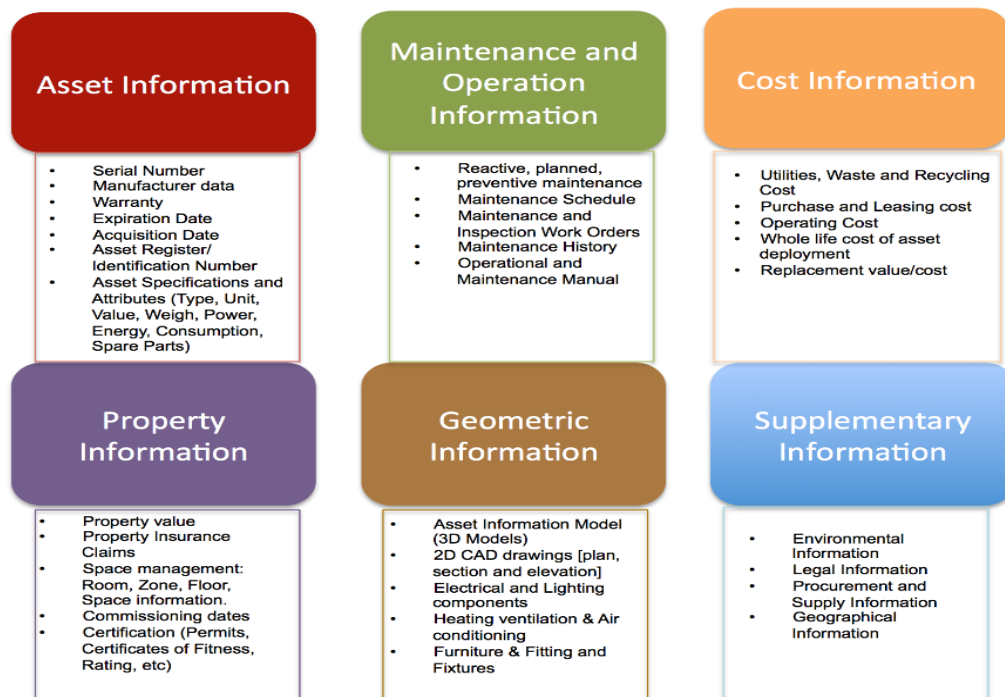


Figure 3.4 Key Information Requirements

3.8.1 Asset Information

An asset can be defined as “an item of property, something advantageous or well worth having, or a property that considered as chargeable for all debts” (Varcoe, 1992). BS ISO 55000 (2014) describes “asset is an item, things or entity that has potential or actual value to an organisation”. In this case, building assets such as air-handling unit (AHU), engine generator or any machinery for a building to function are essential information to facilities managers. According to BS ISO 55000 (2014) standard, the attributes asset information

includes manufacture data, serial numbers, expiration data, acquisition data, asset register (identification numbers) and any asset specification and attributes (e.g. type, unit value, weight, power, energy consumption, spare parts). Identifying each asset is crucial for records and up keeping in FM conduct.

3.8.2 Maintenance and Operation Information

Maintenance and operation is one of the central functions in FM practice and this involves the inspection of a particular component or asset at several time intervals (Mangano and Marco, 2014). These activities can be divided into two groups; corrective maintenance and preventive maintenance planned (Mangano and Marco, 2014). Corrective maintenance is an activity whenever an asset or item in use has a breakdown, then only servicing and repairing are required at that particular time. This type of maintenance also called breakdown, failure-based, or run-to-failure maintenance (Mangano and Marco, 2014). However, preventive / planned preventive maintenance does the opposite function. Its activity aims at avoiding breakdown or failure before it happens. Its main activity includes inspection, diagnostic, adjustment and overhauls of asset/items on regular basis or intervals of time (Atkins and Brooks, 2009). This type of information partly relates to asset information and it includes operational and maintenance manual, inspection work orders and maintenance schedule information. Both maintenance and operation information is critical to perform maintenance activities in managing a building's operation.

3.8.3 Financial Information

Financial information relating to assets, equipment or property values is important to predict the future finances of an organization (Langston, 2003). The financial records are typically used to measure benchmark and business performance (Langston, 2003; Nutt, 2000).. It involves forecasting, estimating, quantification, accounting, adjustment, reporting, monitoring, and benchmarking activities (Langston, 2003; RICS, 2011; RICS, 2015). Cost-related information such as utilities, waste, recycling, and operating cost is valuable in managing the actual expenditure when compared to the budgeted targets (Langston, 2003; RICS, 2011; RICS, 2015) This information not only allows FM to plan for economical operation and efficient use of building, but it also of interest to owners in reducing unnecessary future costs. These attributes about financial information is a key ingredient in deployment and operation of facilities.

3.8.4 Property Information

Property is where every organization operates in both land and buildings (Balch, 1994). Handling a property requires necessary documents for developing strategic decision-making for directing, monitoring and controlling business activities (RICS, 2015). Important property documents and information are commissioning dates, digital certification (permits, rating or fitness), property value, property insurance claim and space management relating to room, zone, floor and space information (RICS, 2015). These information should be accessible whenever an organization plans for the future.

3.8.5 Geometric Information

In a building, geometric information involves any lines, objects or components that is visible within a space (Becerick-Geber, 2012; Kassem et al., 2015). 2D drawings, 3D models, electrical and lighting components, furniture, fittings, and fixture are examples of a geometric information. Normally, this information is stored digitally in the form of text, PDF file, DWG file or DOC file. BIM allows facilities managers to work interactively with visual information more accurately in monitoring and controlling building maintenance and operation. This attribute also supports future refurbishment and renovation works. Of particular interest is that geometric information allows each object and component of the building to be easily navigated remotely from the FM system in case of emergency or breakdown (Kassem et al., 2015).

3.8.6 Supplementary Information

Supplementary information may include data regarding environment analysis information, legal information, procurement and supply information, and geographical information. This information is optional and depends on the owner of the building for documenting either for records or reference. The importance of this category of information can be utilised in assessing building performance, tracking location of building components such as barcodes, or leasing the building to potential tenants.

3.9 Open Building Information Modelling Standards

This section intends to provide an overview of open BIM standards; COBie and IFC. The utilization of open BIM standards such as COBie and IFC for interoperability has allowed project teams to transfer construction information to facility managers at the beginning of the operational phase, however, the use of COBie and IFC remains an uncommon occurrence. This is because of the fragmentation of information exchanged in the building

life cycle remains unresolved and that the FM phase of the lifecycle is the most disconnected from the rest of project phase (Lucas, 2013). The low adoption of open BIM standards was caused by many issues such as shortage of BIM skills (Kassem et al, 2015; Jawadekar, 2012; Williams et al., 2013), lack of collaboration between project stakeholders and facilities managers (Kassem et al., 2015; Becerick-Gerber et al., 2012; Gnanarednam and Jayasena, 2013), and resistance from facilities managers (Kassem et al., 2015; Becerick-Gerber et al., 2012). The subsequent subsections elaborate on COBie and IFC and their issues.

3.9.1 Construction Operation Building Information Exchange (COBie)

The buildings of today are increasingly sophisticated and information is needed for their operation and maintenance (Jordan, 2010). This information may also help to accurately track facilities components, identify building inefficiencies and respond promptly to customer requests (Forns-Samso, 2010). The installation, replacement and scheduled maintenance costs for each component or asset of a facility. A correct inventory of equipment is essential for repair / replacement and maintenance budgeting costs (GSA 2011). In general, the facility manager obtains from the general contractor building the facility, most of the initial facilities information. This is the best time to collect and streamline information on the facility right before the building is occupied (Edgar 2000). The management activities of the facility depend on the precision and accessibility of the data created in the design, construction and maintenance phases of the facility. Failure to provide this information might lead to cost overruns, inefficient building operations and ineffective customer request resolution. Over time, manpower and costs with incorrect or lack of equipment inventories are involved in operations and maintenance. If inventories of equipment are not properly tracked, project ranges, cost estimate reliability is reduced, emergency response is impaired and management decision-making capacity is reduced.

Because most data for buildings are generated during the construction phase, a broad database collection process is important, starting from the design phase, throughout the project life cycle. Therefore, if BIM is to be used as the "FM Life Cycle Portal," the timing of the data collection process is also important early in the life-cycle of the project (Jordani, 2010). According to East (2011), the handing-out of this data in paper lists, product data sheets, warranties, replacement part lists, preventative maintenance schedules and other information is necessary to most contracts. For this type of information, Clayton et al. (1998) coincides with the new term "operational documents," intended to use design and construction information in order to support operations and maintenance. Given that most of

the information has previously to be collected from information, it is costly to collect the data at the end of the job which is currently standard practice.

The Building Operations Information Exchange (COBie) simplifies the work to collect and record project transfer data (East 2011). COBie is defined as an IFC-based data exchange specification for the neutral vendor of the GSA BIM Guide for Facility Management (2012) and describes the exchange of information among project phases and construction phases. Many organizations have still understood the importance of a complete and effective inventory of their support facility management facility (Sullivan et al. 2010). Although it would seem obvious that the most advantageous thing for an organization would be a complete inventory, most organizations do not understand the impact of equipment stocks on their business.

Recognized for the past, the development of the COBie Standard In 1983, the Building Research Council (BRB) proposed an integrated facility information database solution (Scarponcini 1996). FM information was already available to organize, manage and supply other computerized systems such as CAFM, CMMS etc. The range and version of the software products caused data automatic transmission inefficiencies. Therefore, even though it is inefficient, error-prone and tedious, manual information delivery is still commonly used (William Oriental et al. 2012). To meet such challenges and create a non-owned version of the exchange data (East 2007), the specification was developed for COBie. The development process started in 2006 with a comprehensive literature review and private industrial / association initiatives under the National Institute of Building Sciences (NIBS) FM and the Operations Committee. Two main aspects are in the development of the COBie standard. First, to define the minimal requirements, responsible actors and related life cycle phases in terms of specific information requirements. Second, define standards for data exchange in order to remove existing information exchange inefficiencies. Based on business cases, specific business requirements, data transmission plan and software implementation (East 2007), the exchanges of information on the life cycle were evaluated. In the development of COBie, association efforts played a vital role.

Currently, COBie-based information can be delivered in any of the three formats, IFC STEP (standard for exchange of product model) Physical File Format, ifcXML (extensible mark-up language format of IFC) and/or SpreadsheetML (open XML schema used by spreadsheet application such as MS Excel). In various parsers and/or web browsers, IFC STEP and

ifcXML may be interpreted and visualized. However, it requires certain IT-knowledge that not every end-user has to interpret this format. In view of the inexperience of end users and their limited familiarity with the two first file formats, the Tablet represents COBie. COBie deliverable spreadsheet format provides useful techniques for the user to implement, such as sorting, querying, and/or simple math functions. It can also be read by humans, monitored and edited. A deliverable COBie Tab includes several workbooks and columns in which users export information from the software applications data mapping and export tools of BIM and/or computer-aided facilities management (CAFM); and / or manually fill in. The data is distributed in workbooks and columns so that each row contains specific data entities. A COBie table can include thousands of rows of facility data, depending on the delivery phase and the project size.

Despite the easiness of spreadsheets and familiarity of end-users with spreadsheet logic and actions, storing and representing large amount of facility data in a tabular repository with number of dependent sub-sections may have unintended effects and challenges in handling and interpreting COBie data, for example, challenges in visualizing the overall content, duplication of data entries, understanding data dependencies, memory overload due to high amount of number and text-based data, etc. The literature discusses similar issues with regard to usability and cognitive aspects of the tablet (Chen & Chan 2008; Kohlhase 2013; Hendry & Green 1994; Thorne & Ball 2008). Consequently, a large amount of information and a lack of explicit dependence between the cells and workbooks can also summarize the main difficulty end users have when understanding COBie data. In the COBie table, users need to identify the data and their dependencies, which implies a high memory load. The COBie diagram is available for checking and interpretation in the COBie Responsibility Matrix (East 2013). However, it may increase the memory load even further if two different files are handled or a further workbook is included in the existing COBie table.

On the other hand, handling two separate files or adding one more workbook to the existing COBie spreadsheet may increase the memory load even further. The complexities and challenges involved while handling and interpreting the COBie spreadsheet is a matter of concern in construction industries. This research has a double contribution. First, by reviewing the literature about spreadsheet design, human-spreadsheet interaction, spreadsheet errors, and visualization, issues that are common with the COBie spreadsheet representations identified. Second, based on the literature review, this research will propose a framework to enhance the usability and functionality of COBie in BIM. Findings of this

study and the proposed framework are expected to identify and outline the potential areas of future development for COBie, especially from the point of view usability and interaction with the data.

3.9.2 The Adoption of COBie in the UK

In the UK, COBie has been fully recognised in the report of BIM Working Party Strategy Paper as a construction practice in handing over of facility information (DBIS, 2011). The purpose of using COBie is to facilitate Client/Facility Manager to receive relevant facility information for use in the operational stage. According to DBIS (2011), the benefits of using COBie in practice will improve:

- The handover of a building's information to facility manager
- The coordination of maintenance records of existing building
- The delivery of product data/information
- The comparison of Employer Information Requirement (EIR) against the as-built information delivery

Although the benefits of using COBie can be seen gradually once the building has been completed, it appears delivering the COBie for a project can be an obstacle during the handover process. The challenge occurs when information exchange from BIM authoring tools generated through COBie is unable to be imported into existing FM systems of the owner. This could impede the routine task of the facility manager to solve the technical difficulties in identifying errors in COBie data and FM systems. To overcome this challenge, several methods of capturing data can be populated either using a COBie extension provided in the BIM software platform (i.e. Revit), Bi-directional link tools between the BIM software platform and FM systems or delivered via the BIM utility tools or SpreadsheetML (Excel) file format (Autodesk, 2017).

3.9.3 COBie Challenges in FM

Adopting COBie in FM causes many technical challenges when exchanging information. As mentioned in section 1.1, National Building Science (NBS) survey in 2017 found that 72% of respondents did not use COBie as standard of information exchange for FM. In Parsanezhad and Dimyadi (2014) study, it was argued that the barrier of adopting COBie was because the information required by a client/owner was inadequate and unsuitable. In addition, the manufacturer/supplier failed to provide the necessary specification for product

information, which can be difficult for the end-users to deliver in a COBie-compliant format (Parsanezhad and Dimyadi, 2014). Apart from that, not all FM software vendors fully support information from COBie (Becerick-Gerber, 2012; Williams, et al, 2013), as different FM software vendors provide different needs and functionality (NIBS, 2013).

Users may risk losing information or dealing with overwhelming information that can be prone to errors and irrelevant data. NBS (2012) and Fallon et al. (2016) reported that there were overwhelming technical challenges in populating COBie and that they had concerns that this required great effort to produce information. Their report did not clarify if information should be sourced from IFC files or manually created. If the information is to be sourced from IFC files, then issues will arise from compatibility issues and this needs to be first resolved. If the information were to be manually created, then the use of Microsoft Excel would be more favourable for reporting but would be impractical for authoring because it is error prone and time-consuming (Fallon et al., 2016). These phenomena suggests that exchanging information via COBie spreadsheet may not be the best method to access information readily and facilities managers may risk of losing, missing or leading to error-prone information before it can feed into the FM system. Therefore, a bi-directional link developed between BIM systems and FM systems could overcome this issue. On the other hand, other method of exchanging information is the use of Industrial Foundation Classes (IFC). IFC has been developed to facilitate the process of exchanging object-oriented information across various construction software platforms. The next section will discuss further on Industry Foundation Classes (IFC).

3.9.4 Industry Foundation Classes (IFC)

Information exchange from BIM applications to COBie is defined by the IFC format which is the Industrial Foundation Classes (IFC) is an open standard to facilitate the digital information exchange of BIM object data. According to ISO/PAS 16739 , IFC is defined as the “predominant non-proprietary exchange format of building information between AEC/FM software”. This definition was also supported by Eastman et al. (2011) that IFC is “a schema developed to define and extensible set of consistent data representations of building information for exchange between AEC/FM software application”. Simply put, IFC is a common open-standard format that is used to communicate between software applications across the building lifecycle.

IFC was first initiated in 1994 by the International Alliance for Interoperability (IAI), which is now known as buildingSMART (Laakso and Kiviniemi, 2012; Eastman et al., 2011). The core purpose of buildingSMART was to standardize processes, workflow, and procedure for BIM (Laakso and Kiviniemi, 2012; Eastman et al., 2011). This effort also included the development of IFC standardization (Laakso and Kiviniemi, 2012; Eastman et al., 2011). Since then, the buildingSMART's IFC 1.0 has evolved into IFC2X4/ IFC4 to improve the quality of usability and implementation of the standard. An overview of this development is reproduced from Laakso and Kiviniemi (2012) in Figure 13. The subsequent paragraphs explained in **Figure 3.51** and the evolution of IFC.

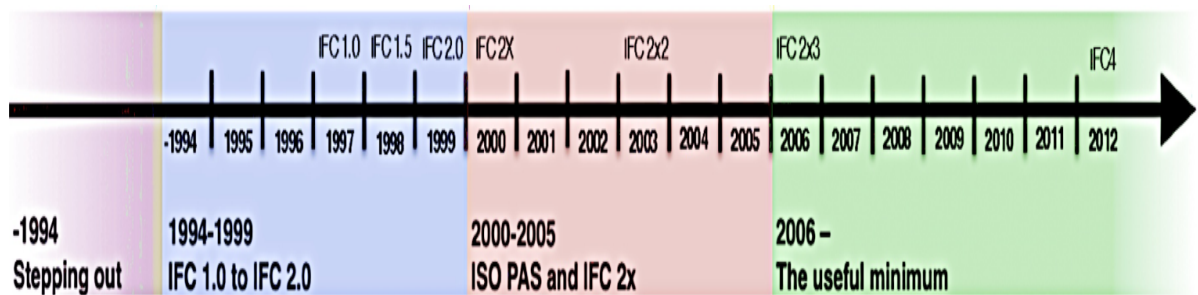


Figure 3.5 Evolution of IFC

The IFC-based format allows integration between design, cost, project, production, and operation and maintenance information in order to reduce redundancy and increase efficiency in building life-cycle (Laakso and Kiviniemi, 2012). The IFC-based format that exchanges information between BIM model and FM systems are defined in IfcFacilitiesMgmtDomain, IfcProcessExtension, IfcSharedMgmtElements, and IfcSharedFacilitiesElements schemas (buildingSMART, 2015; Mitchell and Schevers, 2006). These schemas are the key aspects of facilitating information from an IFC model after a building's construction is completed and serves the needs of a building's operation and maintenance phases. This will allow an IFC-based format to communicate with FM systems such as CAFM and CMMS.

There are several advantages of using IFC that benefits facility management (Sabol, 2008; Mitchell and Schevers, 2006). Firstly, IFC allows more effective process for facility management to handle information more easily (Mitchell and Schevers, 2006). This information can be shared and reused for the whole life cycle of a building. Secondly, IFC was found to assist facility managers/ owners to visualize the facility. The model view enables facility managers/owners to understand the nature and relationships of the facility

during the operational phase of building. For example, a building services' failure can be detected in the model view. In addition, visualization also helps in term of decision making in developing scenarios and their impacts such as, reducing cost for major maintenance works, assessing security or understanding relocation during renovation activities (Mitchell and Schevers, 2006). Thirdly, IFC data are able to manipulate and predict environmental performance, maintenance regime and life-cycle costs (Mitchell and Schevers, 2006). IFC's information driven format facilitates reporting data activities about a building's efficiency and cost savings.

However, although adopting IFC is beneficial, the current iteration of IFC is still incompatible to facility managers who are mainly from a management background and do not have the commiserating IFC skill sets. This creates a knowledge gap in using and understanding the use of IFC data exchange format, which in turn, becomes a barrier when operating a routine task. IFC allows interoperability among project stakeholders, but it was not easy to integrate with the FM systems once the building is completed (Lewis, 2013). The information captured via IFC may result in large file sizes and not all information is useful and relevant during the operational phase (Lewis, 2013). Even worse, IFC could suffer from data loss with each import and export file and, deterioration of information which can be difficult to detect (Venugopal et al., 2012; Hetherington et al., 2011; Amour and Faraj, 2001). The use of IFC has been limited to FM software vendors because of its instability for integration (Shen et al., 2010). As the IFC format continues to evolve, it is difficult for software vendors to keep up with the latest format to be compatible to their own systems. This shortcoming has led to poor progress by FM software vendors to fully adopt IFC altogether; they focus on their own proprietary solution instead and the IFC data exchange format becomes foreign to most of the common FM tasks due to its technical terminology (Shen et al., 2010).

William (2013) argued that BIM built a double walled silo for facility managers because of the inherent language and knowledge gap. Most facility managers are the end-users of FM systems in their organization, which requires their familiarity with the features and functions of a particular facility management system. This includes space management, maintenance regime, work orders and more. Importing and exporting IFC format and understanding its attributes may require new skill sets and training to understand its nature and FM systems' integration. This also requires changes to facilities managers' normal routine of operating FM systems in their building(s). These problems evidences that the knowledge gap about

IFC and the lack of standard and guidelines to communicate using IFC are factors contributing to the unwillingness of facility managers to adopt BIM.

3.10 Mapping COBie and IFC into FM Systems

The implementation of COBie and IFC has been demonstrated and tested with FM software vendors (NIBS, 2013). NIBS announced a COBie Challenge in March 2013 for facility management software vendors to demonstrate the ability of their products to import COBie data for the purposes of facility/asset management and maintenance (NIBS, 2013). The results of their capabilities are adapted from NIBS and shown in **Figure 3.6**

Figure 3.6 has been removed from this version of the thesis due to copyright restrictions

(Source: NIBS, 2013)

Figure 3.6 Capabilities of FM System in Importing COBie

Figure 3.6 showed that 15 FM software vendors have shown their product ability to import COBie data types. Most CAFM / CMMS systems have no model interface or integration capabilities, according to the "Mode" column. This shows that it's not possible to read the IFC data format in many CAFM / CMMS system models but to record data in Excel spreadsheet format (xlsx, csv). The most compatible information with CAFM / CMMS systems is COBie data on space, type and component. Most of this information has to do with the register of assets and space information such as manufacturer details, warranties, serial numbers, floor levels and room numbers easily manipulable on the systems. The 'Document' data in Figure 3.6 indicates that the majority of CAFM / CMMS systems are not compatible. This information consists of an attachment to the CAFM and/or CMMS systems

of a PDF file and/or links to document files. Other than the 'attribute' table, the remaining COBie data is quite compatible with most CAFM / SCC systems. This information mainly comprises performance-based information, including preventive maintenance, safety procedures, materials, tools, training and replacement parts. Due to their unique information mappings and settings that are different from COBie, most CAFM / CMMS systems have constraints when importing these data. From the table results it can be argued that the use of CAFM / CMMS systems for some of the tabs on COBie Spreadsheets is somewhat doubtful and uncertain.

Finally, the 15 FM software suppliers show that CAFM / CMMS systems have different capabilities, different types, sizes and complexities. The nature of COBie as an information facility and structural facility support mechanism can greatly facilitate the exchange of information for CAFM / CMMS systems in streamlining operational and long-term maintenance task.

3.11 Standards and Guidelines for Application of BIM in FM

In an effort of supporting BIM adoption, the BIM TaskGroup and British Standard Institute (BSI) has published several standards and guidelines for digital information and exchange of life-cycle information within the construction industry since 2007 (Cheng and Lu, 2015). In complying with BIM Level 2 in the UK, eight publications of standards and guidelines has been outlined to deliver successful BIM-compliance projects. The standards and guidelines that facilitate the use of BIM are:

- BS1192: 2007 – Collaborative production of architectural, engineering and construction information- Code of practice
- PAS1192-2: 2013 – Specification for information management for capital/delivery phase of construction projects using building information modelling
- PAS1192-3: 2014 – Specification for information management for the operational phase of assets using building information modelling
- BS1192-4: 2014 – Collaborative production of information Part 4: Fulfilling employer's information exchange using COBie- Code of practice
- BIM Protocol
- Government Soft Landings
- Classification
- Digital Plan of Work

These standards and guidelines are accessible to construction players including facilities managers as a fundamental practice in using BIM. However, this study specifically focussed on the standards and guidelines for information exchange in operational phase of buildings. For this reason, PAS1192-3 and BS1192-4 are identified as the crucial documents to FM in handling information during the operational phase. However, a 2017 survey shows that only 26% and 28% of UK construction professionals use PAS 1192-3 and BS1192-4 respectively (NBS, 2017) which suggests their low adoption in the operational phase. Therefore, to investigate these phenomena, the next sub-section elaborated in brief the situation regarding the use of BS1192-4 and PAS 1192-3.

3.11.1 PAS 1192-3 Standard

The standard of Publicly Available Specification (PAS) 1192-3 is developed for managing information for the operational phase of assets using BIM (BSI, 2014b). The purpose of this standard is to guide the operator or FM in handling information captured from BIM during the handover stage. It describes the process of managing asset(s) using BIM and the embedded information that needs for future work such as major work (e.g. renovation, refurbishment), minor work (interior work), maintenance, inherit asset, breakdown and demolition. The aim of this standard is to achieve a single source of approved and validated information of asset(s) known as Asset Information Model (AIM) (BSI, 2014b). The creation of AIM was collated from different sources that included information and data from existing organizational systems, recognizing and relabeling existing data, updated information from an inspection of physical asset(s), and exchange of information of BIM Model from the project phase. The process of acquiring AIM needs to be authorized under the Common Data Environment (CDE) – a collaborative platform of sharing, collecting and disseminate all relevant files, documents and data from multi-disciplinary teams (BSI, 2014b).

3.11.2 BS1192-4 Standard

The BS1192-4 standard defines the UK's usage of COBie, an internationally agreed information exchange schema for exchanging facility information between the employer and the supply chain. This standard is used as a guide to exchange information throughout the lifecycle of the facility. This standard is relevant to facility management task in handling COBie information about the building operation. The deliverables of COBie is the responsibility of the employer, project team, supply-chain and the relationship of information provider and receiver to exchange information throughout the facility lifecycle.

This was evident by how COBie data is populated and explained in section 3.7.1 mentioned earlier. The content in COBie is also determined by the responsibility of each actor in the project for the use in operation stage of building operation (BSI, 2014a)

3.11.3 The Role of the Employer

The main role of the employer in COBie deliverables is to specify the information requirements intended for the facility's operation. The employer should state the spatial and physical information, support for business goals for ownership in the operation stage and compliance and regulatory requirements. These types of information should be informed as part of the Employer Information Requirement (EIR) in delivery of COBie. Spatial and physical information regarding assets, spaces and zones has to ensure its accuracy for auditing and reporting for building inspection and life cycle costing. Other aspects of information that needs to be considered in supporting the business goals for building operation may consist of post-occupancy evaluation review, benchmarking of facility and other measure such as areas, volume or hours of intended usage. In addition, facility operation information that the employer should consider in the EIR document is reproduced from BSI (2014a) itemised in **Figure 3.7**.

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(Source: BSI, 2014a)

Figure 3.7 Employer Information Requirement for Facility Operation

As a matter of security, the employer should determine the confidentiality of security and surveillance information in the EIR if required. Information such as CCTV camera (COBie.Component spreadsheet) or door access code system (COBie.Attributes spreadsheet) should be considered outside of the employers' COBie deliverable. This

information should comply to the security requirement EIR such as security policy, processes and procedures (BSI, 2014a). Furthermore, repurposing of each space or facility should be supported with detailed information such as capacity (areas, volumes, occupancy, environmental conditions and structural load bearing) and repurposing the existing use of Space, Facility and Zone.

3.11.4 The Role of the Project Team

The project team may include the building designer, contractor, and consultant in COBie deliverables. The role of the project team in COBie deliverable is to document the spatial and physical information about the facility. Spatial information includes, Spaces, that are assigned to a Floor and grouping into Zones. Physical information consists of Components and their specification by product Type and grouping into functional Systems. The project team also needs to ensure information availability from the supply chain and security of accessing any sensitive information in COBie deliverables.

3.11.5 The Role of Supply-Chain

The supply chain role is responsible for the specific product information for the use in operation of building. This information may include installation, maintenance operation and emergency procedure. In some extent, it might also embody information on economic and environmental impact of the product or the relationship of products to its Connection and other possibilities. However, the role of supply-chain in proving BIM data has been a challenge due to lack of interest and exposure to BIM. The implementation of BIM may require supply-chain to invest in business resources and pressure of delivering BIM data in a tight time-constraint.

3.11.6 The Relationship of Information Providers and Receivers

The relationship between information provider and receiver is vital for the process of COBie delivery. During the project phase, information providers might be the project team, but during the operational phase the information provider is the employer. However, the role may reverse between information receiver and information provider. The objectives of information provider/receiver are to ensure that there is no significant data loss during each import and export of COBie deliverables and, to check against the EIR regarding issues of data protection, security, and sensitivity (BSI, 2014).

Figure 3.8 has been removed from this version of the thesis due to copyright restrictions

(source: BSI, 2014a)

Figure 3.8 Exchange Facilities Information Process

3.11.7 Implementation of COBie Data Quality

COBie deliverables for management and quality criteria is assessed through validity, structure, consistency and completeness of information. The validity of COBie deliverables should be compliant to the COBie schema provided in the BS1192-4 document. The structure of COBie data is examined through the appropriate data types, clarity of naming, and consistency of units. The consistency of COBie data is determined by comparing and checking the earlier COBie deliverables and maintaining the unique asset naming from the onset of the build project. Completeness of COBie deliverables is reviewed and tested against the EIR and any chosen project stages before conducting any information exchange. Moreover, the completeness of information depends on the veracity, groupings of spatial and physical information, necessary supplementary and operational information, and timeliness of information before handover (BSI, 2014a). The implementation of COBie and EIR delivery are heavily dependent on the employer to manage appropriate information exchanges when operating a facility. The implementation of COBie deliverables need to consider rigorous software application, shared structured data and replicable process. The implementation also covers instruction for existing and new facilities as well as building and infrastructure. For instance, the basic requirements of assets register are Name, Description, Classification, External System, and if possible External Identifier (BSI, 2014a). These assets should also be coded with classification table in the Uniclass system.

3.12 Challenge of Using PAS 1192-3 and BS1192-4 Standard

Until recently, both of the standards guidelines' use and benefits have yet to convince the FM industry. NBS (2017) reports suggests that the uptake of BIM in FM received minimal

attention and lack of interest among facilities managers participated in the survey. This could be attributed to the resistance of facility managers in adopting BIM technologies. Lewis (2013) argued that BIM has been relying on technology itself without considering the adaptability of people who try using it. As mentioned on Section 2.1, FM is about balancing people, process and technology, however, if technology outweighs people and process, it is likely to be a concerning issue in FM (Lewis, 2013). Williams et al. (2013) showed that the majority of facilities managers were aware of BIM but few actually adopted it. The underlying problem of adoption of BIM in FM can potentially be explained using two theoretical framework, Technology Acceptance Model and Innovation Diffusion Theory. This is investigated and discussed in the next chapter.

3.13 Summary of Open BIM Standards and Guidelines

This section aims to introduce and review open BIM standards of COBie and IFC to facilitate the adoption of BIM in FM. It was found that firstly, COBie is a mechanism that represents information exchange from BIM software. The function of COBie is to allow exchanging information from the construction phase to the operational phase. This transition of information exchange is defined by an IFC format. The IFC is an open format that defined information between software applications. The IFC carries object data from a BIM Model to able to integrate with existing FM systems. However, COBie and IFC has received less pervasive use from FM because of a lack of standard guidelines to capture information from COBie and how to use the IFC format.

PAS1192-3 and BS 1192-4 standards guidelines provided a process of handling information using BIM in the operational phase and capturing information using COBie. PAS1192-3 defined how to develop an asset information model (AIM) to manage buildings using BIM. BS1192-4 informed facilities manager/owner how to populate and define information using COBie. While both standards allowed to streamline the task of facilities manager in using BIM, nonetheless the content of standards and guidelines may not be easily understood from the perspective of FM. As a consequence, most facilities managers were resistant to adopt BIM altogether. Therefore, these difficulties and resistance could be attributed to an individual's attitudes to and abilities for using technology. This suggests that the underlying problem of adopting BIM in FM may be explained using technology adoption theories namely, Technology Acceptance Model (TAM) and Innovation Diffusion Theory (IDT).

3.14 Chapter Summary

This section aimed to present an extensive literature on BIM and facility management by providing a critical analysis that can potentially be adopted in FM. Firstly the section reviewed the definition of BIM and how it is adopted in the AEC/FM industry. The applications of BIM influence many aspects of construction practices especially in the FM phase. This was evident through reports of how BIM models could help in facilitating visualization of BIM model, space management, maintenance, emergency, renovation, and FM training and development. Secondly, a review about the benefits and challenges of BIM in FM was presented. Although the benefits proved to streamline many of FM task in the long haul, the current situation confronted undue challenges in people, process and technology aspects. The most distinct challenge is to identify the key information requirement that is suitable to conduct building operation for facilities manager. This is because, not all information coming from BIM software is pertinent to FM task. Therefore, it is crucial to identify what are key information requirements that are pertinent to communicate to the FM system. Open BIM standards such as Construction Operation Building Information Exchange (COBie) and Industry Foundation Classes (IFC) may better facilitate the information between BIM software and FM system. This process was portrayed in the standards guidelines to support the operational phase of a building. The next chapter investigates the extent to which open BIM standards and standards guidelines can facilitate the adoption of BIM in FM.

CHAPTER 4 THEORETICAL PERSPECTIVE

4.1 Introduction

The previous chapter discussed critically state-of-the-art of application of BIM in FM. Following, this chapter investigates the user adoption and technology acceptance of BIM. The investigation discussed in three sections. The first section explores the Technology Acceptance Model (TAM) and the second section explores the Diffusion of Innovation Theory (IDT) and its relationship to adoption of technology in BIM. Thereafter, the third section examines the integration and application of both theories to facilitate a stronger model in examining the adoption of technology in BIM. Then, it continues with the background of research methodology followed by the selected research methods; an overview of key sections is presented in **Figure 4.1** below.

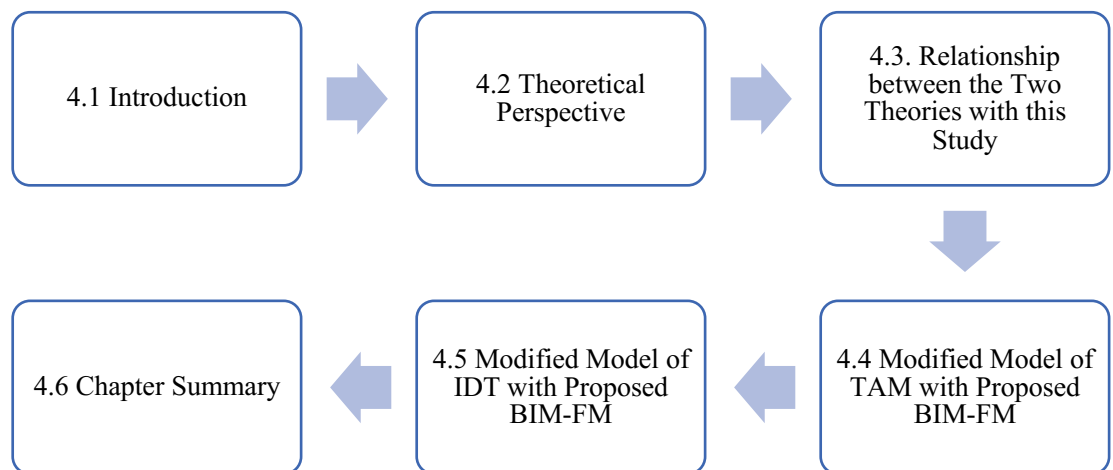


Figure 4.1 Chapter 4 Organization

4.2 Theoretical Perspective

A theoretical perspective is a series of realistic assumptions that influence the questions asked and the types of answers. A theoretical perspective can be understood in this sense as a lens by which we look, concentrate or distort what we see. It can also be considered as a framework to include certain things and to exclude them from view. Figure 4.2 shows the number of theories applied to this study, and these theories will be detailed in the following sub-sections.

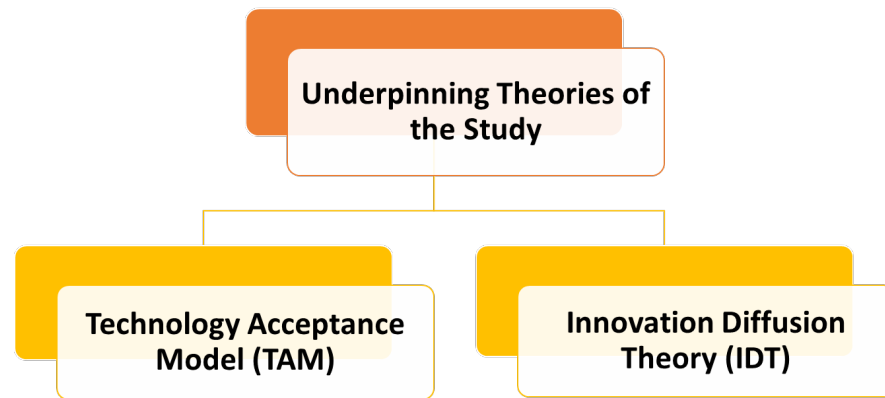


Figure 4.2 Underpinning Theories of the Study

4.2.1 The Technology Acceptance Model

Marangunic and Granic (2015) believe that the constant improvement and technological advancements, particularly in ICT applications, are a dilemma in deciding acceptability and rejection issues. On this basis many models and theories were developed to make more clear on the effective use of technology. In examining issues affecting the use of modern technologies, the TAM (Technology Acceptance Model) emerges from all the models. No broad and systematic research in this field can take place without a significant understanding of the foundations, growth and adaptation, together with the limitations of the model.

The TAM expands Ajzen & Fishbein's Theory of Reasoned Action (TRA) (Al-Suqri and Al-Kharusi, 2015), which was a theory initiated and validated by Fred Davis in 1986. The aim of the theory is the description of factors which determines acceptability of technology, the use of information technology and the parsimonious theoretical model for explaining information technology (Tarhini et al., 2015). Ducey (2013) explains that TAM includes the key determinants of technology acceptance and user behaviour– Perceived Ease of Use (PEOU) and Perceived Usefulness (PU). On the other side, Teo (2013) identifies various factors that encourage the uses of and acceptance of technology. The factors which promote the intention to use and encourage the ability to accept or reject technology include individual differences, social influences, beliefs, attitudes, and situational influences.

In addition, Teo (2003) claimed that the behavior of an individual is influenced by an attempt to carry out the conduct, in other words that the actual performance of the behavior is preached by a person's behavioral intention to participate in TAM activities. Alongside this, Ducey (2013) described this as a parsimonious technology theory in a facility that seeks to

trigger the intent or curiosity of individual technological reactions that may, in due course, affect current use of the technology (Aggorowati et al., 2012). The "intention" that can also be used to predict and forecast a desire for and motivation to conduct and a number of skills is also of great importance to TAM. Third is a personal nature which reflects a human attitude, the second is a subjective norm that has the effect of society and the third is perceived behavioral control (Huda, et al., 2012). This intention is determined by three factors. The intention of the people to adopt a certain skill can therefore be based on the above three key factors.

In particular, several studies on the authenticity of TAM have been conducted. For instance, in predicting the intensity of technological acceptance among pre-service teachers, Aypay, et al. (2012) tested the theory and showed a connection between the model and the acquisition of the information. Jiang et al. (2010) also found that individual technological acceptance practices are valuable but incomplete without considering social factors and personal conditions, two of the factors mentioned in the preceding paragraph. Thakur (2013) discussed issues that affect the consumer's intent to use mobile payment systems and found that the 'performance expectation, energy expectation and social effects of mobile finance are facilitating conditions.' Garg and Garg (2013) suggest that consumer and service quality perceptions affect when formulating perceptions concerning new technologies, subjective and social norms.

Many theories that apply to technology acceptance investigations, as can be seen, have been developed. The following are included: TRA from Ajzen (1980) and TRA from Ajzen (1991). Planned behavior Theory from Ajzen. However, TAM is the most robust theory in user adoption of IT because it can help predict user behaviour by examining the three elements suggested by Huda et al. (2012) and supported by the study of Shroff et al. (2011). Furthermore it has been assessed, and found powerful, the validity of the theory. The TAM was recognized as one of the most commonly used theoretical models in the field of information systems (IS), based on the two central variables of PEOU and PU, for the acceptance and performance of instruction media in the classroom. The TAM is also one of the most important and widely used theories to describe the acceptance of information systems by individuals (Bagozzi, 2007). The variables forming the TAM are also similar to the personal capacity expected of contemporary professionals for technological skills with careful observation.

Davis (1989) thinks that the two important variables, PU and PEOU, influence technological perceptions and suggest users willingness to develop new skills. Extrinsic and intrinsic motivations can considerably affect the scope of the development of new skills (Davis 1989). Far from motivating the activity, it is perceived to be helpful in achieving special results different from the activity itself (Davis, 1989). In contrast, Davis explains moreover that the intrinsic motivation concerns the performance of a task that is nothing else than an obvious strengthening of the activity itself. It is mainly because it is crucial in achieving specific objectives that are not inherent in the usage of the ability itself that PU is relevant for the technology acceptance of technology. The basis for each model variable is discussed below as following.

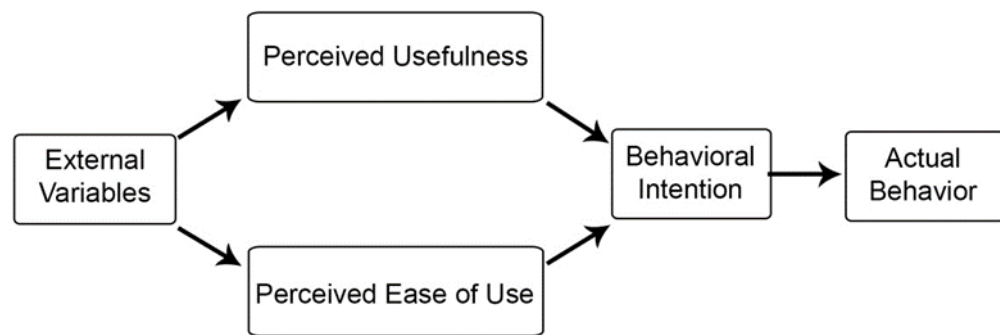


Figure 4.3 Technology Acceptance Model

Figure 4.2 illustrates the two important constructions of the TAM, PU and PEOU. The TAM provides a succinct method for modeling the effects on beliefs, attitudes and intentions of external variables. External variables relate to quality, such as training, computer experience and systems quality, etc., outside of an individual. Fundamentally, external factors lead to attitudes towards the utilization of a certain technology and its final application. The following explanations are provided for the TAM variables.

4.2.1.1 Perceived Usefulness

Increased human skills can be achieved via access to information. Lombardi (2007) pointed out that users' reluctance to accept and use available strategies and techniques to access information prevents the acquisition of capacity for access to authentic information. PU—in Davis (1989) study—is the extent that someone believes it would improve his or her job performance or routine responsibility if a particular method or technique was employed. This perception is based on the fact that the acquired capacity will improve performance. Davis (1989) is also of the opinion that raises, promotions, bonuses and other awards naturally

strengthen people to improve their performance. The TAM is of course worthy of a lot of researchers, because in recent studies (e.g. Yeh and Teng 2012), the TAM showed how such a value can improve the performance of users and has shown itself to be a key technology factor.

4.2.1.2 Perceived Ease of Use

Davis (1989) argued that PEOU is to the extent that an individual feels that it is easy and hassle free to use a certain system, that is, easy use is a free reaction to complexity and difficulty. Thus, more people generally accept and use an application that is perceived to be easier to use. Zhu et al. (2012) add that PEOU shows how easy and uncomfortable the use of certain technologies is for an individual to accept. The system features can also facilitate the usability of the technology and the use of the system. Nanthida (2011) lists some factors that may affect the ease of use of modern resources, including information resources characteristics, work experience, technical equipment, and assistance etc. In PEOU assessment, these are the following factors to consider: computer self efficiency, external control perceptions, internet independence, computer worries, information anxiety, perceived pleasure and objectiveness, usability and behavioral intent.

4.2.1.3 External variables

Winarto (2011) confirms that numerous external variables can be used together with the TAM to indicate methods to be followed when using and adopting new skills. Winarto (2011) has identified over 70 external variables popularized to explain how people acquire new know-how. By contrast, Yousafzai, et al. (2007) classifies the variables into four categories: organisational features, system features, user's own personal features and other variables. **Table 4.1** illustrated the four categories in detail.

Table 4.1 External Variables Proposed the Effect on PU and PEOU

Table 4.1 has been removed from this version of the thesis due to copyright restrictions

Source: Yousafzai et al., 2007

4.2.1.4 Criticism of Technology Acceptance Model

The TAM is a theory widely applied in IS research, and the model is subject to a number of constraints irrespective of its broad acceptability (Chuttur 2009). Chuttur said that scholars are questionable regarding use and theoretical accuracy of the model; thus, it is convincing to conclude that TAM research may have been saturated. Future research could thus focus on the development and development of new models which will use the strengths of TAM while eliminating its weaknesses, as recently shown by the increasing popularity of the Unified Theory of Acceptance and the Use of Technology (UTAUT) (see Venkatesh et al.

2003). Khan and Woosley (2011) identified certain visible limitations of the TAM and concluded that the majority of studies which validated it included students in academic atmospheres, the applications studied were mainly introduction of office software or developments rather than commercial applications. In self-reporting, the TAM measures the variance that is not necessarily accurate. Factors measured in IT adaptation are also influenced by the dynamics of the organization not incorporated into the TAM and also only study 40% of IT use. Khan and Woosley (2011) therefore suggested that the TAM should be broadened to take account of social and human factors.

The TAM is not enough to explain technology adoption because the social influence that technology adoption dictates is ignored. It is not enough to look at adopting technology on an individual basis, because in the area where technology is exposed to individuals it can collectively influence the use and use of environment, exposure, society and economic status (Bagozzi 2007). The TAM was widely criticized and the constraints of many researchers led to the development of an extended model to address its area of deficiencies. The theory "includes doubtful heuristic value, limited explanatory and predictive power, triviality and lack of practical value" has been observed by Priyanka and Kumar (2013). Other scientists like Benbasat and Barki (2007) criticized the TAM for not adapting and adapting to changing IT conditions, which led to theoretical chaos.

4.2.1.5 TAM Applications in BIM

BIM for the coordinated, consistent and computable management of information and knowledge from the design up to the maintenance and operations phases of a building life cycle are becoming ever more relevant in the construction sector. While many researchers and practitioners agree on the potential usefulness and advantages of BIM in building, how BIM can be used and which are the benefits of implementing BIM is still unclear. The adoption and use of BIM therefore remains central to BIM research and practice. The achievement of the intended levels of IT use as IT is a reflection of user acceptance of the technology (Venkatesh 1999), a key measure for implementation success. There is an increasing number of scholarly research projects that examine what determines the acceptance and use of IT among users (Taylor and Todd 1995). The TAM served in particular as a foundation for research into the use of IT and behavior intentions.

Previous research has argued for the research of historical variables that could explain the core TAM variables and extend TAM so as to improve the understanding of the acceptance

and use of existing and new ITs. IT acceptance factors are probably different from the technology, the target users and the context (Moon and Kim 2001). In the traditional, but relatively simple environments, many of the earlier studies have been carried out, including personal computing, e-mail systems, word processing and software tablets. A sound theoretical basis for examining factors influencing BIM use for construction organizations are theory on technology assessment. The buildings for use in this research are based on the theories discussed. Based on their relevance within the BIM context as demonstrated by previous surveys and case studies on BIM use, these structures were selectively used.

In addition, when they studied building and construction, the TAM model was designed by Sons et al. (2014), Lee et al. (2012). Lee et al. (2012) examined the key factors that affect facility managers' acceptance of BIM. Seven external variables were identified; self-efficiency, compatibility, confidence, collaboration, quality of information, condition-friendly resources and condition-friendly technology (Lee et al. 2012). The validity and reliability of the study, however, was not investigated. In the investigation of BIM in Korean design organizations, Son et al. (2014) also adopted the TAM. They examined the factors that had an impact on architects' comportemental intent in BIM adoption. The proposal consisted of five external variables: top management, subjective, compatible and computer-self-efficient support, TAM extension. Results indicated that design firms needed improved support for top-level management, subjective standards and computer compliance to promote BIM adoption. There was no significant technical support variable because respondents used software related to BIM.

Using extended TAM version in prediction of BIM-related topics with a limited sample size within a country, only few parallel studies have been performed up to now (e.g., Lee et al., 2012; Son et al., 2014). To understand that this model applies to every case of adoption of technology, it was important to describe and analyze the TAM model. The development of the TAM model is an ongoing process that can adapt to specific conditions. With regard to which model a particular technology applies, this is related to the research focus. In that case, research will focus on adopting BIM and will establish a framework to help adopt open BIM standards and standards guidelines in FM. In this case, research focuses on the adoption of BIM. TAM models can therefore be seen as one of the core theoretical models of this research.

4.2.2 Innovation Diffusion Theory

In 1962, Rogers launched Innovation Diffusion Theory (Rogers, 1995). An innovation is "an idea, practice or object that a person or a unit accepts as new" (Rogers, 1995). Meanwhile, diffusion is defined as the "process whereby the members of a social system communicate innovation over time through certain channels" (Rogers, 1995). In order to understand why, what rate and how innovative ideas and technologies spread across a social system, IDT was fundamental. In essence, the new innovation process has been investigated for 30 years, and in its book *Dissemination of Innovations* (Rogers, 1995), Rogers describes one of the most popular adoption models. The model has been used as a framework for much research from a wide range of disciplines. The Rogers' theory has been defined by Dooley (1999) as a widely used theoretical framework for technological dissemination and adoption in various disciplines, including policy science, public health, communications, history, economics, technology and education. The dissemination of innovation theory by Rogers is best suited to research technological adoption (Medlin, 2001; Parisot, 1995).

In fact, a lot of research into diffusion involves technological innovation, and so the term 'technology' and 'novelty' were used usually by Rogers (2003). For Rogers, "the technology is a design tool to help reduce uncertainty in the relationships between causes and effects that contribute to achieving a intended result" (p. 13). It consists of two components: hardware and software. While hardware is 'the tool which embodies technology as a material or a physical object,' software is 'the tool's basis of info' (p. 259). The rate of adoption of software (as a technological innovation) is quite slow because of a low level of observability. For Rogers (2003), adoption is a "full application of innovation as the best possible course of action," and refusal is the "not innovation decision" (p. 177). Diffusion is defined by Rogers as "the process of communicating certain channels of innovation thoroughly among social system members over the years" (p. 5). The four key components of the diffusion of innovation, as this definition expresses, are innovation, communication channels, time and social system.

The members of the social systems are classified in five different types of adopters (See Figure 4.4), according to Rogers (2003). The following categories are: innovators, early adopters, early majority, late majority and, laggards, according to Figure 4.3. It is based on "adoption rates" that social system members adopt an innovation (Rogers, 2003). Rogers also explained that adopter categories are based on innovation as classifications of members of the social system. "Innovativeness" has therefore been defined as "a degree to which a

person or other adopting body has adopted new ideas relatively earlier than other members of a system" (Rogers, 2003).

Figure 4.4 has been removed from this version of the thesis due to copyright restrictions

(Source: Rogers, 2003)

Figure 4.4 Adopter Categorization on the Basis of Innovativeness

This categorization can be further elaborated on the basis of its features by studying an innovative distribution curve (Rogers, 2003). A summary of each category of adopts is provided in Table 4.2, adapted from Rogers (2003) and Sahin (2006).

Table 4.2 Summaries of Adopters Categorization Characteristics

Table 4.2 has been removed from this version of the thesis due to copyright restrictions

(Source: Rogers, 2003; Sahin, 2006)

It was noted that, in an attempt to reduce uncertainty about its advantages and disadvantages from this particular innovation, before an individual could adopt innovation, he or she should learn about this innovation (Rogers, 2003). This is important for decisions and becomes a variable that influences whether innovations are to be adopted or rejected.

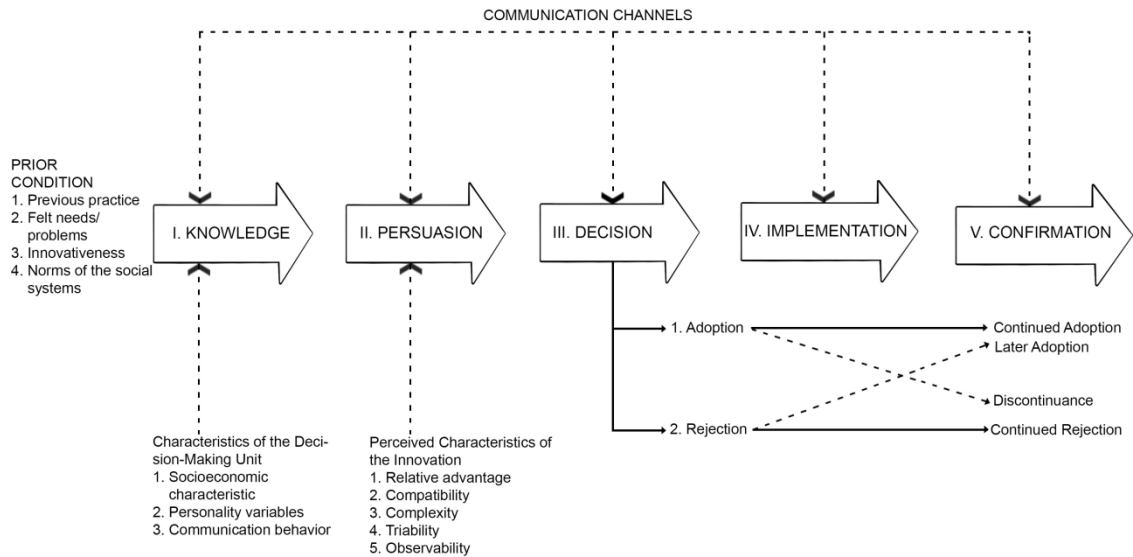


Figure 4.5 Model of Five Stages in the Innovation-Decision Process

Rogers (2003) introduced a new concept called the Innovation-Decision Process Model when studying the innovation process in IDT theory. Figure 4.5 shows an overview of this process. He claimed that the innovation decision-making process was a vital mechanism to motivate an individual to reduce uncertainty as regards the benefits and challenges of innovation in information search and information processing (Rogers, 2003; Rogers, 1983)

The five steps involved this process, according to Rogers (2003), were: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, (5) confirmation. The first step began with the acquisition of knowledge, where a person will learn and search for information about innovation. Each person begins by asking "what," "how," and "why" questions about innovation. There is persuasion when an individual forms an attitude that is positive and/or negative to this innovation. At this stage a person is more affective, and the stage of knowledge is cognitive. The opinions and beliefs of an individual regarding innovation are influenced by the degree of insecurity about social strengthening innovations (peers, colleagues, etc.). Sherry (1997) argues that a person tends to believe information about innovation from close-circle peers and family members outside of this circle.

Next a decision will be taken when a person chooses to take this innovation or reject it. While adoption refers to the "full use of innovation as the best way forward," it refers to "no innovation" (Rogers, 2003, p.). The model allows deliberate decision in the confirmation stage, knowing in Figure 4.5 that an individual may change his decision. In the next phase, innovation implementation will be implemented. The novelty of innovation however can

cause the person to have uncertainties about the outcome. It may be necessary for the individual to receive technical assistance from changing actors and others to minimize uncertainty about the consequences.

Finally, a person will seek support of his decision during the confirmation stage. This decision could move into subsequent acceptance or discontinuity, depending on the individual's support for adoption and attitude. Innovation can be discontinued, whether by replacement or disillusionment (Sahin, 2006). Innovation can be discontinued in two ways. The first concerns the individual who can stop using innovation and choose a better way, while the second concerns the individual's dissatisfaction with continuing innovation that cannot meet the user's requirements. The innovation process was also explained by Rogers (2003) as a 'process to reduce insecurity.'

Whatever the characteristics of people, innovation's properties affect its adoption rate in society itself (O'Connor 2007). Innovation as the cardinal agent on diffusion theory were focused by Rogers and Shoemaker (1971). The characteristics of an innovation can influence acceptance or rejection of an innovation through the attributes of the innovation model (Feder, Gershon and et al. 1982). Barnett (1979) suggested that a decision came after a series of thinking and thinking whether a person actually adopted or denied a particular innovation. Rogers (2003) described the process of innovation and dissemination as "a process of reducing incertitude" (p. 232), and proposed innovation characteristics that reduce innovation uncertainty. Rogers and Shoemaker (1971) noted that five innovation attributes are largely influenced in the adoption of innovation; 1) relative advantage; (2) compatibility; (3) complexity, (4) trialability and (5) observability. Figure 4.6 outlined the five innovation attributes. People are predicting the rate of adoption of innovations by these five characteristics (Rogers, 2003). Rogers thought that the variation of the adoption of new products ranged from 49 percent to 87 percent (Les Robinson, 2009).

- Relative advantage: a simple but powerful concept for the spread of innovation. It is common sense to use a person only if he sees this as a better option than in practice if he adopts a new ideas, new products and a service. If a user finds a new innovation better than that which is operational, he is obliged to embrace the new innovation. The faster the new innovation will spread in a social system. The better the new innovation. The degree of relative benefit often reflects an underdimensional pot (economic profitability, low initial costs, discomfort decreases, social prestige, time

and effort saving, immediate rewards) (Francesco, 2012). Other innovation diffusion elements like communication channels are essential for disseminating the information on the relative benefit of innovation compared with current practices and objects. The faster the rate and more reliable the communication system the faster the rate at which an innovation spreads.



Figure 4.6 Attribution of Innovation

- **Compatibility:** is how compatible innovation is with what people are doing (Kaasinen, 2005). Innovation is seen to be in accordance with consumer needs, values and beliefs, previous ideas and past experiences. It helps to make the new idea meaningful and to see it more familiar (Francesco, 2012). Better innovation is compatible, better adoption chances. For example, an enterprise that wants to introduce a new operating line will find a technology that does not affect existing operating lines. If the new line disrupts the existing operating lines, cost involvement can be increased and the company can cancel the deal. One must not, however, ignore this possibility that two compatibilities can occasionally be an issue, given that it might not be appropriate for users to try out new innovation or not to see it as an innovation.
- **Complexity:** this is how difficult it is to understand and utilize innovated material (Roger, 2003). This attribute has a reverse impact on the rate of innovation adoption as opposed to other attributes. The simpler the innovation the higher the adoption

rate for Rogers. This can not be good in all circumstances, since some high-tech products are perceived by their complexity more advantageous, but the simplicity rule often helps to spread innovation. For example, farmers in Sudan have been reporting that they are not accepting new irrigation practices established by the agricultural department, because the use of those practices has taken far too much direction and accuracy to be followed by the farmers (Barnett, 1953).

- **Observability:** it is easy to visualize the outcome of an innovation and to communicate it to future users. Again, the more clearly a communications system can share innovation results more quickly, the more important it has to be. E.g. companies launching new products often advertise customers that have taken up / bought their innovations with comments and reviews. This gives potential users a sense of assurance to adopt an innovation. The observability building has proved quite complex to Moor and Benbasat (1991), which divides the building into a demonstrable structure and a visibility building. Whilst demonstrability makes the work and characteristics of innovation easier to display, visibility defines the degree of public exposure. The demonstrability of results is that the innovation results, including observability and communication, are tangible (Moore & Benbasat, 1991). The level of visibility that other people can see is the use of innovation (Benham and Raymond, 1996). These two constructions measure ultimately the degree of innovation observability. O'Connor (2007) found that high visibility and internet service demonstrability has led additional users to access the Internet.
- **Trialability:** the degree to which a new innovation is examined or tested before it is actually adopted. The test drive offered by the auto companies is a simple example of trialability, where future customers can experience the product in real life prior to their purchase. It gives future users a sense of certainty to embrace a new innovation. Trialability determines whether the prospective users accept or dismiss a new innovation. It is argued that intercommunication is synonymous with observability and division close to trialability. Price and profit are not always a key factors for innovation while social approval depends in a sense on it. Tornatzky and Klein (1982) identified five other attributes of innovation, including cost, communication & divisibility, rentability, and social approval. Trust as to how confident the innovation provider sees the innovation provider.

4.2.2.1 Criticism of Innovation Diffusion Theory

No high-end technological product was the origin of the notion of innovation diffusion. Instead, its origin may be traced from agricultural fields. All this began in 1928, when researchers began the Iowa State Agricultural Experiment Station studying the adoption patterns of farmers using hybrid maize. Between 1933 and 1939 there were hundreds to thousands of acres planted to hybrid maize. Most Iowa maize growers had adopted it by 1940. (Rogers, 1995). It was then that the categorization of the adopters, in this case farmers, was introduced to Ryan and Gross (1943). The work of his previous colleagues was carried by Rogers (1958) and his renowned work *The Diffusion of Innovations* was published in the year 1962.

The main criticism faced by the theory was that this approach was more agrarian and would not benefit innovations of other sectors. Criticism also began to flow into the agrarian scholars. Goss (1979) noticed the development of various problems through the use of this theory by scholars and experts in developing countries. In addition to changing adoption patterns and changing adoption rates, farmers sometimes developed negative behaviors with regard to good innovations. In addition, the business community has spoken out against the theory that categories of adopted people are static. If innovations match with adoptive organisations, everybody can be an innovator (Downs and Mohr, 1976). Ruttan (1996) pointed out that the theory of projects requires that a small number of people, traditionally regarded as innovators, be focused on monetary and personnel resources. It suggests that appropriate innovations be targeted at specific segments of farmers using marketing techniques. In response to new developments in the maritime industry, the word sailing ship Effect was stated by Gilfillan (1935) for the production of ships that use older technology.

He pointed out that, even after the emergence of steam ships (new technology) in the nineteenth century and diesel in the twentieth century, certain segments of the maritime industry did not replace sailing ships (old technology). Lyytinen and Damsgaard (2001) found that innovation does not require a different phase of acceptance for a person. In dyadic relationships, adoptions sometimes took place and the steps of adoption were difficult to detect. Moreover, some Laggards were found to be more theoretical than the innovators. Innovations and theories have always been improved by criticism and Rogers has always admitted criticism. He took special account of the criticism against the theory in his book in 1962, 1983, 1995 and 2003.

4.2.2.2 IDT Application in BIM

Little research has been carried out on IDT in explanation of technology acceptance with respect to construction industry. The factors influences BIM diffusion using IDT theory were investigated by Panuwatwanich and Peansupap (2013). In terms of determinants of innovation, the impact of five attributes identified by Rogers (2003) were examined. 45 selected positions on the LinkedIN social network platform revealed a significant impact on adoption on relative advantage, compatibility, observability, and complexity (Panuwatwanich and Peansupap, 2013). There was no major impact on the BIM adoption process (Panuwatwanich and Peansupap, 2013). Four of the factors in IDT influenced user adoption. The behavior of adoption for BIM users has not been influenced by BIM testing for full building management, but by BIM's modeling aspect alone.

Recent BIM adoption studies have confirmed that BIM adoption is closely aligned to the process of innovation adoption in the construction environment (Hosseini et al. 2015). In a few recent studies (Brewer and Gajendran, 2012; Cao et al., 2014; Poirier et al., 2015), BIM has been conceptualized as a technological innovation. Furthermore, the most effective approach for exploring BIM adoption in construction companies is to address BIM's adoption using innovation lenses (Murphy, 2014). The IDT is therefore well placed to address research issues relating to the BIM adoption processes in building organisations (Cao et al., 2014; Davies and Harty, 2013; Gledson and Wardleworth, 2016). As such, the IDT chosen as the theoretical starting point is responsible for conducting the present study. Slaughter (1998) described an innovation as the real application of a non-trivial alteration for improving a system or work process new to the respective organization in the construction context. There are two subsequent steps in the process that lead to the use of innovation in a construction company. The diffusion and implementation are the interface between the two (Winch, 1998).

The dissemination process of innovation is defined as a process in which the members of a social system "communicate innovation through certain channels over time" (Rogers, 2010, p. 5). This process is driven and impeded by a large number of inter-and intra-organizational factors. In the formulation of the theoretical model of the study, IDT explains the factors, their origins, contexts, and potential effects envisaged at each stage of dissemination (Slaughter, 1998). Wejnert (2002) shows that the adoption of innovation has a number of factors. Two consequences of innovation adoption are discussed: public effects (for example, adopting a new educational model at national level) and private implications (where the

adoption influences only the person directly). It can be seen that adopting BIM has both public and private consequences as technology can boost the productivity of individual organizations and, due to increased productivity and efficiency for private and public projects, also play a positive role to industry and the country. The environmental factors affecting adoption are discussed by Wejnert (2002). Geographical location, social culture, political conditions, globalisation, and uniformity include these.

There is a national and industry drive towards the implementation of BIM in other states, while political conditions in South Africa are hindering the adoption of BIM, because of the need for a single phase bids, with separate bids from different organizations involved in the project. Other countries implement rules to ensure that BIM is used and programs are implemented to increase awareness, but in South Africa there is no such effort. The rate of BIM adoption in South Africa could be affected. Although the BIM concept has been around for more than 20 years (Merschbrok and Munkvold 2012), due to increasing software, hardware and connectivity progress, it is a latest phenomenon to be utilized as a collaborative tool. Cloud-based BIM environments (Autodesk, 2013) have recently been able to improve the collaborative platform significantly, since it is possible to access the model from anywhere. The technology platform for effective Integrated Project Delivery (IPD) can be seen as a recent phenomenon. Finally, IDT theory provides a pivotal theory for the diffusion of research technology, which can be used for predicting users' decision to adopt an innovation or reject it on the basis of their beliefs in it.

4.3 Relationship Between the Two Theories with this Study

Although the TAM and IDT have come from different disciplines, there are clear similarities. The degree to which a user perceives that the new technology is better than existing technology, and the perceived ease of use, is the contrary to complexity of IDT, are perceived as being useful with TAM and the relative benefit of IDT. This suggests that TAM and IDT partly reconfirm the results of each other. Often TAM and IDT are complementary. IDT involves forming an attitude of support or disadvantage towards an innovation; however, it does not show how this approach evolves into an acceptance / rejection decision, and the readiness for IT to be employed to study the adoption of new innovations is unknown.

TAM provides an explanation of computer acquisition determinants, on the other hand, and actual system usage is determined by user behavioural purpose, which in turn is influenced by the perceived user-friendliness and perceived utility, PU and PEU, to influence a possible

acceptance / rejection decision to make the system use. Research on IT adoption focuses on the determinants of the intentions of users to use new technologies. In a model for analyzing BIM adoption behaviour among FM professionals, two classical theories—TAM and IDT—were integrated. The perceived innovation characteristics are classified as subjective assessment, objective conditions and interaction factors in this IDT–TAM framework.

Research on IT adoption focused on the determinants of user intentions to use new technologies. In a model to analyze BIM adoption behaviour among FM professionals, two classical theories, TAM and IDT, were integrated. Although TAM and IDT have originated in different areas, there are clear similarities between them. TAM PU and IDT have both the degree to which a user understands that the new technology is better than existing technology and the PEOU is similar to IDT complexity (Tran and Cheng, 2017). This suggests that TAM and IDT partially reconfirm and complement each other's findings. IDT, however, does not offer further evidence on how the attitude develops to accept / reject decisions, nor on how readily IT could be used in investigating the adoption of new innovations. Instead, the IDT consists of the formation of favourable or disadvantaged attitude towards innovation. TAM, however, offers an explanation of computer acceptance determinants, and actual system users' behavioural purposes, influenced by PEOU and PU, and influence the eventual acceptance or refusal decision to use their systems, are determined by their users.

In some buildings, the theoretical concept of TAM and IDT is strongly related. Wu and Wang (2005) suggested a stronger model of perceived innovation characteristics could be provided by the integration of TAM and IDT. In order to investigate the user's technology acceptance behaviour in information systems, several studies have successfully integrated IDT into TAM (Lee et al, 2011, Wu and Wang, 2005, Chang and Tung, 2008). The integrated model can be adapted by reviewing these studies to contribute to the new knowledge of the BIM-FM studies and to the formulation of the conceptual model of this research. Lee et others (2011) work together with TAM and IDT theory to examine factors affecting the behavioral intentions of business people in order to use an e-learning system. The five characteristics of IDT constructions were strongly supported by the findings and were directly significant to the belief of PU (Lee et al., 2012). In contrast, although the compatibility and observability structure is insignificant, PEOU beliefs have almost the same results (Lee et al. 2012). TAM and IDT integration was a strong model in predicting the intention of users to use an information system.

In the TAM theory, Wu and Wang's study (2005) integrated compatibility IDT buildings with new perceived risk and cost variables for determination of mobile users ' acceptance of mobile trade (MC). They show that the behavior of users was significantly affected by all variables with exception of PEOU (Wu and Wang, 2005). PEOU was usually a weak determinant of behavioral intention, because user experience gradually decrease in time before and after a particular system (Wu and Wang, 2005). The risk and cost variable perceived was intended to be directly significant by the user. This showed that TAM and IDT integration was not restricted to current key buildings but enabled the researchers to incorporate new variables that directly influence the intention of user behavior.

Chang & Tung (2008) have combined TAM as well as IDT constructs, adding new confidence variables and perceived financial costs to examine how nurses accept e-logistics. The findings strongly supported the integration of TAM and IDT key buildings, which affected the behavior of users (Chang and Tung, 2008). The new variable–perceived financial expenses, because the studies were confined and depended on the demography of the nurses and the type of hospital where they worked, have a negative impact on user behavioral intention. Despite this, results indicated that important factors for prediction of technology acceptance are the key constructs for TAM (PU and PEOU) and IDT (Compatibility).

Because research is limited, the ability to combine TAM with IDT in other fields suggests that this is possible. TAM and IDT have been integrated within building management studies by two theoretical framework structures. The objective of this research is to reduce issues of FM information exchange, as identified in Chapters Two and Three, by integrating key variables of TAM (PU and PEOU), IDT (compatibility, observability and testability) in a new design model, in order to develop a holistic understanding of technology acceptance, particularly in the context of individual professionals.

4.4 Modified Model of TAM with Proposed BIM-FM

In this section, the discussion centred on the modified model of TAM with proposed BIM-FM. One of the key purposes of external variables in original TAM was to trace the impact on internal belief, i.e. PU (perceived usefulness) and PEOU (perceived ease of use) and to link that to actual use (Davis et al., 1989). This will allow for a better understanding of PU and PEOU for practitioners when deciding what sort of external variables could affect their belief and the use of technology (Yousafzai et al., 2007). In this case, studying the external

variables of BIM in FM will contribute to theory development and improve technology acceptance. The proposed factors in the knowledge category were: Classification of BIM data, Employer Information Requirement, As-Built Model, Cost, Interoperability, and Upskilling. These external variables were derived from the key factors that influenced open BIM standards in the extensive literature review and informal discussion with experts. The informal discussion were conducted via email regarding the key factors that influence the adoption of open BIM standards and standard guidelines in order to identify the external variables. **Figure 4.7** illustrated the diagrammatic view of the modified model of TAM with proposed BIM-FM and within the context of this research and discussed in detail all the variables of the model below:

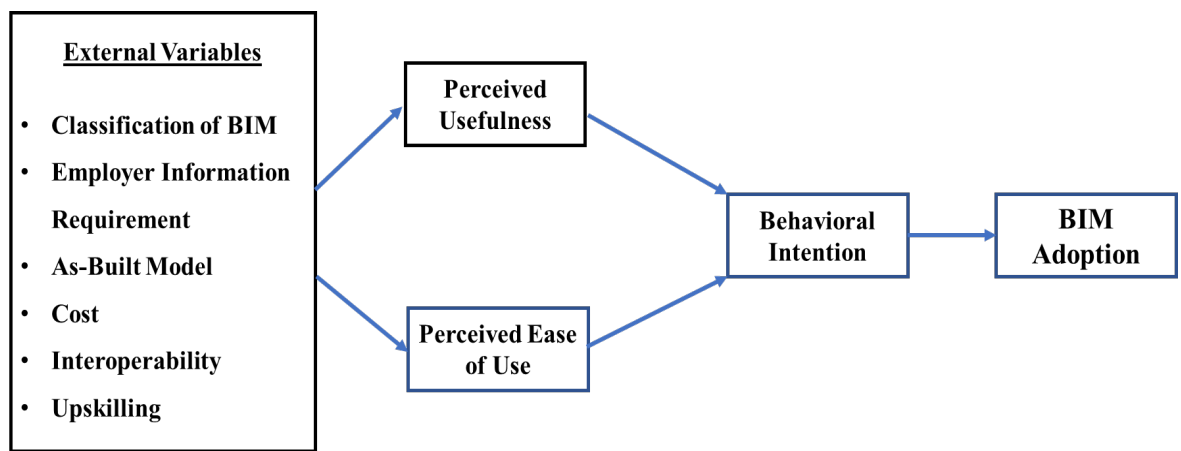


Figure 4.7 Modified Model of TAM with Proposed BIM-FM

4.4.1 Classification of BIM

Data is an important factor that standardizes information captured in COBie data and IFC. As mentioned in Chapter 3, classification supports modelling objects as an identification and creation of components (Jørgensen, 2011). This enables retrieving of data from the native file format and back-checking to the BIM model for future references. Omniclass and Uniclass were the main classification systems used to support asset information in BIM model for the use in operational and maintenance phases. Nevertheless, the challenge of classification systems for certain building elements has a unique function and category that is difficult to define within a BIM model (Jørgensen, 2011). In addition to that, inconsistency and redundancy of naming BIM data has been a problematic area for facility managers. This problem informs the study that classification of BIM data has significant influence to the PU belief.

4.4.2 Employer Information Requirement

A document that sets out to inquire what information is to be delivered at the early stage of the project delivery process (BSI, 2014a). The COBie spreadsheet is useful if the deliverables of information are provided for responsibly. In this case, it was acknowledged that the properties of elements and products created in the BIM Model data was provided by the sub-contractor(s)/supplier(s) information. However, their lack of readiness in providing BIM data has been problematic. Furthermore, the low involvement of facilities manager at the early stage of a project to facilitate the EIR documents' information exchange exacerbates the problem. Consequently, this determines the client's decision whether they would extend the use of BIM in FM stage. Therefore, this study anticipated that EIR has a strong influence to the PU belief in behaviour intention to adopt open BIM standards and standard guidelines in FM.

4.4.3 As-Built Model

A single validated and approved model that contains information related to assets, spaces, replacement, equipment, and operation and maintenance information for FM. The model could potentially use in many areas that are not limited to locate building components, visualization, inspecting maintenance, space management, and future renovation and refurbishment in FM (Becerik-Gerber et al., 2012). However, the challenge of acquiring as-built model requires frequent update in geometry and non-geometry information if the building layout changes or replacement of equipment is taking place. Consequently, the role and responsibility of updating data in the as-built model remains unclear and may require alteration in the design of the existing building that is not within the FM competencies (Kassem et al., 2015; Williams et al., 2013). Therefore, this research anticipated that as-built model has a direct influence to the PU belief in behaviour in adopting open BIM standards and standards guidelines in FM.

4.4.4 Cost

A significant factor in facilitating the adoption of COBie and IFC. Cost-related activities in implementing of BIM-based FM system, hiring highly-skilled personnel and return of investment need to take into consideration before operating in BIM environment (Becerik-Gerber et al., 2012; Starkov, 2012). Williams et al. (2014) argued the lack of proof in reducing the operation and maintenance cost has yet to convince client/ owner decision to adopt BIM. This would suggest that client need to invest a substantial amount of cost to

facilitate the use of COBie and IFC. For this reason, cost is predicted to have a significant influence to the PU belief.

4.4.5 Interoperability

The ability to manage and exchange information between software systems (e.g. BIM systems and FM systems). Seamless information exchange is imperative to enable the software systems to communicate easily between design and construction team and FM team during handover period. Instability of exchanging information such as COBie and IFC could potentially hinder facilities managers to adopt it in practice (Becerick-Gerber, 2012; Gnanarednam and Jayasena, 2013; Lavy and Jawadekar, 2012). In addition, compatibility issues with FM systems has led to focus on their own proprietary solution in capturing information instead of exchanging using COBie or IFC (Shen et al., 2010). Therefore, interoperability is predicted to have significant impact on the PU belief.

4.4.6 Up skilling

The process of learning new skills to solve technical problems arising from the innovation. The integration between BIM authoring tools and FM systems suggested that facilities managers have to work in a 3D environment to facilitate building operation using BIM in real-time. Facilities managers may be used to operating CAFM systems of buildings in non-graphical information, however working in a 3D environment may require additional skills. Such skills are useful in future works for repurposing, refurbishment or renovation of space in the building. However, as mentioned in section 3.4.10, the capability of updating the BIM model in CAFM system is still questionable and foreign to most facilities managers. Therefore, giving the importance of Up skilling is predicted to have significant impact to PEOU beliefs of behaviour intention to adopt open BIM standards and standards guidelines.

4.4.7 Perceived Usefulness

An important factor in technology acceptance has been considered the user perception of utility. Davis (1989) defined the user's understanding of utility in the extent to which someone believes it would improve his job efficiency by using a particular system. This is based on the definition of useful: capable of benefit. Previous research has found that the acceptance intentions were strongly correlated. BIM can be accepted when a person is ready to use information and tools in BIM for his / her own tasks and if the affiliated organization is prepared to establish a co-operation system using BIM. The measuring elements for

perceived usefulness can therefore be largely divided into the personal and organizational recognition that BIM use improves workability and productivity.

4.4.8 Perceived Ease of Use

Previous research suggests ease of use as one of the key drivers for IT success. Perceived ease of use refers to the extent to which a person believes it would be easy to use a particular system. This is a consequence of the definition of facility: freedom from difficulty or great effort. Davis (1989) claiming that a technology is found to be more user-friendly than another. These results suggest that the relation between user-friendliness and acceptance intention is positive. The belief that BIM is simple to use is therefore presumed to be directly linked to the perceived utility, consensus regarding appropriation, and the intention of accepting BIM. Three questions assessed the degree of perceived ease of use: ease of learning to work with BIM, easy information exchange among systems and easy implementation of collaborative guidelines.

4.4.9 Behavioural Intention

The intention to conduct is a measure of the strength of one's intention to perform a certain conduct (Fishbein and Ajzen 1975). Many researchers expect behavioral intent to influence technology acceptance significantly. In most IT implementation research (Saga and Zmud 1994), user acceptance was incorporated as a dependent variable. Davis et al. (1989) suggested that the acceptance of users is a condition of the use of the system. Whatever the view taken, it is clear that the successful implementation of user acceptability is essential. Acceptance of BIM is considered a dependent variable in this research. In order for individuals to fully accept BIM Technology, they should use BIM tools for their tasks and a group should use BIM for compatibility and information sharing throughout the project life cycle. The measures for individuals to accept BIM are therefore ready to use BIM tools and information to accomplish their tasks, ready to spend time using BIM and willing to recommend BIM to co-workers or other entities that cooperate. BIM measurement items are willing to foster the use of BIM by group constituents, willing to recommend that other organizations use BIM in cooperation relations, and willing to develop the technology for BIM applications.

4.5 Modified model of IDT with Proposed BIM-FM

In this section, the discussion centred on the modified model of IDT with proposed BIM-FM. In the original IDT model, the impact of the five attributes stated by Rogers (2003) was

investigated as the determinants of innovation. In the modified model, three IDT innovative characteristics, namely, compatibility observability trialability integrated with the awareness of BIM to test the association with the BIM adoption, **Figure 4.8** illustrated the diagrammatic view of the modified model of IDT with proposed BIM-FM and within the context of this research and described all the variables of the model below:



Figure 4.8 Modified Model of IDT with Proposed BIM-FM

4.5.1 Awareness of BIM

This variable currently shows the existence of BIM's knowledge and understanding, based on the information and experience of respondents. According to the BIM4FM report, 65% of facility managers are aware of BIM, but not all are currently used or are planned for future use (BIM4FM, 2013). This could be attributed to misunderstandings of what BIM in turn causes confusion and problems in visualizing its use (Barlish and Sullivan, 2012). This study forecasts the need for increased awareness of BIM and its adoption to increase the BIM's literacy.

4.5.2 Compatibility with CAFM

To what extent innovation is seen as consistent with potential adopters ' values, past experience and demands (Rogers 2003). In this study, systems should comply with the normal handling and updating information of facilities by facility managers. If exportation of BIM files is usually easy, it is likely that BIM will take place. Panuwatwanich and Peansupap (2013) demonstrated a significant effect on technology adoption of the compatibility variable. This suggests that compatibility is seen as having a significant impact on the behavior of facility managers who want open BIM standards.

4.5.3 Observability

The degree to which the results of an innovation are visible to others (Rogers, 2003). A successful adoption of COBie and IFC requires a systematic method of exchanging

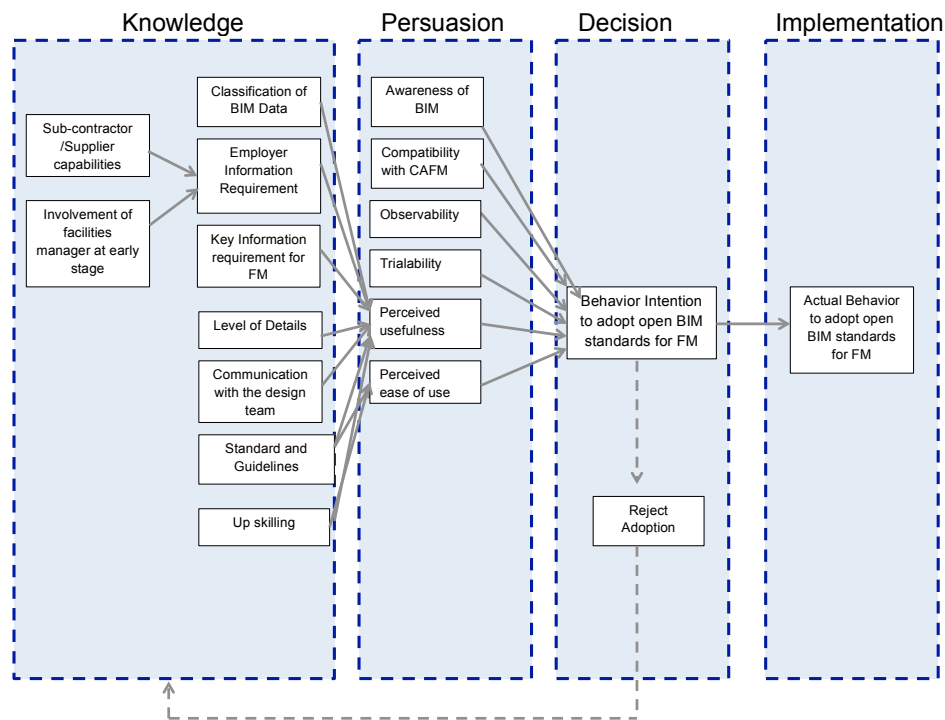
structured information from the design and construction stages to the operational stage. Limited research has demonstrated the adoption COBie and IFC for facility management, which led to uncertainties and resistance from facility managers to use COBie and IFC in the first place. In this research, observability of methods and techniques of others in using COBie and IFC play a significant role in influencing the behaviour intention to adopt open BIM standards.

4.5.4 Trialability

To what extent innovation can be tested on a small scale (Rogers, 2003). COBie and IFC experiment and explore the structure and processes of COBie worksheets and IFC data sharing formats are helpful. In small-scale projects, relevant skill sets can be learned and used to measure the capacities and challenges during testing. Intention to use BIM can be beneficially affected. Testing is therefore considered to be an important factor in the intention to adopt open BIM standards.

In short, in certain constructions both modified models have a similar character and further study the integration and application of the two models in order to facilitate a stronger model for predicting technology adoption (i.e. open BIM standards). The two models were then integrated and modified in accordance with the conceptual BIM-FM Technology Acceptance Innovation Model (refer to Chapter 8 of the proposed Model). A discussion of research methodology is essential if research is to facilitate this research to achieve goals and goals in order to assess the robustness of this proposed conceptual model. Moreover, the proposed model provides justification for the variables based on TAM and IDT theoretical background, and includes additional variables based on BIM literature.

4.6 Conceptual BIM-FM Technology Acceptance Innovation Model



This research integrates TAM and IDT theoretical models to propose a BIM-FM Technology Acceptance Innovation Model. Theories used herein were based on the original TAM model (perceived usefulness, perceived ease of use and behavior intention) (Davis, 1989) and Rogers' (2003) five innovative characteristics (relative advantage, compatibility, complexity, trialability, observability). This research proposes that the five innovative characteristics has a direct relationship towards the behaviour intention of adopting open BIM standards in FM. This is supported by existing research that there were strong relationships among the five innovative characteristics and the behavioural intention (Chang & Tung, 2008; Wu & Wang, 2005; Hardgrave et al., 2003).

4.7 Chapter Summary

This chapter extensively discussed on the theory of Technology Acceptance Model (TAM) and Innovation Diffusion Theory (IDT) in predicting behaviour intention to adopt technology. Since the two theories has similar characteristic in certain constructs, this chapter further examined the integration and application of both theories to facilitate a stronger model in predicting the adoption of technology (i.e. open BIM standards). This section further, proposed two modified models (TAM and IDT) in order to test the robustness of this proposed conceptual model. In order to test the robustness of this conceptual model,

the next chapter discussed the research methodology in essential to facilitate this research to achieve the aim and objectives.

CHAPTER 5 RESEARCH METHODOLOGY

5.1 Introduction

The essence of this research was to establish a framework to better facilitate the adoption of BIM in FM. The previous three chapters established the overall theoretical background and context of this research. This chapter provides a comprehensive description of the methodology employed throughout the research to investigate BIM and FM. This chapter begins with presenting the philosophical position that underlie in this research. Then, it continues with the background of research methodology followed by the selected research methods; an overview of key sections is presented in **Figure 5.1** below.

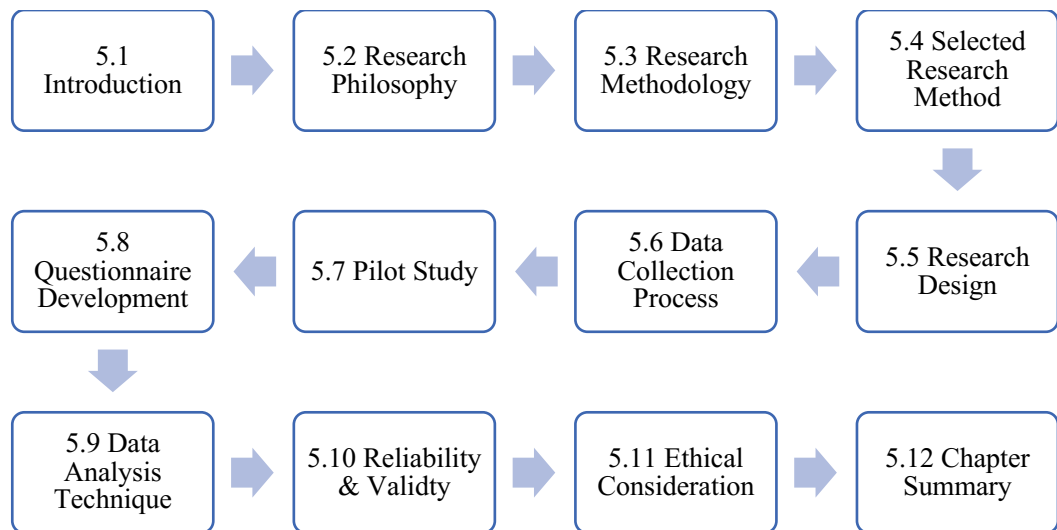


Figure 5.1 Chapter 5 Organization

5.2 Research Philosophy

“The starting point in research into Built Environment is to add something of value to the body of knowledge. This means unanswered question will be identified and studied to produce a suitable answer to the question or solution to the problem. Therefore, a discussion of philosophy is essential before embarking on a research project.”

(Amaratunga et al., 2002)”

In understanding the worldview, philosophers have distinguished two different philosophical assumptions that underlie how the world can be experienced, what constitute knowledge,

and what can be done with that knowledge (Bryman, 2015, O’Gorman and Macintosh, 2015). These distinctions can be categorised as epistemology or ontology (Bryman, 2015, O’Gorman and Macintosh, 2015). Both of these philosophical assumptions are important because they underwrite the outset of a particular research. Epistemology is the way how we gain reliable knowledge, while ontology is about studying the reality and being, or how we view reality (O’Gorman and Macintosh, 2015).

In the area of Construction Management (CM), the epistemology aspect of research is typically divided into three position - positivist, interpretivist, and pragmatic position, however, a combined approach is predominantly adopted (Abowitz et al., 2009). Selecting a universally appropriate research methodology in CM is highly arguable (Mukherjee et al., 2002). This is because according to Love et al. (2002) the nature of CM research might be cross-disciplinary between natural science and social science and one general methodology may not suffice nor satisfy the needs of research.

The positivist approach to research is purely scientific in characteristic. The pursuit of knowledge is often associated with what can be tested by observation of concrete evidence. This process involves testing an existing theory to generate several hypotheses (Bryman, 2015; Matthew and Ross, 2010). The researcher is considered to be objective towards explaining social phenomena by observing the cause and effect (Bryman, 2015; Matthew and Ross, 2010). However, positivisms’ approach has a long-standing debate in explaining social phenomena that are not simply observable by senses, but can be interpreted by human beings (Bryman, 2015; Matthew and Ross, 2010). One way to mitigate this shortcoming was the development of an interpretivism position which emphasize on human interpretation and understanding of social phenomenon from their own experience (Bryman, 2015; Matthew and Ross, 2010). Interpretivist encapsulates human’s perception as a subjective meaning from their point of view of the world. This involves exploring and accumulating humans’ experiences and understanding of social reality which can generate theory (Matthew and Ross, 2010).

The positivism and interpretivism distinctions influenced how qualitative and quantitative research is conducted (Amaratunga et al., 2002). A positivist view is usually associated with quantitative research where it can be achieved from scientific methods in finding results in society and human behaviour (Amaratunga et al., 2002). Interpretivism, however, adopted in qualitative research seek to explore the meaning of social science, which cannot be studied

objectively (Amaratunga et al., 2002). Both positions have conventionally relied on single methods when conducting studies, however, recently mix-method research has gain much attention in breaking this tradition (Johnson and Onwuegbuzie, 2004;).

The underpinning philosophy in mixed method research originated from pragmatism (Creswell, 2007). It is concerned with the application ‘what works’ and ‘solutions to problems’ (Patton, 1990). The view of reality is what works at a time with an emphasis on “what” and “how” to research based on the intended consequences (Creswell, 2007). Pragmatism allows the researcher to be flexible in mixing with other research paradigms, which helps to balance the philosophies of quantitative and qualitative approaches (Johnson et al., 2007). A mixed-methods approach therefore does not adopt a single frame of philosophical assumption but rather takes a holistic approach at solving problems in the reality at that moment (Johnson et al., 2007). Based on the above discussion, this study thus adopts a pragmatism approach in combining qualitative and quantitative approaches research to explain the complex phenomenon of relationships between people and technology.

5.3 Research Methodology

Research is defined as “a procedure by which we attempt to find systematically, and with the support of demonstrable fact, the answer to a question or the resolution of a problem” (Leedy, 1989). It is a meticulous search into examining information that can be used to generate or enhance knowledge (Pole and Lampard, 2002). It is an iterative process that involves critical evaluation of activities undertaken such as selecting relevant information, reviewing theories, selecting methods to solve a problem or provide better solution to a problem (Pole and Lampard, 2002). While the research methodology is a plan that guide the selection of methods (Henn et al., 2009). The research is decided carefully to select appropriate methods that is bound by the influence of theoretical and philosophical implications when conducting research (Seale, 1998, Henn et al., 2009). Henn et al. (2009) argued that the researcher should consider the ethical implications and the outcome of the research, accessibility to the field and the role of values both the author and those who have control over the research agenda. In other words, selecting appropriate methods and the reason of selecting those methods will influence the research outcomes of a study.

However, before the researcher could take consideration of selecting an appropriate methodology, it is of the utmost importance to distinguish between qualitative, quantitative

and mixed method research. Bryman (2012) asserts that the distinction will be useful for a range of issues concerned with the practice of social research.

Qualitative research involves thorough interrogation into a specific subject or events (Amaratunga et al., 2002), which study human activities in everyday life (Miles and Huberman, 1994; Creswell, 2007). The data produced in qualitative research that includes, speech, observations, text or pictures was used to deliver the quality of human experience (Pole and Lampard, 2002). The characteristic of qualitative research predominantly emphasizes words and text in a collection of data to enable a researcher to generate theories (Bryman, 2015). This approach practices combining ideas and facts to form a theory/theories, which also known as inductive reasoning. (Bryman, 2015). Qualitative research adopts a social constructivist/ interpretivism approach to understand the worldview (Hen et al., 2009; Creswell, 2007; Mertens, 1998). This approach assumes that every individual is seen as a subjective meaning in perceiving the world they live in such as objects or things (Mertens, 1998). In other words, the aim of qualitative research depends on the participants' view of a particular events being studied.

The strength of qualitative research is focusing on the real event happening everyday situation in our lives which makes it up-to-date and contemporary. (Amaratunga et al., 2002). A researcher is thus able to obtain data that is rich and holistic to understand and explain a complex phenomenon (Amaratunga et al., 2002). The result of qualitative research provides richness of data in real life situation and gives meaning of a subject that was studied. This can be people's experience on events, process and structures of their lives that is useful in interpreting and analysing the data collected (Amaratunga et al., 2002).

The weakness associated with qualitative research is that handling a large set of data could affect the analysis of data (Choy, 2014). The process of conducting qualitative research is time-consuming especially during the transcription of words and texts (Choy, 2014). At times, the key information could be easily side-track the initial research questions and objectives (Choy, 2014). The other drawback in qualitative research is that it inclines towards being speculative and biased in the meaning of the analysed data, which favoured for personal intention (Morgan and Smircich, 1980). This is because the richness of knowledge can analysed in many different ways to extract the meanings and the researcher understanding may short-sightedly convince the reader and generalized in the research findings. (Mason, 2002).

Meanwhile, *Quantitative research* usually begins from a general interest to a specific issue that emerging questions can be addressed in the research (Neuman, 2006). It requires an extensive review of literature to develop several hypotheses (Neuman, 2006). This process involves evaluating facts and information to existing theory and test it out before decided to support and refute the theory—which also known as deductive reasoning. (Creswell, 2007; Bryman, 2012). The theory is usually measured in numerical data that are attributed to a particular statement or information (Pole and Lampard, 2002) that makes it appropriate in predicting peoples' behaviour and attitude in a study (Creswell, 2007). Quantitative research generates quantity of data collection and statistical analysis. It typically adopts a positivist or sometimes called a “scientific approach” (Hen et al., 2009); that conducts research based on a calculative measurement of the objective reality that exist in the world (Creswell, 2007). This means that knowledge is never absolute, where research is constantly in the process improving and testing hypotheses to explain a particular issue and events (Creswell, 2007).

Several advantages of quantitative research was identified. Firstly, the researcher is able to make comparisons and replicate methods easily for application in their specific studies (Amaratunga et al., 2002). Secondly, the subject of the research investigates objectively through measurement rather than subjectively through personal opinion and suggestion. (Amaratunga et al., 2002). Quantitative research facilitates more timely analysis and tabulation of data (Choy, 2014). The numerical data enables to compare and test relationship between several hypotheses and facilitates findings from the respondents using the scales of agreement and disagreement (Yauch and Steudel, 2003; Easterby-Smith, 2008).

In contrast, the weaknesses of quantitative research was identified as: (1) limited to justify underlying meaning and explanation of a given subject and (2) tend to easily generalized and come to conclusion of the situation in a single quantitative study (Amaratunga et al., 2002; Johnson and Onwuegbuzie, 2004). Despite the mainstream of both qualitative and quantitative research, '**mix methods**' has become a noticeable research methodology (Saunders, et al., 2012). Mix methods research introduce both qualitative and quantitative methods at the same time. The data is individually collected and analysed according to their respective methods (Saunders, et al., 2012). This means qualitative data is analysed using coding technique and themes, while quantitative data analysed statistically in form of tables, charts and graph. Both methods also can be conducted in sequential or parallel manner (Saunders et al., 2012; Creswell and Clark, 2007).

The mixed methods stems from pragmatism approach, which allows researcher to use different assumptions in solving problem at the time (Creswell,2007; Patton,1990). It embraces the collation assumptions, worldviews, and form of data collection and analysis in the research findings (Creswell, 2007). Thus, the researcher can synthesise and interpret their data collection to support the research findings. (Amaratunga et al., 2002; Tashakkori and Teddlie, 2003).

A study can attain several benefits in adopting a mixed methods approach. Johnson and Onwuegbuzie (2004) claimed that the virtue of using mixed methods; (1) can support both strengths and weaknesses of qualitative and quantitative (2) generate better results and conclusion through integration of data findings and analysis. (3) contributes to theoretical and practical knowledge (4) can increase the generalisability of the results. In conclusion, a mixed methods approach provides robustness in data findings and analysis to support better conclusion in a research study.

Using a mix-methods approach can be confusing and complicated if the researcher does not entirely understand the need to adopt it. Lack of proper guidance makes mixed methods difficult to conduct. (Bryman, 2006; Leech et al., 2010). Östlund et al. (2011) argued that mix-methods causes instability and uncertainty of methods due to the lack of proper evidence and how it can be repeated in future research regarding the design, ways to conduct and interpretation of the result of the study Östlund et al. (2011) further adds that it is unclear how researcher weigh its argument in the results that mainly from qualitative or quantitative findings. Other factors that should also be considered when using mix methods is the duration of time available and budget constraint for conducting the research (Johnson and Onwuegbuzie, 2004). **Figure 5.2** illustrated the mixed method research flow in a diagrammatic view.

In this study, a mixed-methods approach was deemed to be appropriate given the complexity of the subject in bridging technology and people in a holistic picture. The aim of this study was to explore the adoption of BIM in facility management and to propose an integrative conceptual model by combining two different theories. Previous studies proposed key variables to explain the adoption of BIM in facility management, however, these did not specifically investigate the context of adopting open BIM standards (i.e. COBie and IFC) in facility management.

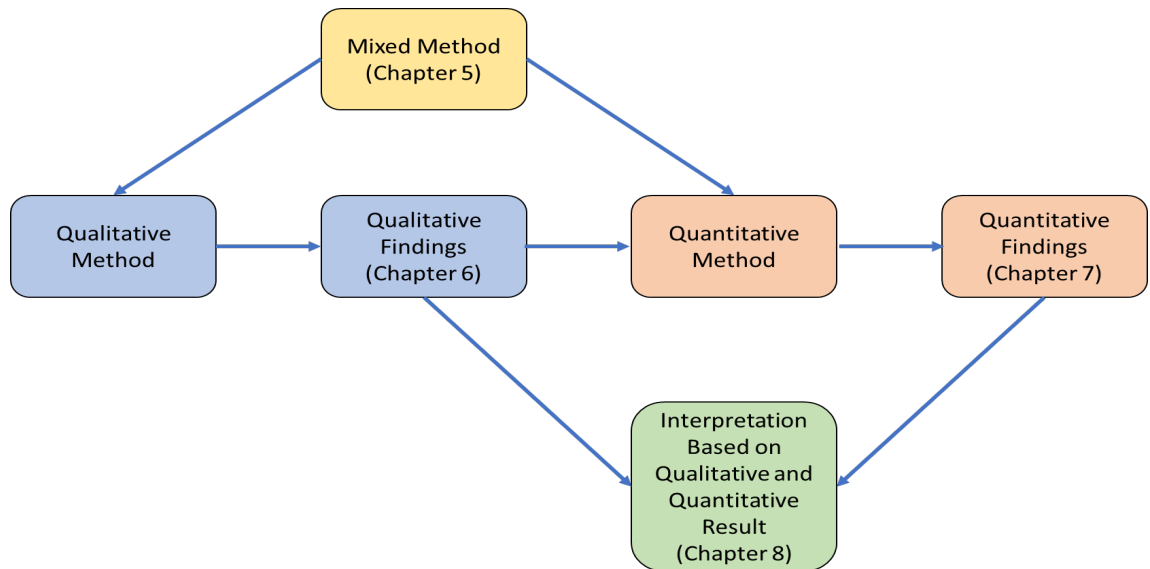


Figure 5.2 Mixed method research flow of this research

Therefore, this research intends to investigate the key factors in adopting open BIM standard in facility management by employing a qualitative in-depth interview to support the understanding of new key variables which were previously unreported in literature. Subsequently, findings inform the quantitative structured-survey distributed in several professional social media platforms to explore the extent of BIM guidelines that can support the adoption of open BIM standards in facility management. The data collected are used to test the relationship between all the extended key variables and existing constructs of integrated model to form a framework that facilitates the adoption. This framework will then be validated through telephone interview with the in-depth interviewee participants and revised accordingly.

5.4 Selected Research Methods

Research methods are “techniques and procedures used to obtain and analysed data” (Saunders et al., 2012). In construction management research, mix-methods are strongly recommended to better understand the complex nature of construction industry (Dainty, 2008). However, the research aim and objectives are the key factors that determine the selection of research methods (Lancaster, 2005). Thereof, this research adopts both qualitative and quantitative methods in addressing the research objectives.

The research objectives should guide researchers into selecting appropriate methods for data collection and analysis to answer the research aim and objectives (Lancaster, 2005). **Table**

5.1 was developed to illustrate the research aim and objectives to its relevant research method. This research used exploratory sequential mixed methods design to collect data. This included qualitative in-depth interviews, quantitative structured-survey and expert telephone interview. Sample of these documents are available in appendix A and C. The complementary of these methods will allow the researcher to gain a great amount of information from participants and vigorous results can be increased (Robson,1993; Kaplan and Duchon, 1988). Sequentially, a structured-survey was distributed through a hosting web-based survey packaged (i.e. SmartSurvey), which is a convenient and flexible method to approach key participants.

Table 5.1 Selected Research Methods

Research objectives	Research Methodology	Selected Research Design
RO1: To determine the key information requirement for BIM-driven FM.	Qualitative	Literature review
RO2: To identify the key factors that influence the adoption of BIM in FM.	Qualitative	In-depth interviews
RO3: To investigate the extent to which BIM guidelines can support the adoption of open BIM standards	Quantitative	Structured online survey
RO4: To establish a framework that can facilitate the open BIM standards and standard guidelines.	Qualitative	Expert telephone interview

Initially, the survey was developed from extensive literature review and informal discussion with experts. The university ethics committee approved the survey and the recruitment of participants was among the BIM, FM experts. The results of the survey is analysed using statistical software SPSS in form of tables and charts. Following an analysis of the survey responses, an in-depth interview was conducted with key with key experts (i.e. BIM experts and FM experts) either by face-to-face, video call or telephone interview to gain their knowledge and experience on the research topic (Milena et al., 2008). Analysis of the resulting data helped to inform the conceptual framework which will be validated through telephone interview with the in-depth interviewee participants and revised the framework accordingly.

Finally, findings will inform the research discussion and future work.

5.4.1 Qualitative Methods: In-depth Interview

Qualitative methods can be conducted through interviews, focus-group interviews, observation, and reviewing of relevant documents and records. (Maykut & Morehouse, 1994; Mertens. 2009). The process usually involves “organizing, disassembling and

reassembling data to prepare them for interpretation” (Yin, 2010). Relevant to this study, an in-depth interview is qualitative methods employed to develop an understanding about the key factors that influenced the adoption of BIM in facility management. In-depth interviewing is a technique conducted with a small number of participants to extensively discuss and explore a particular idea, program, or situation. (Boyce and Neale, 2006; Saunders et al., 2012). This is conducted with the researcher first asking participants a series of open-ended questions where responses are made using participants’ own words. This process involves audio recording or note-taking for subsequent transcription and analysis (Braun and Clarke, 2013).

In-depth interviewing can be divided into two types of interviews: unstructured interview and semi-structured interview (Bryman, 2012; Saunders et al., 2012). An unstructured interview is conducted when the interviewer has key topics, issues or an interview guide to be discussed with participants (Bryman, 2012; Saunders et al., 2012). Questioning is usually informal, with wording and sequencing of questions varying from interview to interview (Bryman, 2012; Saunders et al., 2012). In semi-structured interviews, a set of listed questions are prepared in the form of an interview schedule with a varied sequence of questions. The questions asked are more general within the research area than what is normally reflected from the questionnaire (Bryman, 2012; Saunders et al., 2012).

There are several advantages of conducting in-depth interviewing. First of all, the researcher is able to gain rich and detailed information from key experts (Braun and Clarke, 2013). Data can be analysed usefully as key themes or codes (Braun and Clarke, 2013). In addition, this data may provide unanticipated new perspectives or findings (Braun and Clarke, 2013). Secondly, this method allows the researcher to be flexible in conducting interviews (Braun and Clarke, 2013). The researcher can probe and ask for unplanned questions to the key experts whenever necessary to accommodate the research questions (Braun and Clarke, 2013) or when a new and/or interesting phenomenon is discovered. The other advantage is that the researcher could have some flexibility when accessing to vulnerable groups, such as patients or children (Braun and Clarke, 2013). As compare to quantitative methods, not all potential respondents are willing to complete questionnaire due to identity exposure, time factor or sensitivity of information.

Despite the advantages of in-depth interviews, several disadvantages should also be taken into consideration. Firstly, In-depth interviewing is time-consuming for both researcher and

participants (Braun and Clarke, 2013). Normally, most interviews will last longer than anticipated due to the interest of topics or unrelated disclosure of information (Braun and Clarke, 2013). The researcher may easily be side-tracked by the participants' life history or certain events (Braun and Clarke, 2013). In addition, transcribing, organizing and understanding collected data can be time consuming. The other disadvantage of in-depth interviews is the "lack of breadth due to smaller sample sizes" (Braun and Clarke, 2013). The smaller sample size could easily create bias and generalised findings based only on a few participants' knowledge and experience (Braun and Clarke, 2013). Furthermore, the lack of anonymity in interviews could jeopardize some participants' reputation and identity. The researcher should be clear and honest with participants about the purpose of research, and consent the information given by them are safe and secured for academic use only.

5.4.2 Quantitative Methods: Online Survey

Quantitative methods typically involve numeric forms of data collected from a large sample of participants (Creswell, 2011) and is analysed statistically (Lancaster, 2005). There are a number of techniques to collect quantitative data, which is typically in the form of structured interviews, self-completion questionnaire or online surveys (Saunders et al., 2012). Online surveys can be administered using either email survey or through web surveys (Saunders et al., 2012). In this study, the online survey method was used to investigate the extent to which BIM guidelines can support open BIM standards. The rationale of using online survey is to test a set of variables establish in the framework as to whether it is correspond to a wider population.

Nowadays, the use of Internet has greatly assisted researchers to distribute their questionnaires more efficiently (Simmons, 2008; Vehovar and Manfreda, 2008). A researcher can utilise the Internet as a tool more than just browsing information but also a platform to administer questionnaire online using multiple platforms to collect data (Simmons, 2008; Vehovar and Manfreda, 2008). The questionnaire can be designed in an electronic format, such as a Word or PDF document (Tuten et al., 2002). Alternatively, a web-based questionnaire can be designed using Smart Survey or Google Form (Tuten et al., 2002). This web-based questionnaire can be easily linked and attached in an email or Internet forum to reach broader participants. Potential participants can decide to complete the questionnaire at any time and anywhere via mobile phone, laptop, workplace computer ,or touch screen tablet(Tuten et al., 2002).

Conventionally, a self-completion questionnaire is distributed by post, fax, or personally delivered. This form of distribution require researcher to provide a contact list of the target participants (Cooper and Schinder, 2011). It may also be attached with cover letters to increase the likelihood of responses from participants. However, it is difficult for researcher to get access to the potential participants in correspond. This is one of the setback of questionnaire technique. The benefits of web-based questionnaire has gradually superseded the conventional way of distributing questionnaire. One of benefits is that online questionnaires are relatively inexpensive to produce and distribute (Evans and Mathur, 2005). Researchers could send an email invitation to potential participants with an attachment or a link to the web-based questionnaire (Evans and Mathur, 2005). This can greatly reduce the cost of photocopies and postage (Bandilla, 2002). Moreover, some web-hosting questionnaire may charge very little, or even provide free production and distribution services (Hewson and Laurent, 2008). Apart from that, the Internet provides access to a worldwide connection across geographical and beyond time limits. (Fricker, 2008; Rhodes et al., 2003). This is because participation is based on access to the Internet at preferred times and places (Rhodes et al., 2003).

The other benefit is anonymity can be guaranteed in online questionnaires where conventional questionnaires can not (Evans and Mathur, 2005). A conventional questionnaire requires the researcher to identify a list of potential participants before sending a copy to them. This could risk their anonymity in participating the questionnaire. The Internet could minimise the risk of exposing a participant's identity prior to completing the said questionnaire in a closed group forum in professional social media site LinkedIn. Researchers may achieve a broader population especially for sensitive research topic such as medical or politics issues (Rhodes et al, 2003). Finally, web-based questionnaires could facilitate more efficient time management for data entry and analysis (Tuten et al., 2002). This is because most web-hosting questionnaires can convert data into Excel or SPSS formats to facilitate statistical analysis (Saunders et al., 2012).

Employing online questionnaire has also its own weaknesses. Firstly, it may suffer from a lower response rate than the conventional questionnaire because factors of time of data collection, questionnaire layout, sampling frame and others (Saunders et al., 2012; Tuten et al., 2002). Kwak and Radler (2002) argue that responses to online questionnaires are relatively lower than mailed survey when conducted during the same period of time, using the same questionnaire and amendment in the sampling framework. Moreover, a meta-

analysis study comparing web and mail surveys showed that web surveys had an average of 34% response rate while paper-based surveys had a 45% response rate (Shih and Fan, 2008). Secondly, online questionnaire has a lack of sampling representativeness (Evans and Mathur, 2005; Rhodes et al, 2003). Although the Internet can reach more participants, those who do not have access to Internet or computer facilities will immediately be excluded from the research sampling (Evans and Mathur, 2005; Rhodes et al, 2003). Finally, the researcher has limited control over participants who may repeatedly complete the questionnaire (Fricker, 2008).

As mentioned in Chapter 1, the purpose of this study was to establish a new framework and to test the variables between constructs. The aim is to establish a BIM-FM Technology Acceptance Innovation Model to better facilitate the adoption of open BIM standards and standard guidelines. To achieve this aim, a structured survey was considered a suitable research instrument to measure variables of interest (Sekaran and Bougie, 2013). It was appropriate for a descriptive and explanatory research (Saunders et al., 2012). All variables and their relationships were proposed based on the literature research. The web-based survey was considered a suitable technique for primary data collection. This is because it was identified that all of the potential participants can easily access to the Internet to complete the questionnaire. All completed questionnaires were automatically stored and saved into the researcher's database system. In addition, the web-based questionnaire is accessible to the potential respondents in professional social media platform (i.e.LinkedIn).

5.5 Research Design

The research design is “a technical plan that attempts to link the beginning and ending of study” (Yin, 2003). The research design in this study is conducted through five stages of research methods in the following sequence:

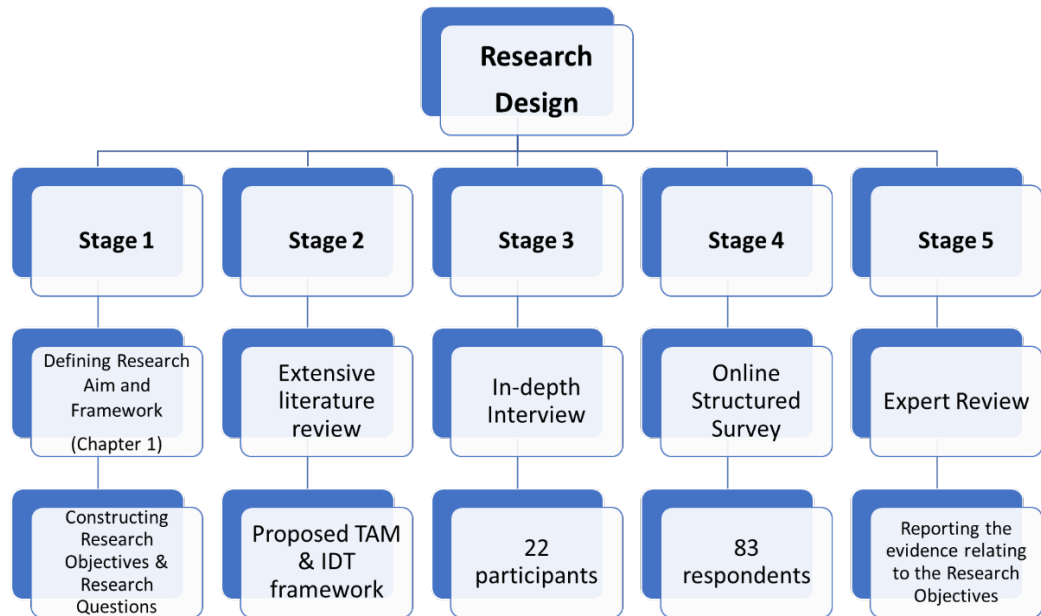


Figure 5.3 Research Design

Stage 1: Established the aim and the framework

Established the aim and the framework of this research that can better facilitate the adoption of open BIM standards and standards guidelines in FM. Beside aim of the study, the main objectives of the research constructed in Chapter 1 to facilitate the extensive literature review in Chapter 2, 3 and 4, and the design of the research in Chapter 5.

Stage 2: Extensive literature review

The literature review was essential to form a grounding of the study (Ridley, 2012) and to provide a background for the gaps in knowledge. Rowley and Slack (2004) stated that a literature review was to “distil the existing literature in a subject field in order to support the research topic, questions or hypotheses”. This was presented in Chapters Two, Three and Four that includes discussion about FM, building information modelling BIM, TAM and IDT theories. The conceptual framework, which aligned with the research objectives stated in Chapter 1, was developed from the literature. In addition, the literature review helped with choosing the appropriate methodology and methods for this research.

Stage 3: In-depth interview with key experts

Interviewing was one of the techniques of “communicating with people with a purpose of gathering information” (Berg, 2001). Rowley (2012) pointed out that an interview was useful to “understand people’s experiences, opinions, attitudes, values and processes about a certain research topic”. This technique was considered to be appropriate to the research because it

was anticipated that the resulting data had the ability to provide insights from BIM experts and facility managers about BIM and FM related issues.

In fulfilling the data criterion, a series of in-depth interviews were conducted. Interviews were conducted with twenty-two key BIM experts and professional facility managers working with BIM-related environment. The criteria for selecting the participants who held a managerial position and had five years of experience using BIM. This resulted in considering professionals who holding management positions from FM software companies, BIM consultant companies and FM consultant companies as potential participants. This type of interview recorded 22 contact hours and outcomes were coded as the key factors that influences the adoption of BIM in facility management, challenges and issues, and current levels of BIM implementation and future expectations. The coding technique were conducted and analysed manually and using NViVO software.

Stage 4: Online structured survey

Online structured survey was a quantitative method that enabled the researcher to reach “a great number of participants with common interests in a short period of time, regardless of geographical distances” (Wright, 2005). Prior to distribution, the researcher completed the final version of the structured survey as shown in Appendix C. This was distributed through a SmartSurvey, a web-package online survey. The online questionnaire was divided into two parts to establish a) FM demographics and, b) the level of awareness and knowledge of open BIM standards and standard guidelines. The respondents were recruited from the professional social media LinkedIN in the close group discussion – BIM4FM, BIM Experts and BSRIA. The reason of selecting these respondents is because of the common interest in BIM for facility management topics and, open BIM standards and standard guidelines. Therefore, the sample population from the targeted groups were deemed to be sufficient to facilitate the objective of this research project.

Overall ninety-seven completed responses were received and only eighty-three were valid responses were retained for data analysis process. Data from the online structured survey were contextualised into pie charts and tables to show the significance of key factors influencing the adoption of BIM standards and standard guidelines. SPSS statistical software was used to analyse the quantitative study in using univariate analysis such as frequency, means, median and bi-variate analysis such Pearson’s correlation.

Stage 5: Conducting expert telephone interview

The expert phone interview provided the basis for developing a more holistic understanding about nuances of concern surrounding adoption of BIM and the validity of the proposed model. The information gathered from the main, thorough interview participants about the BIM implementation strategy is confirmed by two telephone conversations with the construction industry expert. The researchers can learn a large number of information in a very short space of time by telephone expert interviews and can also direct researchers to further research material and potential allies. Experts can give important insights into the challenge through direct questions and they can help to advance the discussion and the study framework. Expert telephone interviewees also contribute their research knowledge and experience (Milena et al. 2008). Data analysis helped confirm the conceptual framework that will be tested for testing and validating the reliability of the implementation strategy framework in facility management in the near-future in a single case study. Furthermore, this final stage involves drawing conclusions from the results of findings and framing recommendations for future development.

As a result, the research design described above reflects the aims of the research, the nature of the research, the extent of interference of investigators, the study population, the research environment and the study time horizon (Cavana et al., 2001).

5.6 Data Collection Process

This section outlines the procedures for collecting data. The procedures include the process of identifying, approaching and conducting in-depth interviews with respondents, the unit for analysis, respondent profiles, the interview schedules and the field work experience. In the population they study, researchers are usually unable to make direct observations of each individual. Data are instead collected from a subgroup of people called "the sample," which are used to provide inferences on the population as a whole. Selection of the field, types of respondents, sample size and sample method were carefully planned and applied as follows in order to ensure that the data collected are reliable and valid:

5.6.1 Selection of Study Area and Respondents

Sekaran (2003) suggested that researchers select the subjects studied in order to collect reliable data carefully. Therefore, the sample population includes key BIM experts and professionals from the UK working in a qualitative, BIM-based environment through an online survey of Europe, the United States, Australia, Canada, New Zealand, Middle East

and Asia for the quantitative phase. The studying population includes experts from the United Kingdom and BIM related environment.

In addition, the terms "selection of respondents" described by Sudman and Kalton (1986) as a list of population elements to draw the sample from. Complete listings or records containing all elements of the survey population are hard to find in practice. The population sample unit was established as BIM experts and business facilities managers who collaborate with BIM-related environment UK to meet the research objectives. The study selected 22 experts from the UK and interviewees from professional social media LinkedIN for the close-knit discussion group–BIM4FM, BIM experts and BSRIA for the quantitative phase–as part of the study.

5.6.2 Selection of Sampling Method

Sampling is described by Sekaran (2003) as the procedure whereby certain elements within a given population may be selected as representatives of the whole population and classified as probabilities or unlikely. It takes time, effort and expenditure for the researchers to select unlikely convenience sampling. In addition, it is possible for informants to easily collect necessary primary data from the informants they have selected.

5.7 Data Collection Method

Data collection is regarded as the imperative aspect of the research study because it assists the researcher in collecting the information that can be used for analysing the research aim and objectives (Sekaran, 2003). There are two main methods of collecting data which are primary and secondary. Both types of data are considered as significant because it contributes towards in-depth analysis of the research problem (Babbie, 2012).

5.7.1 Primary Data Collection

Primary data are also referred to as first-hand data because the researcher collects data from specific groups or persons considered relevant to this purpose. Inquiries, observations, experiments and interviews are among the common methods used. Instead of depending on what's available the researcher collects data according to study requirements. The principal method of collecting information is an interview chosen by the researcher.

The interview is a two-way communication strategy for the purpose of gathering relevant information and data (Creswell, 2008; Walliman & Walliman, 2010). The research can

gather a large range of information from this strategy to help carry out a thorough practical analysis of the problem. In addition, some open-ended questions are asked to the individuals selected, and the responses are either stored in writing or audio. The researcher explained in this study the purpose and aims of the in-depth interview. The managers involved requested that they read and accept the consent signature of the supplied information sheet.

5.7.2 Secondary Data Collection

In addition to face-to-face interviews and telephone interviews, the current survey employed several methods and sources to collect information and evidence to answer questions from the research. The secondary data source contains printed documents that contain BIM, IFC, COBie and British standards information (BS 1192-4: 2014) and Publicly Available Specification (PAS 1192-3: 2014).

5.8 Pre-test Study

A pre-test for both the in-depth interviews and online-survey was carried out before starting the main fieldwork. The purpose of the pre-testing interview was to check the feasibility of interview questions in terms of length, clarity, consistency, and context. While, the pre-test online survey was administered to test whether the questionnaire was comprehensible, appropriate, and presented in a consistent manner. The data collected from both pre-tests were analysed and revised accordingly to ensure the quality and feasibility of the study. The data findings from the pre-test study recommend improvement in the interview questions and questionnaire items before commencing to the actual fieldwork

5.8.1 Analysis of Pilot Interview - Qualitative Phase

The pre-test interviews were conducted with **three interviewees**; two BIM experts and a FM expert. Data were analysed using a thematic data analysis to improve the content and wording of a revised interview questions and questionnaire items. The interview session was divided into two main sections. The first section discussed the background knowledge and experience in BIM and FM. This was followed by a discussion about four different aspects of a) the relevance of information requirements for handover, b) the key factors that influences the adoption of open BIM standards and standards guidelines, c) the extent to which BIM guidelines supported the adoption of open BIM standards and, d) suggesting a concept/framework that can facilitate open BIM standards and standards guidelines in FM. The interviews were recorded in a digital audio recorder with consent from participants. The

result of this interview was manually analysed and annotated as themes. This is explained in the next section.

5.8.2 Analysis of Pre-test Online Survey - Quantitative Phase

A pre-test online-survey was employed to test the feasibility of the study. The online survey is divided into two parts: a) Knowledge and Experience of BIM and FM in construction projects, and b) The extent of BIM guidelines that can support the adoption of open BIM standards. The purpose of pre-testing a survey is to check regarding length, content, language use and comprehension. The result of this survey is analyzed using descriptive analysis. All comments and feedback will be taken into consideration in improving the structure and content of this survey. The respondents were recruited from the industry professionals, academicians, colleagues and staff in the department. A total of nineteen respondents participated, but only eleven respondents had successfully completed the pilot survey. The respondents were invited via email and web link to the pre-test survey to give their comments, feedback, and suggestion. The pre-test survey started in January until March 2017.

5.9 Questionnaire Development and Operationalization of Items Instrument

On average, the respondents took 10-15 minutes to complete the pre-test survey. It consists of 24 main items and 97 sub-items individually. While all valid respondents attempted to respond all questions, however, the remaining respondents attempted to answer the survey either in mid-process or withdraw after the screening "yes/no" question. There was difficulty in answering all the questions, due to the length of questionnaire items. Some respondents completed the basic questions that involve; primary jobs functions, the average size of the organization, type of facilities operates, and their experience in BIM, but stopped in the middle of completion. This is because the designs of some questionnaire items may affect the answer to the remaining questions in the online-survey. Hence, the designs of certain questions should be skipped and directed more suitable questions. This was observed with the items asking about the experience in COBie and IFC. If the answer is "no experience," then they may not be able to answer the rest COBie and IFC-related questions. Also, not all participants have the time to complete a lengthy questionnaire, which could easily discontinue and decided to leave the survey. Therefore, it is necessary to omit some questions and make a revision of the structure in the survey.

The other problems appeared is using specialist language and complexity of questionnaire items. This was observed in the section where questions regarding key information requirement, which consists of answers that are too specific. Some respondents provided a comment on the complexity of the questions that causes confusion and finding a hard time to complete it. Hence, it necessary to re-assess and simplify the context of the questions and revised for the main survey. There were also few typographical and grammatical errors in some of the sentences that should be addressed. This was noted in few statements in the identification of key factors for the adoption of BIM in FM. Few respondent suggests that the Likert scale should be labelled individually to “scale 1- strongly disagree”, “scale 2- agree”, “scale 3- neutral”, “scale 4- disagree”, “scale 5- strongly disagree” replacing the statement from “scale 5 – strongly agree to scale 1- strongly disagree”. This amendment has been made to prepare for the main survey.

Other comments and feedback suggest that making questionnaire items more suitable and appropriate for target respondents; in which case FM professionals, so that they could provide answers for the questionnaire. Furthermore, it is advisable that making questions that is not compulsory because it may affect the response rate of the online-survey. The original constructed questionnaire instrument for pilot study shown in **Table 5.2**

Table 5.2 Original Questions Used During Pilot Study

Awareness of BIM
• I’m familiar with the term COBie and how it works in FM • I’m familiar with how COBie works for FM • I’m familiar with the term IFC and how it works for FM practice • I’m familiar with how IFC works for FM practice • I’m familiar with the standard guidelines PAS1192-3 and how it works for FM practice • I’m familiar with how PAS1192-3:2014 helps in adopting BIM in FM • I’m familiar with the standard guidelines BS1192-4 and how it works in adopting COBie • I’m familiar with how BS1192-4:2014 helps in adopting COBie in FM • I have experience in the use of COBie and how it works for FM • I have experience in the use of IFC and how it works for FM practice • I have used the standard guidelines PAS1192-3 and how it works for FM practice • I have used the standard guidelines BS1192-4 and how it works in adopting COBie
Compatibility with FM system
• The use of COBie improves the way I work • The use of COBie facilitates effective working • The use of COBie has changed the way I worked • COBie will improve the handover data from construction to operational phase • The use of IFC improves the way I work • The use of IFC facilitates effective working • The use of IFC has changed the way I worked • IFC will improve the handover of data from the construction to operational phase

Trialability
• I have experimented using COBie Being able to try out COBie is important in my decision to adopts it • I have experimented using IFC data exchange format Being able to try out IFC is important in my decision to adopts it • I am still experimenting using COBie • I am still experimenting using IFC • I have used COBie in live projects • I have used IFC data exchange in live projects • I will continue to explore the use of COBie in future • I will continue to explore the use of IFC in future
Observability
• I have seen case studies on how to use to import COBie to FM system • I have seen demonstrations of the importing COBie into FM system • I have seen case studies where IFC has been used in FM • I have seen demonstrations of the use IFC data format in FM • There is sufficient guidance on PAS 1192-3 to adopt BIM in FM • There is sufficient guidance on BS 1192-4 to adopt COBie
Perceived Usefulness
• COBie is a useful mechanism for handing over data from construction to operational and maintenance stage • COBie will benefit FM practice • IFC has a structured information for handing over data to operation and maintenance stage • Industry Foundation Classes (IFC) is a useful data exchange format • IFC represent all the data required for FM • PAS 1192-3:2014 provides clear guidelines for adopting BIM in FM • BS1192-4:2014 provides clear guidelines for populating COBie • PAS1192-3 standard and guidelines facilitate the development of EIR • BS1192-4 standard and guidelines facilitate the development of EIR • The quality of information contain in COBie is high • The quality of information contain in IFC is high
Perceived ease of use
• COBie spreadsheet is easy to for facilities manager to read and understand use • COBie spreadsheet has an easy interface to present information user-friendly interface • IFC is an easy format for facilities manager to use • IFC is a user-friendly data exchange format • PAS 1192-3 standard helps facility managers to understand how to managed information easily • BS1192-4 standard helps facility managers to populate implement COBie easily
Behaviour Intention
• I have intention to adopt open BIM standards and standards guidelines in near future • I anticipate that I will adopt open BIM standards and standards guidelines in my work • I intent to apply open BIM standards and standard guidelines in my work • I have adopted open BIM standards and standard guidelines
Cost
• Capturing of information in COBie may involve expensive cost in hiring specialist (e.g. computing firm, technical specialist) • The benefits of information populated in COBie are greater than its cost. • Capturing of information in IFC may involve expensive cost in hiring specialist (e.g. computing firm, technical specialist) • The benefits of using IFC are greater than its cost.
Classification of BIM Data
• The use a of classification system is useful in structuring FM data

• The Uniclass/Omniclass/SFG20 standard is important to for defining information in COBie • The Uniclass/Omniclass/ SFG20 standard helps enhances the use of COBie to be useful to in FM systems • Information that carries Uniclass/Omniclass/SFG20 standard are readable in FM systems
Employer Information Requirement
• The EIR is useful mechanism in capturing information required for FM • The EIR contains too much information that cannot be held within a spreadsheet
Standards and Guidelines
• The content in standards and guidelines (i.e. PAS1192-3 & BS 1192-4) is overcomplicated • The content in standards and guidelines (i.e. PAS1192-3 & BS1192-4) is sufficient to facilitate the adoption of BIM in FM
Interoperability Data Exchange
• The COBie can easily be used to import data into FM system • The IFC format allows integration with my FM system • 3D model information is necessary to facilitate information management in my FM system
Common Data Environment (CDE) As-built Model
• AIM As-built Model is important for facility managers to coordinate and shared helps facilities managers to identify the relevant information in COBie • AIM As-built Model helps facilities managers to reduce redundant information in COBie • AIM As-built Model helps facilities managers to identify errors in COBie • AIM As-built Model allows collaboration with others project teams helps facilities managers to identify missing information in COBie
Upskilling
• Training workshops help me to enhance my skillset in updating COBie information in FM system • Training workshops help me to enhance my skillset in using IFC data exchange format to update graphical information in FM system • I'm competent in using COBie and to integrate information them into FM systems • I'm competent in using IFC to integrate information them into FM systems
Concepts/ Tasks
• Reduce the content of COBie to more relevant material • A process map for BIM use in FM • The Early involvement of FM in EIR document • Suppliers and Manufacturers has an important factor to play in providing details for COBie data input • Reduce the cost of training in promoting the use COBie and IFC for FM • Regulatory enforcement in using COBie and IFC for FM • Communication with design and construction team to get FM information in the COBie and IFC • Assigning BIM manager with BIM to update information in COBie and IFC in the FM system

Since the results of the small sample reliability test would not represent the population accurately due to insufficient data, the presence of missing data, feedback revisions and the subtle barriers that may inhibit an respondent's interest in filling out the questionnaire are crucially important to monitor. The questionnaire in the final survey instrument, according to the recommendation by Babbie (1990), were reduced on the basis of the answers received

during the pre-test. Consequently, the instrument was amended and the new Questionnaire introduced in Chapter 6 based upon the comments and suggestions of the pilot study respondent

5.10 Data Analysis Technique – Qualitative Phase

Qualitative research data analyzes are quite different from quantitative (Patton, 2005). The data analyzes used in this study include data transcription and coding, and analysis methods. The recorded interview sessions were kept in the researcher's computer hard disk drive and backed up in external hard disk. A naming code was individually assigned, as shown in Chapter 6. Each recorded interview session was transcribed manually in a MSWords document before being analysed in NViVO, a qualitative data analysis software. According to Katz (2002), analyzing qualitative data (such as interview transcripts) is to filter through the myriad of relationships that make up our social worlds and show how they work together in ways that makes sense for those who enact them. In other words, the process of breaking down raw data into actual text and analysing them in a clear and transparent manner helps both the researcher and reader to understand a particular situation better.

The interview transcripts, which consisted of a group of texts, were labelled into codes to symbolize meaning to descriptive or inferential information. Saldanã et al (2013) divides codes into two major stages: first cycle and second cycle. The first cycle coding are the codes assigned to a group of data. The coding method for the chunks of data can either be in:

- *Descriptive coding*– Assign label to data to summarize in a word or short phrase that provide indexing and categorizing
- *NVivo coding*- Advance coding via a computer software that uses words of short phrases from interviewee's own language
- *Process coding* – Coding method that involves strategic implemented time sequence, actions, and things that change or happen in a particular period of time.

The second cycle coding also known as pattern codes is an approach after the process of the first cycle coding. This method involves grouping or combining the summaries in the first cycle coding into smaller number of categories, themes, or constructs. The functions of pattern coding allow the researcher to: a) filter large amounts of data into smaller numbers of key data, b) analyse during the process of data collection in order to get more focused and accurate results in the fieldwork, c) elaborate data into a cognitive map, and d) lay the

groundwork for cross-case analysis by identifying common themes and processes. After the second cycle coding, interpretations of the codes were further developed by combining the researcher and the interviewees' understanding, concepts and concerns for this study.

5.10.1 Data Analysis NVIVO software

NVIVO is software developed by the QSR International to provide researcher with the tools that assist in undertaking qualitative analysis. The use of NVIVO helps to increase in the effectiveness and efficiency in the process of managing data and focus on the methods in examining the meaning of data collected. This assist researcher to organize, record, link and identify patterns of data to answer their research questions without losing the meaning and access to the original sources of data (Bazeley and Jackson, 2013). One of the main feature in NVIVO functions allow researcher to conduct the word query, that counts the numbers of word that frequently use from the source of data gathered. The word query can also convert the frequency of words into a graphic form called the 'word cloud' as shown in Chapter 6. The purpose of the using the 'word cloud' is blow up the image words appear on the result of word query in different font sizes that dependent on the counts of a particular words.

5.10.2 NVIVO coding

Apart from NVIVO feature of word query, coding is one of the most essential methods commonly use in conducting qualitative analysis. A code is a representation of a body of text from description through labels for topics and themes to more interpretive or analytical concepts (Bazeley and Jackson, 2013). Through NVIVO, a code can be created through 'nodes' that highlighted in a body text from the source of data collected that includes interview transcriptions, raw field notes and informal discussion via email. The nodes created can be classify into parent nodes or child nodes depending on themes highlighted to form a hierarchy structure of coding in NVIVO as illustrated in the **Figure 6.3**.

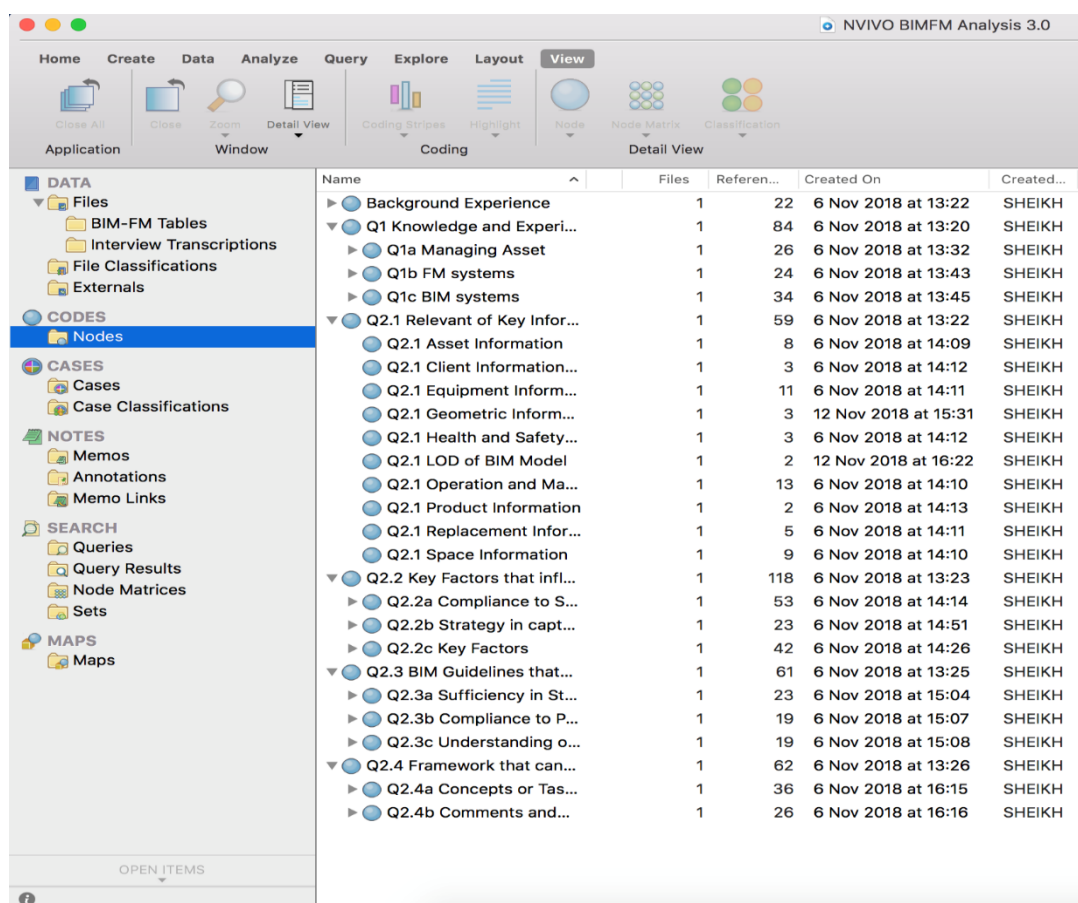


Figure 5.4 Nodes in Hierarchy Structure of Coding in NVIVO

5.11 Data Analysis Technique – Quantitative Phase

In the course of primary data collection, data pre-screening was performed. After each questionnaire answer has been collected, it has been verified that no questions have been left incomplete. In this study all the questions with numbers were encoded and the primary data were entered for analysis using statistical software, the Statistical Package for Social Science (SPSS) version 22. For each item, appropriate representative names, data types, data values and data measurement types were specified, such as scale, ordinal or nominal. Data analysis involves three objectives, according to Sekaran (2003), (1) a sense of data collection, (2) a test of data goodness and (3) a test hypothesis for the study. The following sections outline all analysis techniques used to evaluate research objectives and hypotheses in order to achieve these three targets and the objectives of this study.

5.11.1 Cross-Sectional Analysis

Transversal analysis is used to study correlations between sections. All the hypotheses of the study were met with cross-sectional analysis between the variables. Hussey and Hussey

(1997) noted that cross-sectional studies are a positive methodology for obtaining variables information in different contexts and need to be carried out simultaneously.

5.11.2 Descriptive Analysis

According to Babbie (1990), the descriptive study is not used only to identify the relation between variables at the research point, but also for descriptive purposes. Descriptive analysis refers to "transformation of raw data into a form to describe a number of factors in a situation where it is easy to understand and read" (Sekaran, 2003; Zikmund, et al., 2012). Sekaran (2003) also said that the statistics describing the interest phenomena are "statistics." This study analyzes demographic data with descriptive methods of analysis such as frequency distribution, percentage and accumulative per cent to understand the sample data better. In addition, a distribution percentage of variables was performed in order to obtain an overview on the respondent's perception of the variables of interest.

5.11.3 Reliability Analysis

Reliability analysis was subsequently carried out to confirm that these measures produce consistent results on several occasions (Onwuegbuzie & Daniel, 2002). According to Zikmund (1991), the concept of reliability is defined by repeatability and internal consistency. Cronbach's alpha is the most common measure of measurement reliability with a thumb rule that suggests that the value of Cronbach's alpha must be higher than 0.70 and higher indicates higher reliability (Nunnally, 1978).

5.11.4 Correlation Analysis

The correlation (r) value, with reference to Hair, et al. (2010), can be any between -1.0 and + 1.0, and this value refers to the force of association between two metric variables in which the positive r is a direct relation and the negative r is a mutual relation. The strengths of correlations are classified as small ($r = 0.10-0.29$), medium ($r = 0.30-0.49$), and great ($r = 0.50-1.00$), according to Cohen (1988). In order to analyze the relationship between independent variables and dependent variables a two-tail analysis of Pearson's product-moment correlations was conducted.

5.12 Reliability and Validity

Credibility of research in qualitative research, in particular in positivist terms (Partington, 2002), has created a strong debate. The trusts and authenticity criteria in evaluating research quality are suggested by Guba and Lincoln (1994). The current research has compiled with

established criteria in accordance with logical research design during the whole of this research to ensure confidence and authenticity.

5.12.1 Reliability

The test of reliability will ensure that other researchers can derive the same results through the same research methods as the original investigator has outlined. The goal of the reliability test is to minimize distortions and mistakes. Other researchers can repeat the process and obtain the same results by correctly documenting the procedures of the case study and making it operational as possible. Furthermore, the case study protocol can increase reliability (Yin, 2003). Regarding the researcher's preference and questions of respondent prediction, it admits that there might be a possible prejudice in the organization, members of the organization and issues associated with the study between the researcher and the studies contexts. The researchers made every effort, by integrating opinions from different departments, to minimize the effect of the relationship. The study has been carried out over a long time as one of the respondents' bias countermeasures. This made it more relaxing and natural for respondents to behave (Cavana et al., 2001). The researcher has also conducted the protocol for case studies. This protocol helped the investigator collect data by concentrating on the subject of the cases study and anticipating the problem of case study.

5.12.1.1 Internal Validity

Internal validity is developed through the establishment of a causal link, showing certain conditions leading to other conditions. This is to distinguish it from a false relation. The model matching is one of the techniques used for increasing internal validity in case study data analysis. The empirical pattern of the research is compared with the forecast pattern. The results help increase the internal validity of the case study if the patterns match (Yin 2003).

5.12.1.2 External Validity

External validity means to test "the generality of the results of a study beyond the immediate case study" (Yin, 2003). Yin (2003) stresses that in surveys, it is possible to generalize a statistical widespread use of the sample into a greater universe. For case studies, however, due to the purposefully small sample, it is not possible to examine a detailed phenomenon. Therefore, generalization depends on analytical generalization for case studies. Analytic generalisation is generalized in' which is used as a template to compare the empirical results of the case study with previously developed theory. If the same theory is demonstrated in

two or more cases, replication can be claimed "(Yin 2003). In case studies, the "theory" of what is being studied is a complete research design (Yin, 2003). In addition, according to Cavana et al. (2001), only organizations that have the same situation can replicate case studies with regard to the nature of the problem and its definition of problems.

The researchers provided thorough descriptions of the research for references and comparisons in order to allow for successful transferability from this research context to the present reader context. The early section in this chapter explains the development of this research in theory in detail, such as the selection of the site of the case study, the development of the conceptual and theoretical frameworks, the development of the data gathering instrument, and the selection of samples. This information helps readers to decide how close the contexts can or cannot match.

5.13 Ethical Consideration

Qualitative or quantitative research is one of the important aspects that every researcher must consider. The researcher will focus on all kinds of research ethics that are suitable from the perspective of the study to make the study valid, reliable and appropriate (Sekaran & Bougie, 2010). Before collecting data the researchers have passed through the ethical examination process at university level. This research was approved by the University Committee with the necessary ethical approval. Some of the common research ethics that the researcher has to consider in the course of this study are:

5.13.1 Data Management

Research data management is part of research activities that contribute to the effectiveness of research. There are certain special problems that are potentially evasive of research ethics in the management of data. The scientist must ensure the ethical and accountable collection of data. In addition, any type of informant personal information must be managed correctly together with a guarantee that it can not be obtained by any third party that has no link with the study (Walliman & Walliman, 2010; Andrew, Pederson & McEvoy, 2011). The researcher must therefore ensure that all data collected are managed efficiently at the time the study is conducted and that nothing not appropriate is not reported in the study. Digitally recorded every stage of interview sessions. The data from the interviews were then transferred to the personal laptop and password protected.

5.13.2 Privacy

The researcher has to ensure that informant privacy is maintained in relation to ethical requirements before, during and after the study. The data relating to the research must be personal or otherwise secure. Research must also maintain confidentiality to prevent confidentiality between the organization and the informants. The researchers are therefore responsible to ensure that the data collected from various people are kept secure (Zikmund et al., 2012). The researchers secured the location where they stored the information using unique passwords that are only passwords for authorized individuals. The collected data was not shared publicly and was not uploaded to the social network. In addition, all personal and organization information have been modified despite the initial quotation of some interview data.

5.13.3 Informed Consent Letter

The present research included the design of an informed consent letter and a qualitative phase for the participants. A brief introduction to the researcher, the objective and the research objectives was contained in the letter. The participant was also asked to nominate potential participants for this research. The individual who has agreed to participate in this research has been prepared with an informed consent letter (See Apendix B).

5.14 Chapter Summary

In this study the philosophy and paradigm of the study were described and the methodology selected was explained. Within the study, a mixed methodology approach was adopted to explore open BIM standards and standards guidelines in FM. The chapter discussed the study's design and data collection methods. The technique of the interview, the online survey and its analysis method were explained. Finally, problems related to the reliability of research, validity and the ethical aspects affecting the study were addressed.

CHAPTER 6 QUALITATIVE FINDINGS

6.1 Introduction

The previous chapter comprehensively discussed on one of the selected research methods used to undertake this research. Based on the sequential mixed-methods adopted, this chapter firstly present the data findings collected from the in-depth interviews conducted with BIM/FM experts to address the research objective in Chapter 1. The chapter starts by describing the background details of participants in data collection. Then, the adopted in-depth interview technique is presented and discussed. Following this, the feedback resulted from the participants are transcribed and analysed in NViVO software to define the themes and codes that have emerged. Finally, the themes and codes are identified as the key factors that influence the adoption open BIM standards and standards guidelines to make inform the quantitative method in the next chapter. An overview of key sections is presented in Figure 6.1.

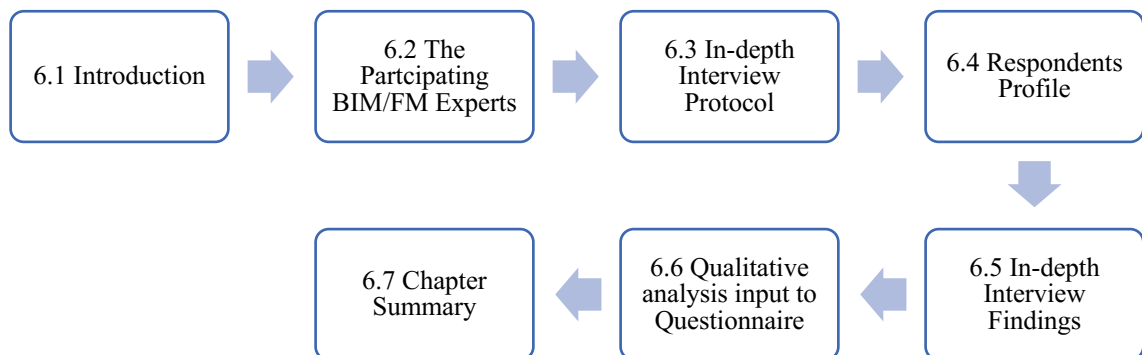


Figure 6.1 Chapter 6 Organization

6.2 The participating BIM/FM experts

The aim of the data collection is to identify forces that influence the adoption of open BIM standards and prevailing standards guidelines. As indicated in Chapter 1 the in-depth interviews were regarded as the best method to capture this data. Recommended number of interviewees to obtain sufficient results in this context can be between six to eight (Rowley, 2012). Therefore, twenty-two key professionals with BIM/FM-related knowledge and experience were contacted for face-to-face interview or phone interaction. Although each interview was done at the researcher's convenience, the participants may decide in advance on the best date and time that would fit their schedule

Table 6.1 illustrates the background details of each participant. Eight of them were BIM experts, while nine demonstrated credibility as FM experts/FM end-users/FM software experts, all of whom five years of work experience. Apart from this, during the telephone interviews, the participants were asked to introduce any other members from their social network that could potentially participate in this research.

Table 6.1 Profile Background of Interviewed Participants

Code	Background	Experience
ID01-BR	BIM Expert	5 years
ID02-AS	FM Software Expert	10 years
ID03-RT	BIM Expert	6 years
ID04-JP	BIM Expert	3 years with BIM
ID05-EJ	FM Software Expert	18 years
ID06-SB	FM End User	5 years
ID07-SO	BIM/FM Expert	15-20 years
ID08-PS	Chief Technology Officer	20 years
ID09-EB	FM Software Expert	17 years
ID10-DB	BIM Academics	31 years
ID11-SM	BIM Expert	20 years
ID12-PM	FM Software Expert	25 years (6 years with Archibus)
ID13-JH	BIM Expert	19 years
ID14-HK	FM Expert	15 years/ 4 years with BIM
ID15-MF	FM End-User	2 years working with BIM
ID16-AA	BIM Expert	7 years
ID17-SD	BIM Academics	12 years
ID18-DF	Building Services Expert	15 years
ID19-GK	BIM/FM Expert	5 years
ID20-KVR	IT Director	12 years
ID21-BT	BIM Expert	15 years
ID22-CB	BIM Expert	10 years

Due to the confidentiality issues, anonymity was maintained to protect the actual participants. The background and experience of the participants are mentioned to demonstrate the tendency and variation of the participants' answers based on their experience. Therefore, each participant was anonymously re-identified based on their current position and experience. The new identification is consistent with the ethical requirement to

protect confidentiality of the participants. For instance, the FM Software Expert with twenty years of experience is labelled as ‘ID12-PM’. Pertaining to the validity issue, all the participants are experts in their esteem field and considered as the credible source of information. They are the most suitable participants for this research as they fulfilled the selection criteria of this study, and qualified by virtue of current knowledge, skills and experience in BIM, and/or BIM/FM project(s). This enables the researcher to understand and explain the adoption of open BIM standards and prevailing standards guidelines.

6.3 In-depth Interview Protocol

The main topics of discussion during the in-depth interview divided into five categories (as shown in Figure 6.2, which are (1) Knowledge and experience of BIM and FM in construction projects, (2) Relevance of key information requirement, (3) Key factors that influence the adoption of open BIM standards and standards guidelines, (4) BIM guidelines supporting the adoption of open BIM standards, and (5) Framework that can facilitate open BIM standards and standards guidelines.

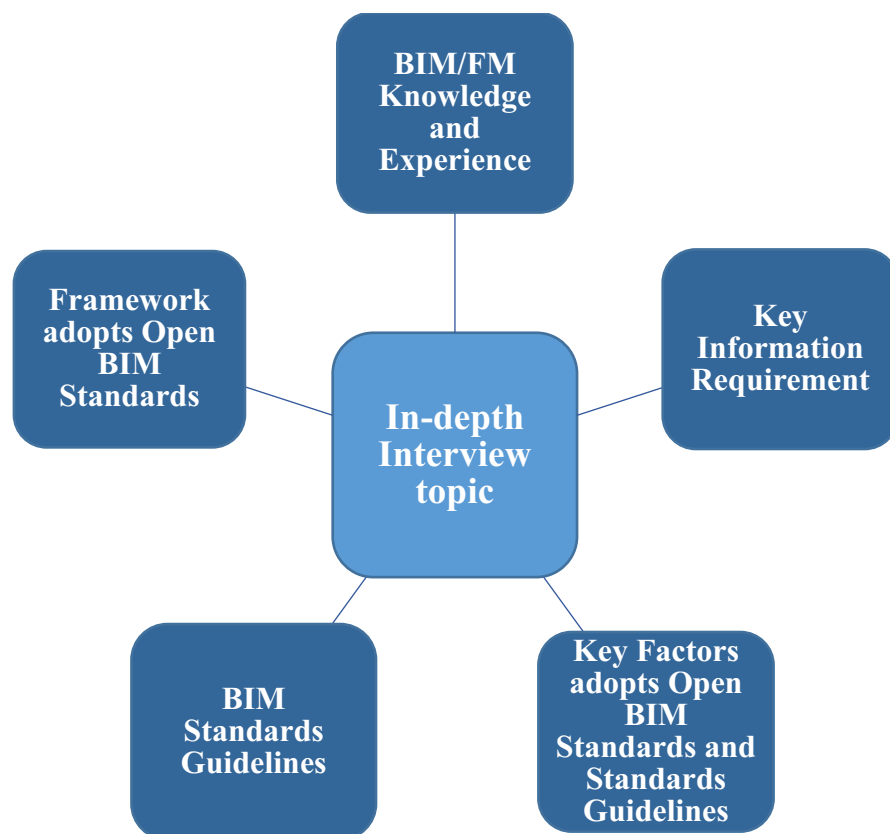


Figure 6.2 Topics discussed during the in-depth interviews

Each participant was given an information sheet, a consent form and a set of questions via email prior to the interview to allow time for collection of thought. The consent form was

either signed at the start of the face-to-face interview or was read aloud during the telephone conversation to gain verbal consent before the interview commenced.

6.4 Respondents Profile

A summary of the twenty-two interviewed participants profile tabulated in Figure 6.3

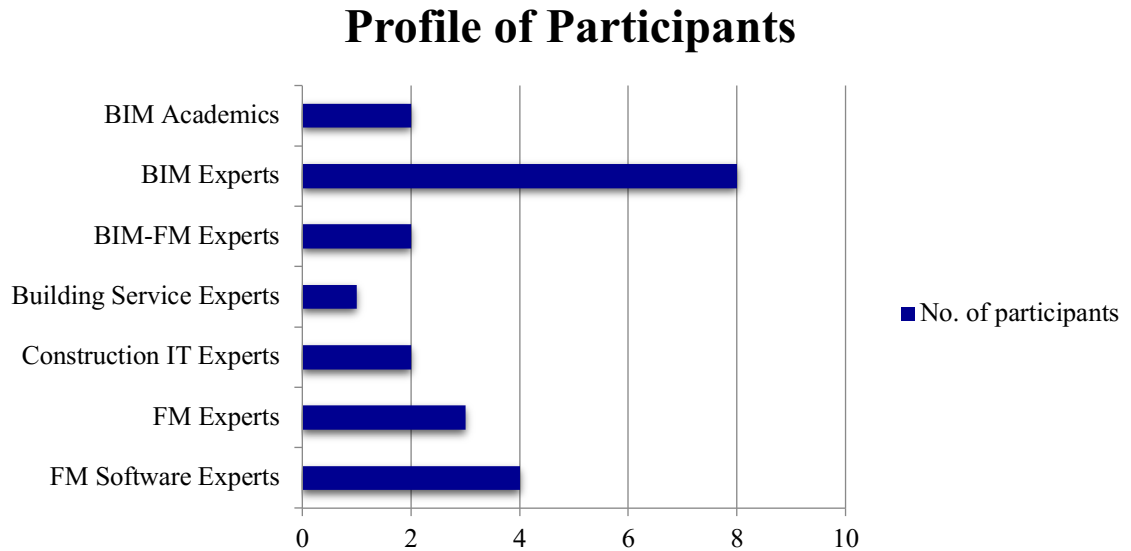


Figure 6.3 Profile of Interviewed Participants

Twenty-two selected participants were interviewed and found eight of the them are FM experts that include FM Software and Building Service experts. Four other participants are FM Software experts while three are identified as FM experts. Apart of this, two participants found to be BIM Academics, two participants BIM-FM experts, and two other participants addressed as construction IT expert. Last but not least, one participant identified as the Building Service expert.

6.5 The In-depth Interview Findings

The results of the in-depth interviews of the 22 participants are presented in this section. The qualitative analysis used selective coding of the interview scripts for the themes and classes related to the questions of research. During coding and analysis using NVIVO data analysis, the categories were inductively derived by data. From the NVIVO data analysis, the discussion of qualitative in-depth interviews results interpreted from the data collected during the fieldwork phase. Furthermore, the audio recordings from twenty-two participants transcribed verbatim and analysed in themes and coding assigned in NVIVO. Therefore, the following subsections explore extensively on the meaning of emerging themes and coding

assigned. In addition, response patterns were also compared to the theoretical considerations drawn from the literature.

6.5.1 Category 1 - BIM/FM Knowledge and Experience

In category 1, the analysis examines the (i) knowledge and experience in managing assets, (ii) knowledge and experience in FM systems and BIM systems and (iii) summary of BIM/FM knowledge and experience in construction projects.

6.5.1.1 Knowledge and Experience in Managing Assets

The first question of the interview discussion focused on identifying the level of knowledge and experience in managing assets, FM systems (i.e. Planon) and/or BIM software (i.e. Revit) in construction projects. Firstly, the interview question discussed on the knowledge and experience in managing asset. From the qualitative analysis, seven participants (ID02-AS, ID05-EJ, ID07-SO, ID09-EB, ID15-MF, ID19-GK, ID21-BT) were found to discussed extensively on the procedure of managing asset/s. From the qualitative data analysis, six main themes are constructed from the interview transcripts of participants that shared similar characteristics (see Figure 6.4). The main themes include (a) establishing early information requirement, (b) establishing the maintenance regime (c) Implementation of BIM, (d) assigning, classifying, and verifying asset, (e) using traditional method, and (f) don't manage asset.

Knowledge and Experience in Managing Asset

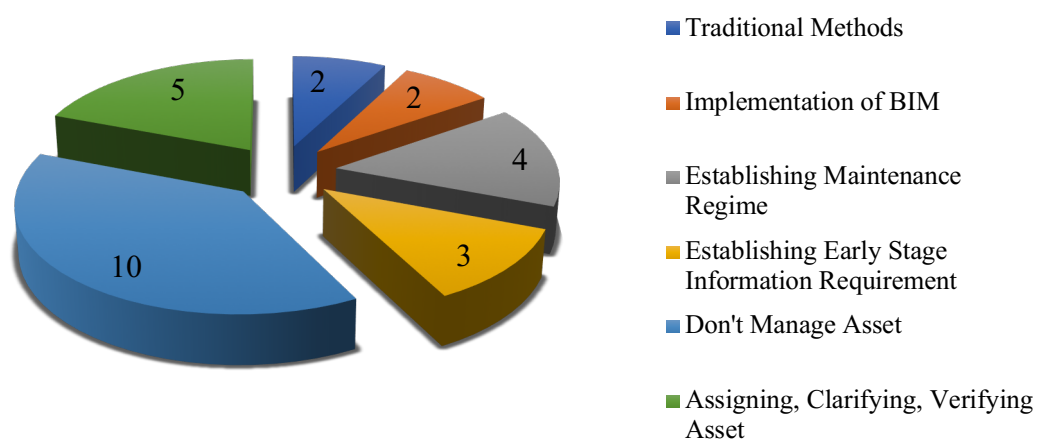


Figure 6.4 Knowledge and Experience in Managing Asset

6.5.1.2 Establishing Maintenance Regime

Establishing a maintenance regime in managing asset is one of the crucial activities in FM task. Maintenance regime is about improving the cost-effectiveness of maintenance in an organisation (CIBSE, 2014). Four participants (ID02-AS, ID05-EJ, ID09-EB, ID15-MF) in the interviews mentioned that setting the maintenance regime may involve activities as such, ad-hoc maintenance, corrective maintenance, defining maintenance cost and reactive maintenance. Therefore, establishing maintenance regime is one of the main themes that has been analysed in the main findings that is priority task for FM core function.

6.5.1.3 Assigning, Classifying, Verifying Asset

The next theme analysed in the main findings is assigning, classifying and verifying asset in the building facilities. The main activities include assigning asset in unique identifier, classifying asset in categories and verifying the quality of data of the asset. Three participants (ID07, ID12, ID15) indicate to manage building asset efficiently, the information acquired about the asset should be recorded, categorised into structure and checking its data quality in the FM system to be able to access properly in day-to-day operation. All three participants discussed the importance in assigning each asset into unique identifier or reference numbers, classify into a structure and/or asset classification system that would be later used in planning maintenance and finally checking the quality of data to ensure it is accessible in daily routine of FM task.

6.5.1.4 Implementation of BIM

From the thematic analysis, the use of BIM in managing asset has emerged as a theme from the main findings. As discussed from the literature, the potential of using BIM could provide benefits in many aspects of FM task. Two participants (ID14, ID15) took part in the interview discussed on their knowledge and experience using asset information model to capture information use for managing asset. Both discussed their knowledge and experience in using asset information model that is useful to simulate and identify existing asset in the building easily in the FM system.

6.5.1.5 Establishing Early Stage Information Requirement

Early stage information requirement has emerged as one of the themes in the main findings. Setting the early stage information requirement is essential to inform clients and designers to take consideration in maintainability aspects of building service design to reduce the whole life-cycle cost and total cost of ownership (CIBSE, 2014). Two participants (ID19 and ID21)

highlight the importance of setting the client information requirement and asset information requirement in managing asset in early stage of a BIM project.

6.5.1.6 Traditional Methods

Based on the main findings, two participants (ID07 and ID16) mentioned that they practice the traditional methods of conducting FM task. The routine of task may involve on-site observation of the existing building asset and recording of asset-related information. Participants ID07 argue that it still a struggle to gather all information via BIM that insist on reverting to the normal practice of facilities manager. On the hand, participant ID16 argue that buildings often change in ownership that require a swift change how the building is operated with a cost-effective benefit to both tenants and service provider. The BIM –driven practice is costly and may not be viable for the changes in ownership.

6.5.1.7 No Experience in Managing Asset

On the other hand, ten participants (ID01, ID04, ID03, ID08, ID10, ID13, ID16, ID17, ID18, ID22) who took part in the interview mentioned that they have no experience in managing asset. This is because of their position and background involve primarily only in the design and construction stage.

6.5.1.8 Knowledge and Experience in FM systems and BIM systems

Pertaining to knowledge and experience in FM systems and BIM systems, the interviewees confirmed the usage of various FM systems and BIM systems in managing assets. **Figure 6.5 and Figure 6.6** illustrated the outcome of the interview.

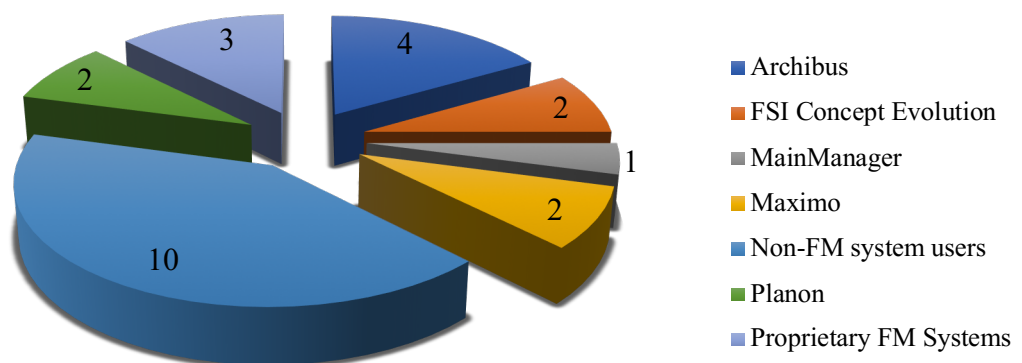


Figure 6.5 Knowledge and Experience in Using FM Systems

Figure 6.5 identified Archibus, Planon and MainManger are apparent as BIM-based FM systems due to their compatibility with BIM model. On the other hand, FM Concept Evolution and Bespoke FM system account for the traditional FM systems with restricted compatibility with BIM-based environments. Archibus is the most commonly used FM system in managing assets, as attested by four participants' (ID02-AS, ID12-PM, ID15-MF, ID19-GK) asset handling operations via Archibus system in handling asset activities. Five participants (ID05-EJ, ID07-SO, ID09-EB, ID19-GK, ID20-KVR) mentioned of operating an alternatives BIM-based FM system (Planon, MainManager, Maximo) in managing asset activities. Furthermore, four participants (ID06-SB, ID10-DB, ID14-HK, ID18-DF) mentioned they used traditional FM systems (FM Concept Evolution, Prioprietary FM system) in managing their assets. The result also identified four participants were non-FM system users.

Knowledge and Experience in using BIM systems

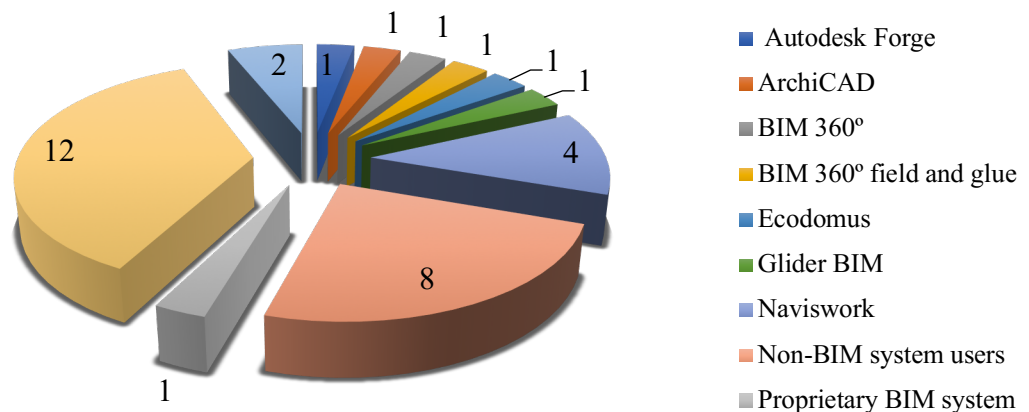


Figure 6.6 knowledge and Experience in Using BIM Systems

On the other hand, **Figure 6.6** shows ten different BIM systems labelled as classified in managing asset. From the data findings, Revit is the most widely operated BIM system, more than half of participants (ID01-AS, ID03-RT, ID04-JP, ID05-EJ, ID07-SO, ID08-PS, ID11-SM, ID19-GK, ID20-KVR, ID21-BT, ID22-CB) are using Revit for designing, evaluating, viewing and assigning classifications to BIM models. Different BIM applications have different functions. The BIM 360° enhances collaboration work, The ArchiCAD and Bespoke BIM system serves as alternative platforms to Revit, while Solibri is used for checking and verifying COBie data.

6.5.1.9 Summary of BIM/FM Knowledge and Experience

Through the cross-analysis, the participants that experienced in managing asset are those with knowledge of FM. Those who don't have any experience in managing asset are solely involved in design and construction stage and may not involve in FM-related task. Therefore, the question about managing asset may not be viable or directly related to their professional background experience. In addition, participants who operate the FM systems are considered BIM- driven. The FM systems previously mentioned are all BIM-driven that allowed users to import COBie/IFC information exchange in the systems. Therefore, participants who experienced using FM systems could also be knowledgeable about BIM.

Apart from that, a majority of participants (ID01-BR– ID05-EJ, ID07-SO–ID09-EB, ID11-SM–ID17-SD, ID19-GK–ID22-CB) are proficient using BIM systems. The BIM systems listed previously made of several functions that focus on design and construction stage. The BIM systems include authoring tools, clash-detection tools, model checking tool and lifecycle asset management information tool. However, three participants (ID06–SB, ID10–DB, ID18–DF) indicate that they have not used the any BIM systems but merely act as design consultants that only reviewing the BIM model in clash detection with others project team members or involving in the document-related BIM processes.

6.5.2 Category 2 - Relevance of Key Information Requirement

Several categories of key information requirement were analysed in the findings to facilitate the use of operation and maintenance phase during the information handover to FM used. The notable findings of categories of relevant key information requirement shown in **Figure 6.7** which includes (i) asset information, (ii) space information, (iii) operation and maintenance information, (iv) replacement information, and (v) equipment information. However, the remaining categories of information requirement were classified as miscellaneous information.

Key Information Requirement

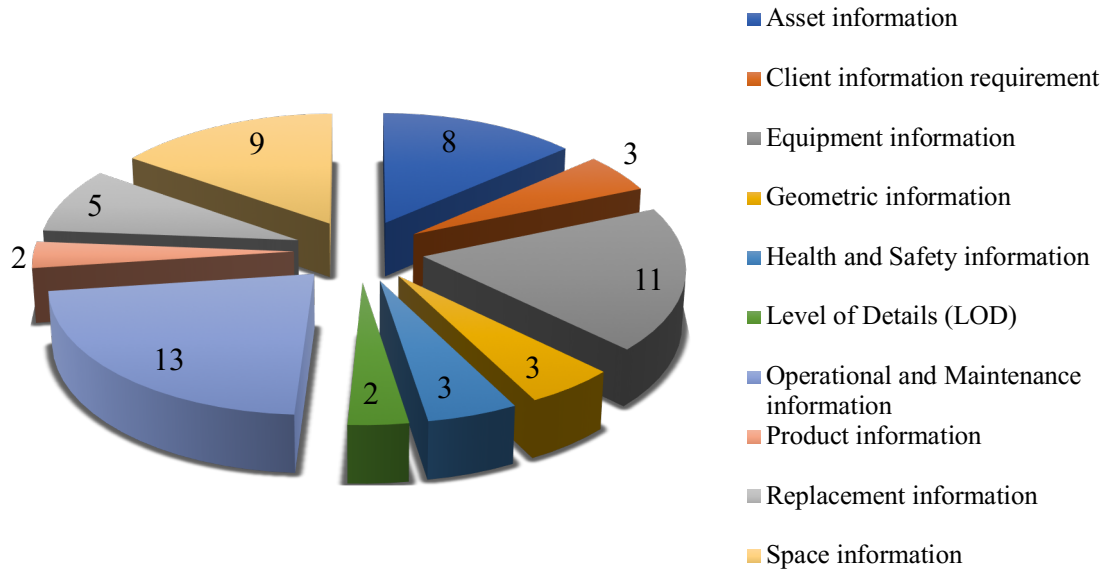


Figure 6.7 Key Information Requirement

6.5.2.1 Asset Information

From the main findings, eight participants (ID05–EJ, ID06–SB, ID08–PS, ID09–EB, ID12–PM, ID15–MF, ID16–AA, ID19–GK) perceived asset information as crucial in the operation and maintenance of building. They agree that asset information such as asset registers (unique ID, reference number, etc), life expectancy of asset and commissioning dates are valuable aspects during information handover. A survey conducted by Williams et al (2014) found that asset management was among the crucial materials needed in FM systems. Therefore, it is suggested by the finding that asset information is one of key information requirements to help facilities managers to identify asset and keep track records.

6.5.2.2 Space Information

Space information, also known as space management, includes activities of assigning space coding or room numbering guidelines in relation to assets locations. Nine participants (ID05–EJ, ID06–SB, ID09–EB, ID12–PM, ID14–HK, ID15–MF, ID16–AA, ID17–SD, ID19–GK) emphasized on space information as key information requirement for the FM tasks to identify the type spaces and rooms utilize in the building. The results undertaken thus far are consistent with an earlier study by Becerik-Gerber et al (2012), confirming that space information was indeed a crucial aspect in handling the facilities and location of assets.

As a result, space information is important aspect to facilities manager to identify the types of space/rooms where assets located.

6.5.2.3 Operation and Maintenance Information

Operation and maintenance information is the underlying FM practice that involves the inspection of a particular component or asset at several time intervals. Thirteen participants (ID02, ID03, ID05, ID07, ID08, ID11, ID12 ID13, ID15, ID16, ID20, ID21, ID22) agreed that defining a maintenance plan and coding for a particular asset are relevant information and it should be established before starting building operation. One good reason for this is that it supports previous studies by Becerik-Gerber et al (2012) and Williams et al (2014) who found that a facilities manager acquired information for operation and maintenance enable facilities manager is able to plan long-term building inspection with the help of acquired information for operation and maintenance. Therefore, to a high level, operation and maintenance is one of the key information requirements for FM.

6.5.2.4 Replacement Information

Furthermore, another piece of highly required information is replacement information. In the event of an equipment failure, broken asset or a malfunction, information or specification about a product are equally important for the manufacture or supplier as part of the process of refunding, replacing, or repairing the product. Facilities managers need that information as well to place orders for replacement. Four participants (ID07, ID08, ID13, ID14) jointly agreed that replacement information such as replacement parts, specification, value and cost are highly advantageous to a facilities manager's efficiency, such requirement is highlighted in the BS1192-4 standards, emphasizing on the importance of replacement information as part of defining Employer Information Requirement (EIR) to enable facilities managers to make use of the information to estimate the expected service life and cost of replacement.

6.5.2.5 Equipment Information

The next category of key information required for managing a building operation is equipment information, which is mainly about the mechanical, electrical and plumbing (MEP) matters. An equipment list featuring the heating, ventilating, air-conditioning and lighting systems are necessary for inspection in case of an emergency in the building. Almost half of participants (ID03, ID07, ID08, ID11, ID14, ID15, ID16, ID17, ID18, ID20) saw this as an imperative act in running building operation to ensure functionality at all times. A study by Becerik-Gerber et al (2012) even highlighted the importance of equipment

information as a crucial requirement for FM to inspect whenever there is a defect or faulty occur. Hence, it has shown that the equipment information to FM wherever there is a need to inspect a reported defect or fault.

6.5.2.6 Miscellaneous Information

Miscellaneous information was established as the key information requirement as the emerging information that mentioned by the interviewees. The information included are the health and safety information and product information that particularly relevant to certain organization. Health and safety information includes Occupational Safety and Health compliance, industrial hygiene (i.e. indoor air quality), risk assessment, sprinkler systems, fire extinguisher information, fire alarm system and more. Meanwhile product information could attribute to length, width, height, colour, weight of a particular asset. On the other hand, other opinions indicate the key information would depend on the client's requirement to decide their priority in managing their building.

6.5.3 Category 3 - Adoption Factors of Open BIM Standards and Guidelines

This section aimed to investigate the second objective of this research; the key factors that influence the adoption of open BIM standards and standards guidelines. Three areas were discussed with the participants regarding (i) compliance to any standards and guidelines, (ii) strategy in capturing information for FM use, and (iii) the key factors that influence the adoption of open BIM standards and standards guidelines.

6.5.3.1 Compliance to Standards and Guidelines

In the first part of the discussion, the participants were asked if they complied with the standards and guidelines in adopting of open BIM standards in general. Seventeen participants (ID01-BR, ID03-RT, ID04-JP, ID05-EJ, ID07-SO, ID08-PS, ID09-EB, ID12-PM, ID11-SM, ID13-JH, ID14-HK, ID15-MF, ID16-AA, ID17-SD, ID19-GK, ID20-KVR, ID21- BT) indicated their compliance to some standards and guidelines. Table 6.2 elaborate in detail the standards and guidelines that had been mentioned by the participants.

On the other hand, five participants (ID02-AS, ID03-RT, ID06-SB, ID18-DF, ID22-CB) who took part in the interview mentioned that they have yet to comply with any standards and guidelines in adopting BIM. Even though yet to comply, three of the participants (ID10-DB, ID14-HK, ID12-PM) mentioned that they are not to follow the conventional standard

of doing BIM project, and another two participants (ID06-SB, ID14-HK) mentioned that they are still developing the proper strategy to start a BIM project within their organization.

Table 6.2 Compliance to Standards Guidelines

Standards guidelines	Content	Frequency
PAS 1192-2:2013	Specification for information management for the capital/delivery phase of construction projects using building information modelling	13
BS1192-4:2014	Collaborative production of information. Fulfilling employer's information exchange requirements using COBie. Code of practice	12
PAS1192-3:2014	Specification for information management for the operational phase of assets using building information modelling (BIM)	5
PAS1192-5	Specification for security-minded building information modelling, digital built environments and smart asset management	2
UNICLASS	A unified classification for the UK industry covering all construction sectors. It contains consistent tables classifying items of all scale from a facility such as a railway down through to products such as a CCTV camera in a railway station	2
SGF20	Library of maintenance specifications for building engineering services is the industry standard for planned maintenance and an essential tool in tendering, service level re-modelling and auditing.	2
CIC BIM Protocol	The supplementary legal agreement that can be incorporated into contractual documentation establishing obligations, liabilities and limitations on the use of building information models.	2
EIR	A document designed to establish information management requirement that is intended to be part of the wider tender document set for the procurement of the design and construction team.	3
BSRIA Soft Landings	A building delivery process which runs through the project, from inception to completion and beyond, to ensure all decisions made during the project are based on improving operational performance of the building and meeting the client's expectations.	1
BIM Execution Plan	Developed both pre- and post- contract and is prepared as a direct response to the Employer's Information Requirements (EIR).	1
ISO 55000	A standard that provides terminology, requirements and guidance for implementing, maintaining and improving an effective asset management system.	1
BS1192: 2007 +A2016	Collaborative production of architectural, engineering and construction information. Code of practice	1

From the **Table 6.2**, the main findings identify that PAS1192-2 and BS1192-4 are noted as the most significant standards mentioned. The former is established as a guide to implement BIM during the design and construction phase, while the latter is established to guide the adoption of COBie. However, only five participants (ID07-SO, ID12-PM, ID15-MF, ID17-SD, ID19) indicate to comply PAS1192-3 standards. The findings suggest that PAS1192-2 is more common among the participants that involved in BIM project in the design and construction than those who mentioned PAS1192-3 that can facilitate the adoption of BIM in operational and maintenance phase. As the results, the awareness of PAS1192-3 is still low among the participants. Meanwhile, the BS1192-4 in adopting COBie is mostly common for both participants with the knowledge of BIM and/or FM in this context.

6.5.3.2 Strategy in capturing information for FM use

In view of this strategy, the interview session direct participants to describe their strategy in capturing information for FM use. Multiple strategy has been highlighted in **Figure 6.8** and were grouped into three main themes, i.e. (i) people, (ii) process, and (iii) technology.

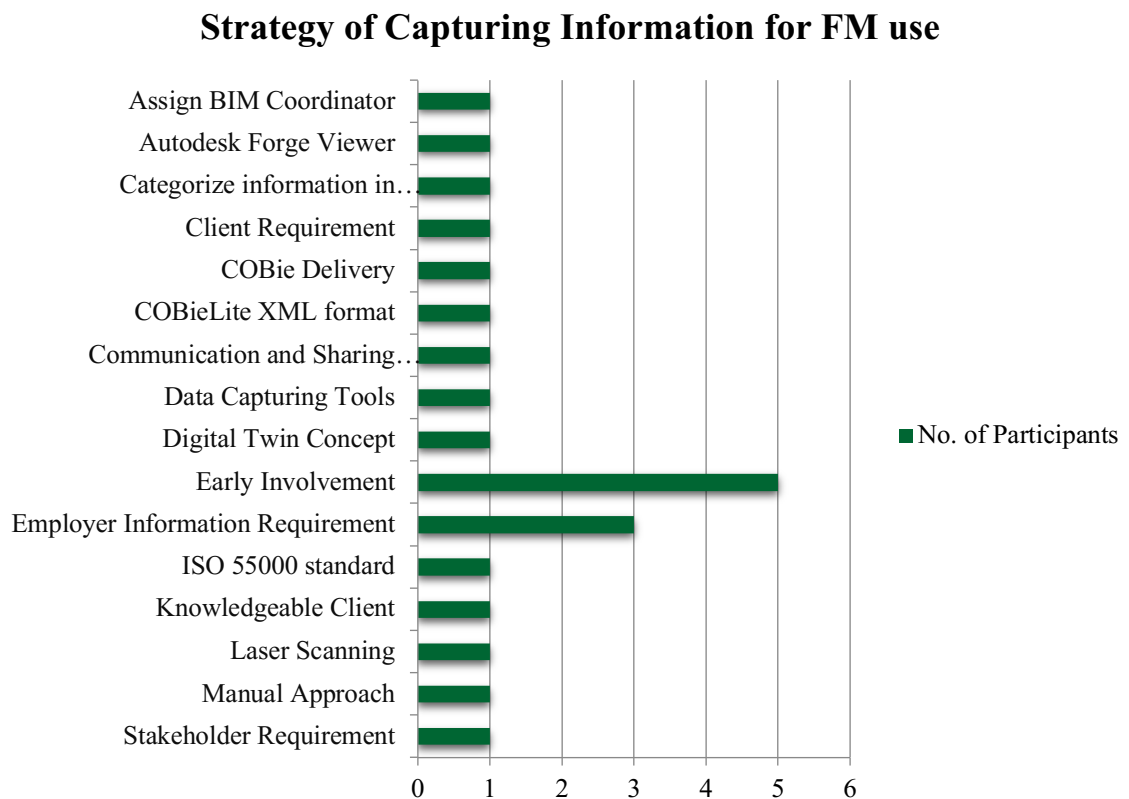


Figure 6.8 Strategy of Capturing Information for FM Use

6.5.3.2.1 People

Client Requirement/ Employer Information Requirement (EIR) - The most notable finding is the Employer Information Requirement (EIR). It might be inferred, thus, that at least six participants (ID11-SM, ID13-JH, ID14-HK, ID16-AA, ID20-KVR, ID21-BT) had viewed the EIR as the determinant to whether COBie deliverables and IFC will be extended to FM. However, the view of two other participants (ID14-HK, ID20-KVR) were favourable to the role of facilities manager whom they thought was essential to client/employer who would like a better understanding of the information that they required in EIR. This finding provided for a trace of consistency with the extensive literature reviews and expert discussions. Therefore, the EIR is indeed a key factor that helps influence the adoption of COBie and IFC in FM.

Assign BIM Coordinator - Another strategy used to capture information for FM is to assign a BIM coordinator. The role includes in managing digital handover information from construction to operation maintenance phase. This could ease the task of facilities manager to focus on other tasks during the handover stage. BIM coordinator may act as a mediator between the design and construction team to FM team in sharing digital information exchange through COBie or IFC to assess its quality and validity of the information. In the main qualitative analysis, interview participant ID22 suggest the BIM coordinator should be able to manage information modelling and manipulate of those information for FM use.

6.5.3.2.2 Process

Categorization information in Classification - Classification of information is essentially important in exchanging information using COBie or IFC in FM to able to understand the specific type of information about facilities. The use classification system such as UNICLASS, OMNICLASS and SFG20 is useful in defining the structure and hierarchy of information in FM system. In main qualitative findings, interview participant ID15 suggest that the process of defining information in classification systems would help in information delivery to FM systems.

Communication and sharing information - Communication between project team and FM team allow information to be shared in a mutual agreement. The role of facilities managers may act as a supervisory or facilitator role between client side, contractor and supply-chain in liaising effectively the meet the key information requirement for FM. Interview participant

ID07 suggested a dialogue between the design and construction and FM need to establish to allow mutual understanding to facilitate the information requirement about facilities.

Early phase involvement of FM - Involvement of facilities managers in an early stage is favourable, as told by the participants when asked about the strategy in capturing information for FM use. They viewed early stage involvement as the key to setting up for information requirement. Five participants (ID07-SO, ID12-PM, ID16-AA, ID17-SD, ID21-BT) mentioned involvement by supporting EIR is even more significant in making sure the relevant information is ready upon completion of the building.

Standard Guidelines - The standards guidelines such as ISO55000 standards enable of facilities managers to understand the process of managing asset acquisition. The ISO55000 standards provide terms and definitions, requirements and guidelines for implementing maintaining and improving an effective asset management system. In the findings, interview participant ID21 proposed the use ISO55000 enable to support and guide facilities managers in defining asset management policy, asset management plan and other organization policy and strategy for the handover. ISO55000 standards also imparted in the PAS1192-3: 2014 standards aligning with the implementation of BIM in operation and maintenance phase.

COBie delivery/COBieLite XML format - COBie is created purposely for information exchange and creation between commercial software systems (i.e. BIM and FM systems) to share non-graphical information about facilities. In the findings, two participants (ID09-EB, ID19-GK) assert that they use COBie delivery as the strategy to capture information for FM. Interview participant ID19 suggest to adhere to COBie delivery such as COBie drops that helps to accumulate the granularity of data from the design and construction stage to FM stage. On the other hand, interview participant ID09 asserts that the development of COBieLite format allows them to filters BIM information to a set of relevant information for FM use.

On-site building survey - Traditional method of capturing information is through building survey. It involves thorough inspection, user demonstrations and witnessing of commissioning and test. It is one of the practical part of conducting FM task. During the pre-handover, a provision pre-handover checklist (i.e. issuing certificates, inspection of equipment or services, O&M manuals, record drawings, etc) are issued to ensure all the activities and programme are met with the contract requirement and mutually agreed. In the

qualitative findings, two participants (ID07-SO, ID18-DF) suggest relying on building survey to capture necessary information inside the building into the FM system, alongside with using COBie and IFC.

6.5.3.2.3 Technology

Model viewer - Model viewer application allows user to access cloud-based FM with 3D model, equipment data and FM systems. The use of model viewer allows time-saving in navigating information through 3D model instantly and customize solution for occupants needs. Interview participant (ID09) describe converting a Revit file to Forge Viewer (model viewer) to navigate graphical information for FM use to locate asset information.

Data capturing tools/ Laser Scanning - Data capturing tools such as laser scanning, bar coding, radio frequency identifier (RFID) greatly facilitate in capturing information as required by the facilities managers. Participant (ID15) proposed the use of laser scanning and smart senses allow facilities managers to capture information on-site. Meanwhile, ID14 also suggest assisting data capturing tools and converting traditional documents enable facilities managers to work alternative to the use of COBie and IFC data exchange.

Digital twin concept - A digital twins is a highly complex virtual model that in tandem with a physical object in real-time data. The use of digital twin in FM allow facilities managers to analyse data from the connected sensors along with sources of information to make prediction of the building performance throughout its life-cycle. It allows identify faults, troubleshoot from distance and improves occupants satisfaction (Mikell and Clark, 2018). This concept initially suggested by interview participants (ID08) that digital twin allow facilities manager to manage the process of capturing information digitally using smart sensors within the building and publishes in a digital format instead of capturing data manually.

6.5.3.3 Key Factors Influences of Open BIM Standards and Guidelines

The last part of the discussion was about the key factors that influence the adoption of open BIM standards and standards guidelines in FM. The findings were clustered into eight main themes, (i) Value of BIM, (ii) Up-skilling, (iii) Cost, (iv) Communication with design and construction team (v) Awareness of BIM in FM, (vi) Regulation and Policy, (vii) Willingness to change. Since all the participants came from a diverse background, they have difference opinions in the adoption of open BIM standards and standards guidelines. **Figure**

6.9 highlighted the key factors that influences the adoption of open BIM standards and standards guidelines followed by detail explanation.

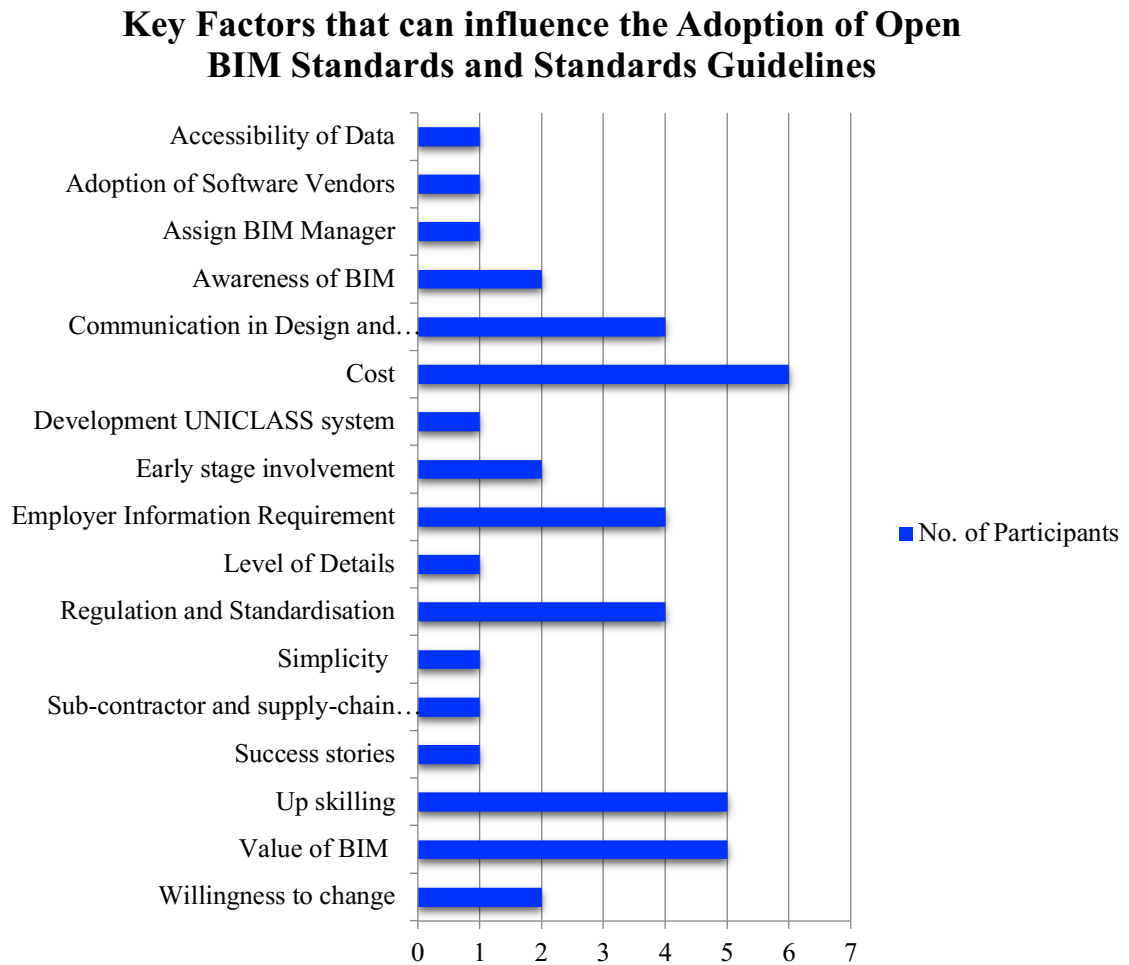


Figure 6.9 Key Factors Influenced Adoption of Open BIM

6.5.3.3.1 Value of open BIM standards

Under TAM, “perceived usefulness” refers the degree to which using IT could improve an individual jobs performance (Davis, et al. 1989). Similarly, the value of using open BIM standards (i.e. COBie and IFC) to FM has yet to realize its efficiency in conducting operation and maintenance tasks. Previous literature has discussed the benefits and challenges in adopting COBie and IFC (Parsanezhad and Dimyadi, 2014; DBIS, 2011; Becerick-Gerber, 2012; Williams, et al, 2013; Sabol, 2008; Mitchell and Schevers, 2006; Venugopal et al., 2012; Hetherington et al., 2011; Amour and Faraj, 2001). While according to main findings, four participants (ID06-SB, ID11-SM, ID16-AA, ID20-KVR) argued that the value of COBie and IFC could offer to improve the productivity of facilities manager’s tasks and client’s organization. Therefore, the value of COBie and IFC is a significant key factor that would have influence as part of the framework.

6.5.3.3.2 Simplicity

The more complex the BIM model is, the harder it gets to check each and every information its contained. User-friendliness and simplicity of using COBie and IFC in the FM systems help to increase the productivity of facilities managers. Simplicity shared similarity under the 'PEOU' variable in TAM – the level that COBie and IFC can be use without any complexity (Rogers, 2003). The qualitative analysis suggests simplicity in addressing the adoption of using COBie and IFC is necessary to equipped facilities managers with better understanding with the knowledge of knowing how to handle the digital information. Hence, under the TAM's variable, this study supports PEOU to have strong influence to facilities manager's behaviour intention to adopt open BIM standards and standard guidelines.

6.5.3.3.3 Awareness of BIM

Disruptive technology and innovation emerged may require a duration of time for people to understand how it works and bring value to them. Similar to BIM, awareness of the term BIM and how it benefits to facilities managers require knowledge and experience before deciding the adopts open BIM standards and the standards guidelines. In the literature, awareness of BIM is still low among facilities managers and attributed to misconceptions about what constitutes BIM which in turn causes a lot of confusion and difficulty in visualising its use (BIM4FM, 2013; Barlish and Sullivan, 2012). However, in the qualitative analysis, two interview participants (ID13-JH, ID17-SD) assert the awareness of BIM among facilities managers is the key to realise that information they would receive are flow in digital format as oppose to traditional paper-based documents. COBie and IFC are the means of information exchange that allow facilities managers to conduct operation and maintenance task efficiently. Therefore, the awareness of BIM supported the framework to have a strong influence to behaviour intention in adopting open BIM standards and standards guidelines.

6.5.3.3.4 Success Stories to Proof the Adoption COBie and IFC

Case studies and success story is significant to proof the adoption COBie and IFC is feasible and beneficial to FM task. In the literature, the lack of success stories in using COBie and IFC in FM hinders the value its bring to FM. Under IDT, the characteristics of 'observability' posit the degree to which the results of an innovation are visible to others (Rogers, 2003). This means the results of adopting COBie and IFC are able to assess by facilities managers through success stories/case studies Meanwhile, interview participants (ID12) suggest that learning through success stories can support the process of adoption in operation and

maintenance phase. Therefore, this study support ‘observability’ variable has a significant influence to behaviour intention in adopting open BIM standards and standard guidelines.

6.5.3.3.5 Cost of BIM Adoption

The cost of adopting COBie and IFC may translate to facilities manager as investing into the COBie-compatible, IFC-compatible FM software, training, hiring or outsourcing FM provider or IT specialist and the return on investment (ROI) analysis to client in adopting open BIM standards. A significant finding related to cost in adopting of COBie and IFC in FM has a significant influence. Six participants (ID15-MF, ID16-AA, ID18-DF, ID20-KVR, ID21-BT, ID22-CB) revealed that the financial benefits and evidence in payback period has yet to be proven. Although COBie and IFC are open standards guidelines and delivered primarily by the design and construction stage, the decision for its application will be extended to the clients upon completion of building. This finding, which is supported the study of Williams et al. (2013), is used to demonstrate the operational savings before a facilities manager could engage in a BIM-driven work environment. Another important issue related to the cost of implementing a FM system is COBie and IFC compatibility and hiring high-skilled personnel to manage the information delivery. In a nutshell, there are cost and competency issues accruing from the adoption of COBie and IFC before any work with BIM commences.

6.5.3.3.6 Up-Skilling

Acquiring knowledge, learning ability and training as part innovation and improving necessary skillset of facilities manager is essential in tackling technical problems at the workplace and organisation (Pärn et al., 2017; Jawadekar, 2012; William et al., 2013). The findings suggested up skilling as an important factor to reflect the facilities manager’s skill in adopting COBie and IFC. This show that while it is useful to update information in COBie and IFC within the FM system, increased learning can on the other hand help facilities manager to identify any changes or errors in the information. Learning and development, as suggested by four participants (ID08-PS, ID12-PM, ID19-GK, ID22-CB) offers a variety of work efficiency toward undertaking the information delivered via COBie and IFC. In support, previous studies by Jawadekar (2012) and William et al (2013) found that up skilling among facilities managers is important in handling COBie and IFC in the FM system.

6.5.3.4 Development of UNICLASS

In the literature, the challenges of adoption of COBie and IFC may attribute to lack standardisation of information. Classification of BIM data facilitates the function of COBie and IFC to determine the relevant and usefulness of information received in FM system. In the UK, the use of UNICLASS classification system can greatly help to understand the type of information about facility. In the qualitative analysis, participant ID15 argue the development of UNICLASS product table has enable facilities manager to see the granularity of product tables, thus, facilitate the facilities managers in handling COBie and IFC format in the FM system. Therefore, the classification in BIM data is posit to have significant influence to behaviour intention in adopting open BIM standards and standard guidelines.

6.5.3.5 Accessibility of Data

To access data is required facilities manager equipped with the right IT infrastructure and FM system to be able to access information readily. In the literature, FM systems (i.e. CAFM/CMMS) are the tools for facilities manager to access information regarding operation and maintenance task, as shown in Chapter 3, several commercial FM systems are able to exchange information in most of the COBie spreadsheets than IFC format. Hence, assisted cloud-based FM system could help in facilitating model viewer for visualisation and navigation purposes. In support participant ID12 explained that the importance of accessibility of data in terms of the processes and workflow of how data is delivered across FM system in a usable and understandable format as oppose to a large set of data reserved.

6.5.3.6 Other Emerging Key Factors in the Interview Findings

6.5.3.6.1 Adoption of FM Software Vendors

The development of compatibility data exchange format to feed BIM information about facility is significant to promote the adoption of BIM in FM. Only a handful of FM systems can accept both COBie and IFC into their system. Most FM systems are database management systems that are compatible with MS Excel (.XSL) format. Therefore, adoption of COBie and IFC among software vendors plays an important role to promote the capability to work in a BIM-enabled practice among facilities managers. In fact, participant ID05 argued that the awareness of adoption of COBie and IFC through FM software vendors to promote a wide market for BIM-based FM.

6.5.3.6.2 Assign BIM Manager

As previously discussed 6.5.3.2.1, the lack of skilled set and knowledge in the FM industry in BIM leads to facilities managers to assign BIM manager to handle the process of transferring information from BIM to FM system. As this position becomes IT-led facilities manager whose scope of work focus on interrogating, checking, validating the information received from BIM systems–COBie and IFC, and requesting information from the design and construction team for any error or missing information about the facility. Participant ID03 points out in appointing BIM manager to coordinate information exchange in COBie and IFC in FM system.

6.5.3.6.3 Level of Details.

The level of details means the extent to which the details of non-graphical information required by the facilities managers. A wide array of information in BIM model can be overwhelming and hard to determine its usefulness to FM task. To set the level of details required in early stage would help to set a relevant key information requirement at the outset of BIM project. In the findings, participant ID03 suggest facilities manager should define to what level of details they required as part of BIM execution plan to facilitate the adoption of COBie and IFC in FM phase.

6.5.3.6.4 Sub-Contractor and Supply Chain

The sub-contractor and supply chain contribute to the information received in FM. As most of sub-contractor and supply chain has yet the capability to adopt BIM itself can hampers the adoption COBie and IFC in FM. Participant ID03 argued that the challenges in the readiness of sub-contractor and supply-chain working with BIM poses challenges to capture the key information required for facilities manager to conduct operation and maintenance task.

6.5.3.6.5 Communication with Design and Construction Team

The uses of BIM have been heavily discussed in design and construction in generating 3D, 4D, 5D and nD (Abbasnejad and Moud, 2013; Lee et al, 2003). Therefore, to increase the awareness of capturing the information needed in the BIM model, facilities manager should closely communicate with the designer and contractor to request the key information requirement before the commissioning and handover period. Four participants (ID01-BR, ID15-MF, ID17-SD, ID19-GK) in the main findings indicate that vigorous communication and engagement with design and construction team can facilitate the adoption of COBie and

IFC. Furthermore, previous studies highlighted the importance of communication with the design and construction team can improve the adoption of COBie and IFC (Wang et al., 2013; Williams et al., 2013).

6.5.3.6.6 Regulation and Policy

Governmental institution and organisational policies such as the BIM4FM, BIFM, BSRIA, buildingSMART, BRE, BSI should play a significant role in promoting the adoption of COBie and IFC in FM. Establishment of standards and guidelines and support in technicalities of information exchange and language use in FM can influence the process of adoption better. Four participants (ID11-SM, ID12-PM, ID14-HK, ID20-KVR) raised the issue of government regulation and policy in BIM level 2 to push different types of BIM project to FM and active role of buildingSMART, BIFM and BIM4FM to provide technical support and guidance to make the adoption of open BIM standards simpler.

6.5.3.6.7 Willingness to Change

The ever-changing workplace culture and the introduction to various cutting-edge technologies has impacted the practice of facilities manager. As most of the facilities managers not IT literate, the use of BIM (i.e. COBie and IFC) could easily intimidated and alienated in the process, thus, resistance attitude towards BIM consequently affect the rate of adoption in their organisation. According to the findings, two participants (ID08-PS, ID18-DF) highlights the fear of technology and lack of incentive in adoption of open BIM standards and standards guidelines influence the willingness to change in FM practice. Previous literature discussed on the change management or practice dealing with technology (Lewis, 2013; Noor and Pitt, 2009).

6.5.3.7 Summary of the Adoption of Open BIM Standards and Guidelines

Through the cross-analysis, it was found that the compliance of BS1192-4 for adopting COBie fares better than the PAS1192-3 standards. This means the awareness of BS1192-4 for adopting COBie is widely used than the PAS1192-3 standards that guide FM in implementing BIM. Ten participants (ID01-BR, ID03-RT, ID05-EJ, ID07-SO, ID08-PS, ID13-JH, ID15-MF, ID16-AA, ID17-SD, ID19-GK) claimed to comply to BS1192-4 standards in adopting COBie, but only two participants (ID09-EB, ID19-GK) actually used it as the strategy in capturing information for FM use. This suggests that those with the knowledge and experience in BIM and FM understand the use of COBie for FM, even though

other participants (e.g., ID01-BR, ID04-JP) acknowledge COBie as a means of client requirement may not have knowledge of extended use for FM.

Apart from this, the compliance of both BS1192-4 and PAS1192-3 only limited to participants with both knowledge of BIM and FM. Participants (e.g. ID03-RT, ID11-SM) with knowledge and experience only in BIM area, suggest to start at the outset of BIM project by setting the employer information requirement for FM use. In contrast, participants with knowledge and experience proposed the value of BIM and cost of adoption and involvement in the early stage can influence the adoption of open BIM standards and standards guidelines better. Therefore, the emerging issues revealed in the main findings include assigning BIM manager and willingness to change in practice seems to suggest that the skill gap among facilities managers can be the main challenges that impedes the willingness to change in practice.

6.5.4 Category 4 - BIM Guidelines Supporting Adoption of Open BIM

The BIM guidelines supporting the adoption of open BIM standards were divided into three sub-topics, (i) sufficiency of standards and guidelines for FM, (ii) compliance of standards and guidelines (PAS1192-3 and BS1192-4), and (iii) understanding of standards and guidelines in adoption of BIM in FM.

6.5.4.1 Sufficiency of Standards and Guidelines

Referring to the in-depth interview, participants were asked whether there are sufficiency of standards and guidelines in adopting open BIM standards in FM context. Figure 6.10, eight participants (ID01-BR, ID04-JP, ID10-DB, ID13-JH, ID14-HK, ID15-MF, ID20-KVR, ID22-CB) argued that inadequacy of standard and guidelines for FM due to unclear roles, lack of accessibility to facilities manager and only addressed to the design and construction team. On the hand, only four participants (ID07-SO, ID08-PS, ID12-PM, ID16-AA) agreed that facilities managers could access to various resources in standards and guidelines to make an informed decision to adopt COBie and IFC. In spite of this, four participants (ID02-AS, ID05-EJ, ID06-SB, ID17-SD) are optimistic that the proper standards and guidelines are yet to establish officially and in progress. The remaining six participants (ID03-RT, ID09-EB, ID11-SM, ID18-DF, ID19-GK, ID21-BT) argue that the existing standards and guidelines are opaque, overcomplicated and full of ambiguity for facilities managers that lead to difficulty in adoption.

Sufficiency of Standards Guidelines

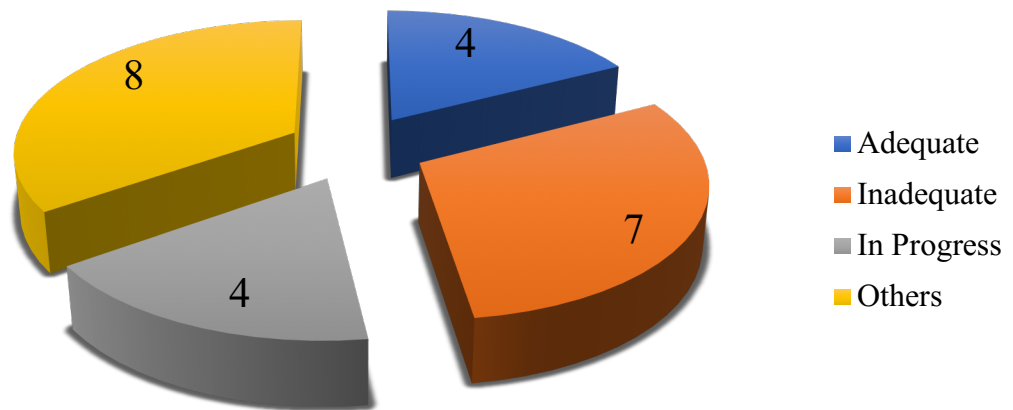


Figure 6.10 Sufficiency of Standards Guidelines

6.5.4.2 Compliance of PAS1192-3 and BS1192-4

The next question discussed on the compliance of standards and guidelines PAS1192-3 and BS1192-4. Perceived to **Figure 6.11**, only five mentioned (ID03-RT, ID07-SO, ID12-PM, ID15-MF, ID17-SD) to complied to both PAS1192-3 and BS1192-4 standards guidelines. While, the other five participants (ID01-BR, ID04-JP, ID05-EJ, ID09-EB, ID13-JH) point out that they complied only BS1192-4 in delivering COBie.

Compliance to PAS1192-3 and BS1192-4

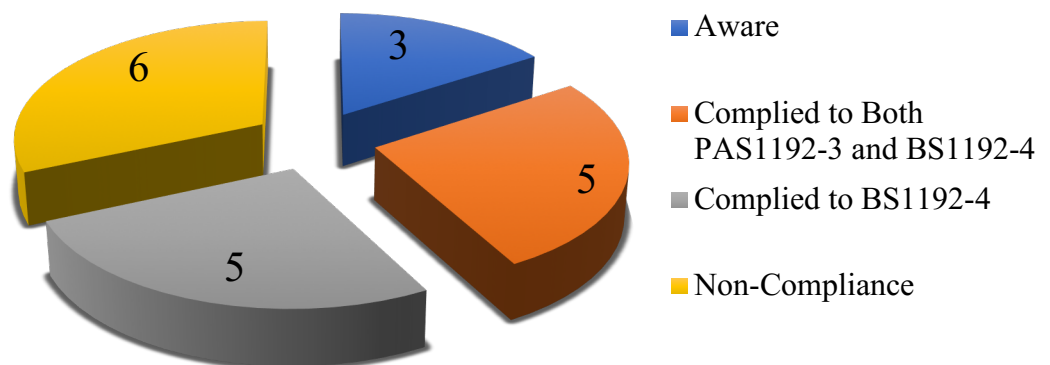


Figure 6.11 Compliance to PAS1192-3 and BS1192-4

However, another five participants (ID02-AS, ID10-DB, ID16-AA, ID18-DF, ID21-BT) claim that they do not comply to any of these standards and guidelines. Finally, the remaining three participants (ID06-SB, ID11-SM, ID14-HK) indicate otherwise as to merely aware of both standards and guidelines for reference and advising client to comply.

6.5.4.3 Understanding of the adoption of open BIM standards in FM

Subsequently, the interview question that was discussed with the participants is to express their opinion on the issue of facilities manager understanding of the above-mentioned standards guidelines in adopting open BIM standards. In **Figure 6.12**, twenty participants (ID01-BR, ID03-RT, ID04-JP, ID05-EJ, ID06-SB, ID07-SO, ID08-PS, ID09-EB, ID10-DB, ID11-SM, ID12-PM, ID13-JH, ID14-HK, ID15-MF, ID16-AA, ID17-SD, ID19-GK, ID20-KVR, ID21-BT, ID22-CB) were in agreement that facilities managers do not entirely understand the standards and guidelines in exploiting open BIM standards. From the findings, most participants suggested that facilities managers may have limited knowledge pertaining to COBie and IFC. This shows that unclear set of information requirements that limits their ability to understand the potential of managing the building operation. On the other hand, the remaining three respondents (ID02-AS, ID16-AA, ID18-DF) stated otherwise that they are uncertain about standard guidelines could facilitate the adoption better.

Understanding of standards guidelines in adopting open BIM standards in FM

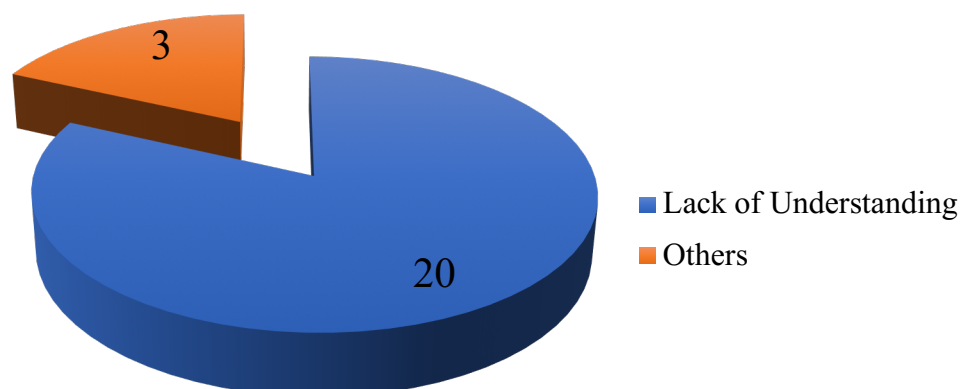


Figure 6.12 Standards Guidelines In Adopting Open BIM Standards in FM

6.5.4.4 Summary Supporting Adoption of Open BIM Standards

Overall, it was clear that the inadequacy and low compliance of PAS1192-3 and BS1192-4 standards combined with the lack of understanding in the standards and guidelines create complexity and uncertainty in willingness to adopt COBie and IFC. Although, participants with great knowledge and experience in both subject BIM and FM claim to comply to these standards and guidelines, they argue it may not necessarily be comprehensible to facilities managers audience. In addition, both participants with great knowledge and experience that limited to one area either BIM or FM assert similar view of inadequacy of standards and guidelines to support the adoption.

6.5.5 Category 5 - Framework Facilitate Open BIM Standard and Guidelines

Framework discussion were part of the interview questions. The framework suggestion was discussed into two parts, (i) concepts on how to exploits open BIM standards (COBie, IFC) and the standards guidelines in adopting BIM in FM, and (ii) further comments/recommendations. From the results, it was confirmed that BIM knowledge, the EIR and involvement in design and construction stage significantly influence to the framework that facilitates the adoption of open BIM standards and standards guidelines.

6.5.5.1 Concepts/Tasks to Exploits Open BIM Standards and Guidelines

The participants were asked to suggest a concept/task on how facilities managers could exploit open BIM standards and the standards guidelines. From thematic analysis, several themes discovered eight main areas with respect to exploiting open BIM standards and the standards guidelines. **Figure 6.13** described the themes and explored the eight identified areas. These areas include (i) Value of BIM, (ii) Awareness of BIM, (iii) Early involvement, (iv) Communication in design and construction team (v) Employer information requirement, (vi) Hands-on experience, (vii) Success stories/Case studies, (viii) BIM knowledge.

Key Concepts/Tasks to exploits Open BIM Standards and Standards Guidelines

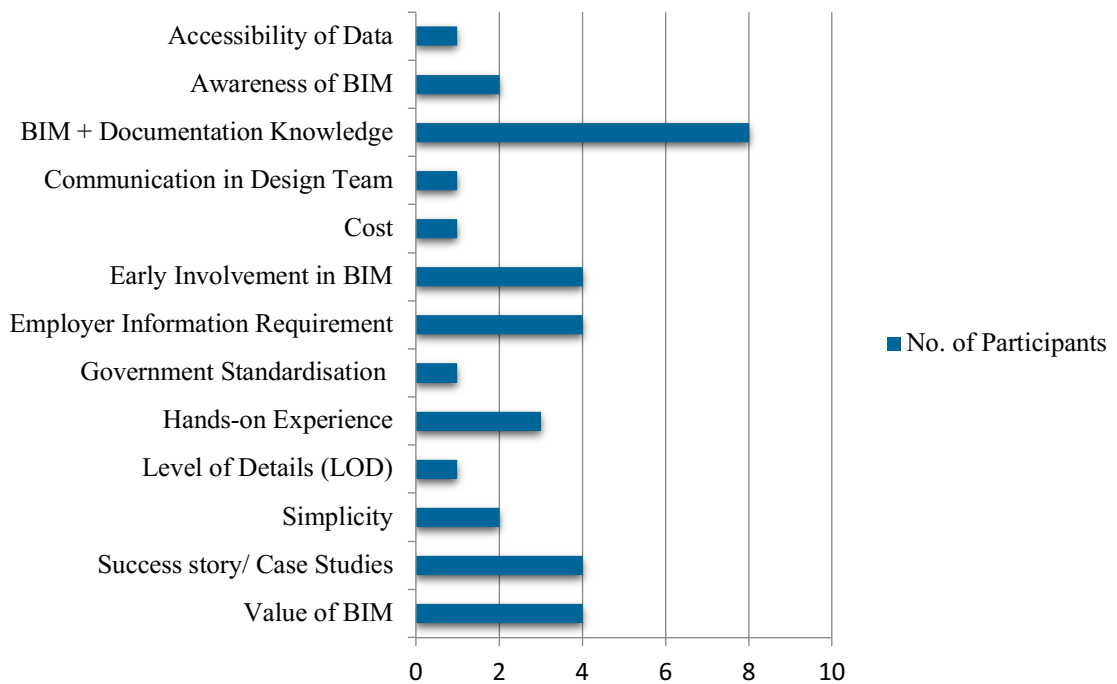


Figure 6.13 Key Concepts/Tasks to Exploits Open BIM Standards

6.5.5.1.1 Value of BIM

Recurring theme from section 6.5.3.3, the discussion of the value of BIM (i.e. COBie and IFC) to FM is vital to influence facilities manager to decide whether they will adopt it in practice. In-depth interviews with two academicians and four practitioners highlighted the value of using COBie and IFC, and further emphasised that this could bring to facilities managers in terms of performance, operational use and to the building owner.

6.5.5.1.2 Early Involvement

Similarly, early involvement of FM in outset of a project could inform client and designer to deliver COBie and IFC as an information exchange to FM. Requesting the necessary information requirement to maintain and operate building could save time of checking, requesting and verifying the data during the handover stage and increase the performance and productivity in reducing the probability of missing information and error in conducting FM task. The qualitative findings propose that early involvement and engagement with client's project could better facilitate the adoption of COBie and IFC and the standards and guidelines.

6.5.5.1.3 Communication with Design and Construction Team

The gap between design and construction team and FM team is still an on-going debate has yet to reach a consensus. The disparate between built environment disciplines leads to hands-off attitude anything that is beyond their scope of work. Communication with design and construction team enable facilities manager to discuss the sort of information required in COBie or IFC format and also advise on the design for maintainability and serviceability aspect of building to save operational cost. One interview participant (ID16-AA) suggest that communication with design and construction team can build rapport in delivering relevant key information in the form of COBie/IFC format to better facilitate the adoption during the operation and maintenance stage.

6.5.5.1.4 Employer Information Requirement

The EIR document is set out for client to determine the information requirement to informed the project team, main contractor, supply chain at different stages of BIM project. This document contains standards methods of procedure, role and responsibility of supplying, delivering, exchanging information in COBie and IFC to operation and maintenance phase (BSI, 2014). From the findings, four participants (ID03-RT, ID04-JP, ID07-SO, ID16-AA) suggest the inclusion of FM in the EIR influence the likelihood of adopting of COBie and IFC and standards and guidelines in operation and maintenance phase.

6.5.5.1.5 Hands-On Experience

In IDT, trialability is the degree to which innovation may experimented and test on a limited basis (Rogers,2013). Similarly, hands-on experience of testing and experimenting COBie and IFC in small-scale project could help facilities managers to make informed decision in the intention of adoption. Three participants (ID07-SO, ID14-HK, ID21-BT) indicated that the hands-on experience of using COBie and IFC would enable facilities managers to understand and familiarize with the nature COBie and IFC to able to integrate with the FM system.

6.5.5.1.6 Success Stories /Case Studies

Success stories or case studies of full scale BIM-FM project enable FM to evaluate the benefits and challenges that they will faced in adopting COBie and IFC and the standard guidelines. Several case studies has been demonstrated in the previous literature in university buildings, public library in the UK (Kassem et al, 2015; Condihoto et al., 2013; Onyenobi et al., 2010). However, the demonstration of using COBie and IFC remains limited to the extent

to which COBie and IFC could influence facilities managers to adopt it in near future. While in the main findings, four participants (ID08-PS, ID12-PM, ID17-SD, ID19-GK) support the argument more evident-based of using COBie and IFC in BIM-FM project is needed demonstrate its value to facilities manager in order to better facilitate the adoption.

6.5.5.1.7 BIM Knowledge

Knowledge of BIM-FM related is necessary for facilities managers to understand the information exchange (i.e. COBie and IFC), associated documents as such EIR, Asset Information Requirement (AIR), Organization Information Requirement (OIR) that provided in the PAS1192-3 and BS1192-4 standards. The knowledge gap among facilities managers in working with COBie and IFC, know-how to update information in FM system and strategic plan for operation and maintenance are crucial to have adequate knowledge before they could decide to for adoption. Seven participants (ID01-BR, ID05-EJ, ID07-SO, ID08-PS, ID09-EB, ID11-SM, ID19-GK) suggested facilities manager should equipped the knowledge of BIM that related to their practice and understand the role and responsibility in using COBie and IFC as information exchange to integrate in the FM system as oppose to the manual handing over of information in operation and maintenance phase.

6.5.5.2 Comments and Recommendation

The last question provides interview participants to express their thoughts, opinion and recommendation in this research study. From the thematic analysis, three main areas highlighted regarding to (i) knowledge of BIM, (ii) value of BIM, and (iii) Collaboration and Communication. Out of three areas, the importance of BIM knowledge among facilities managers emerged as most noticeable theme in the findings. Seven participants (ID01-BR, ID02-AS, ID07-SO, ID14-HK, ID18-DF, ID19-GK, ID22-CB) agree acquiring relevant knowledge handling BIM in FM especially in adopting COBie and IFC. Figure 6.14 describe the comments and elaboration of each comment accordingly.

Collaboration and Communication with the design and construction team can support facilities manager in sorting the information required in COBie or IFC format and also advise on the design for maintainability and serviceability aspect of building to save operational cost. Three participants (ID03-RT, ID15-MF, ID17-SD) recommend collaboration and communication between project team and FM team allow better facilitation in delivering relevant key information requirement in COBie and IFC.

Furthermore, the **value of BIM** in FM indicates the extend to which BIM could be useful to both facilities manager and owner. In the analysis, three interview participants (ID09-EB, ID14-HK, ID19-GK) comment the value of BIM for facilities manager and owner of building to realise the feasibility and viability that the adoption of COBie and IFC can resulted increased in job performance and cost reduction.

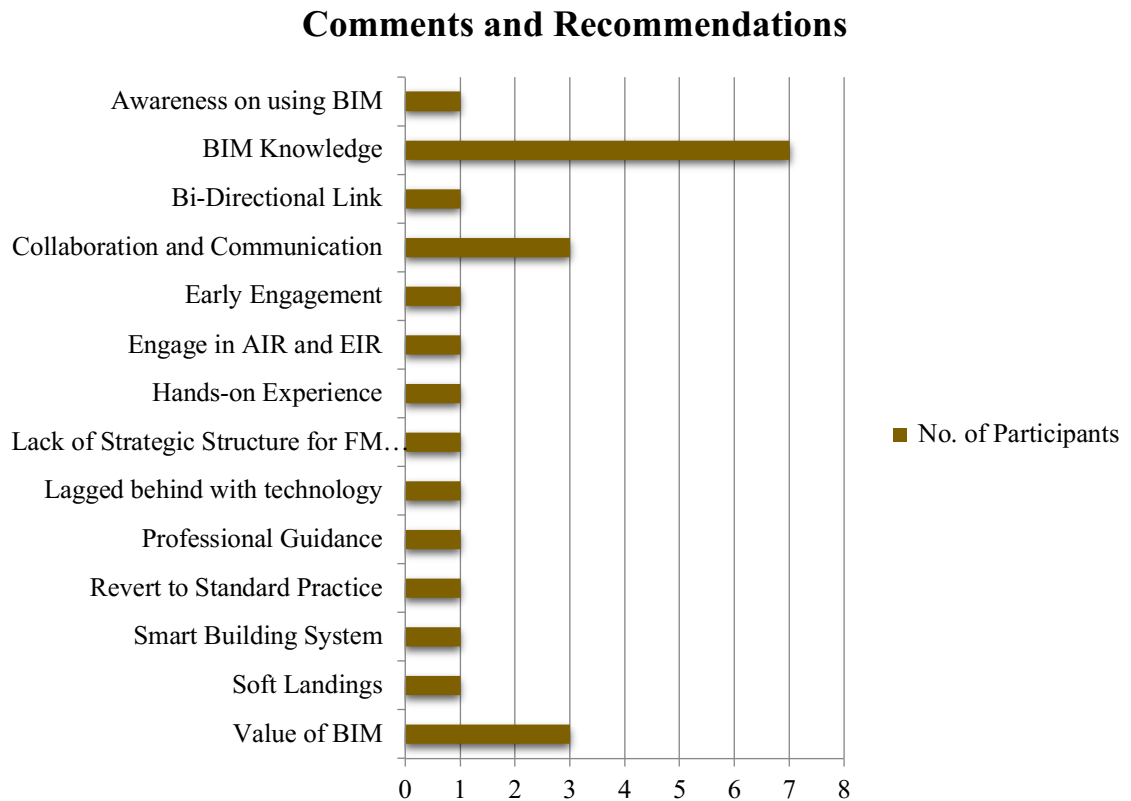


Figure 6.14 Comments and Recommendations

6.5.5.3 Summary of Framework of Open BIM Standards and Guidelines

In conclusion, three main concepts have been reinforced through the framework to facilitate the adoption of open BIM standards and standards guidelines. Participants with a great knowledge of BIM and FM proposed the main concept of the framework is the knowledge of BIM that pertinent to FM such understanding of the EIR, asset management strategy, organizational information requirement and successful stories to assess how it can be adopted. On the other hand, participants with knowledge and experience (e.g. ID16-AA, ID17-SD) only in BIM propose communication with design team and engagement with client in EIR document can improve the adoption better. Meanwhile, participants with knowledge and experience only in FM propose the value of BIM to FM and successful stories that determine the adoption can improve the efficiency of handling FM task. The emerging issues highlighted by the participants including simplicity of the BIM processes in

FM and cost of adoption influence the uptake of open BIM standards and standards guidelines.

6.6 Qualitative Analysis Inputs to Questionnaire Items

The qualitative analysis showed that the primary questionnaire items were formulated and reiterated from the literature reviews, informal discussions with experts, pilot studies and the main findings. From the main findings, each area of the discussed topic during the in-depth interviews conformed to the questionnaire items, as shown in **Figure 6.2**. Morgan (2014) suggested that the goal of qualitative inputs in a survey is to determine the constructs of the questionnaire items. The purpose was to support the creation of each item through wordings for the questionnaire that is meaningful to the respondents (Morgan, 2014). At the same time, the qualitative input also discussed on the emerging issue in qualitative data and as well as validating the proposed questionnaire items. Therefore, the results from the qualitative study was used to inform with the formulation of the questionnaire items.

The questionnaire items, revising variables and statements of construct based upon the results from the in-depth interviews, are the main themes of this section. The main part of the questionnaire was created to assess the two main sections. The first section comprises a series of background questions; primary job function, average size of organization, type of facilities, knowledge and experience in BIM/FM, and experience in BIM systems and/or FM systems. The second section is divided into four categories; (1) relevance of key information requirement, (2) key factors that influence the adoption of open BIM standards and standards guidelines, (3) BIM guidelines that support open BIM standards and, (4) framework that can facilitate the adoption of BIM in FM.

6.6.1 Background Information

The multiple-choice background information questions were adapted from the previous studies (Becerik-Gerber et al, 2012, Williams et al, 2013) in order to identify each respondent's primary job function, average size of organization, types of facilities involved, and knowledge and experience in BIM/FM, BIM systems and FM systems. The constructs of each question remain the same but the choice of answers was added based on the findings of the main qualitative study.

6.6.2 The Extent BIM Guidelines Can Support Open BIM Standards in FM

This section intends to understand to the extent to which the BIM guidelines are supportive to open BIM standards in FM. Questions include the relevant of key information requirement; key factors that influence the adoption of open BIM standards and standards guidelines; BIM guidelines to support open BIM standards and standards guidelines; and framework that can facilitate the adoption of open BIM standards and standards guidelines. The statements in the Likert-scale questionnaire items were measured using a five-point scale from being ‘strongly agree’ to ‘strongly disagree’. As pointed out by Sekaran (2003) the purpose of the Likert-scale is to measure respondent’s rating of feelings, attitudes, or perceptions related to a series of individual statements or items.

6.6.3 Relevance of Key Information Requirement

The questions regarding key information requirement were adapted from the based on the PAS1192-3 standards. However, during a pilot survey, respondents mostly skipped the questions, which caused the researcher to revise the measurement to a Likert-scale instead to improve the response rate. The proposed relevant of key information requirement was adapted from PAS1192-3 standards in the following areas;

- Technical information (engineering data and design parameters, commissioning dates and data, operational data, etc)
- Managerial information (unique asset numbers, location of the assets, spatial data relating to asset, warranties and guarantee periods, etc)
- Legal information (details of ownership, asset related contractual information)
- Financial information (whole life cycle cost, operating costs, downtime impact, etc)
- Commercial information (description of assets and asset systems, functioning of asset, vendor data, key performance indicators, etc)

However, during the in-depth interview, participants provided a different set of relevance to the key information requirement for FM. They highlighted the following areas for information handover:

- Asset information (asset register/records, life expectancy, commissioning dates, etc)
- Space information (space coding, room numbering, assigning space in relation assets, etc)
- O&M information (full-plan schedule- maintenance regime, frequencies of maintenance, etc)
- Equipment information (equipment list MEP, equipment life expectancy)

- Replacement information (replacement parts, specification, value and cost)

The information provided in PAS1192-3 covers a high-level category of information requirement and overlaps with the information in the main qualitative findings. For example, the managerial information has similar category as asset information in the qualitative findings. Therefore, the questionnaire items adopt the terms used in qualitative study is specific and the language used is more appropriate to represent the relevant key information requirement for FM domain. This was also consistent with the terms used in the previous studies (Becerik-Gerber et al, 2012, Williams et al, 2013).

6.6.4 Construct Statements for Quantitative Phase Questionnaire

Integration of technology acceptance model (TAM) and innovation diffusion theory (IDT) were employed to construct statements for the questionnaire. The key factors that influence the adoption of open BIM standards and standards guidelines are initially derived from the extensive literature reviews, informal discussions with experts, and a pilot study. Table 6.3 shows the list of the variables adapted from TAM- related statements from the questionnaire.

Table 6.3 Statement of Questionnaire – TAM and IDT

Awareness of BIM
• I'm familiar with the term COBie ~~and how it works in FM~~ • I'm familiar with how COBie works for FM • I'm familiar with the term IFC ~~and how it works for FM practice~~ • I'm familiar with how IFC works for FM practice • I'm familiar with the standard guidelines PAS1192-3 ~~and how it works for FM practice~~ • I'm familiar with how PAS1192-3:2014 helps in adopting BIM in FM • I'm familiar with the standard guidelines BS1192-4 ~~and how it works in adopting COBie~~ • I'm familiar with how BS1192-4:2014 helps in adopting COBie in FM ~~• I have experience in the use of COBie and how it works for FM~~ ~~• I have experience in the use of IFC and how it works for FM practice~~ ~~• I have used the standard guidelines PAS1192-3 and how it works for FM practice~~ ~~• I have used the standard guidelines BS1192-4 and how it works in adopting COBie~~
Compatibility with FM system
• The use of COBie improves the way I work • The use of COBie facilitates effective working ~~• The use of COBie has changed the way I worked~~

- COBie will improve the handover data from construction to operational phase
- The use of IFC improves the way I work
- The use of IFC facilitates effective working
- ~~The use of IFC has changed the way I worked~~
- IFC will improve the handover of data from the construction to operational phase

Trialability

- ~~I have experimented using COBie~~ Being able to try out COBie is important in my decision to adopts it
- ~~I have experimented using IFC data exchange format~~ Being able to try out IFC is important in my decision to adopts it
- ~~I am still experimenting using COBie~~
- ~~I am still experimenting using IFC~~
- I have used COBie in live projects
- I have used IFC data exchange in live projects
- ~~I will continue to explore the use of COBie in future~~
- ~~I will continue to explore the use of IFC in future~~

Observability

- I have seen case studies on how to use to import COBie to FM system
- I have seen demonstrations of ~~the importing~~ COBie into FM system
- I have seen case studies where IFC has been used in FM
- I have seen demonstrations of ~~the use~~ IFC data format in FM
- ~~There is sufficient guidance on PAS 1192-3 to adopt BIM in FM~~
- ~~There is sufficient guidance on BS 1192-4 to adopt COBie~~

Perceived Usefulness

- COBie is a useful mechanism for handing over data ~~from construction~~ to operational and maintenance stage
- COBie will benefit FM practice
- IFC has a structured information for handing over data to operation and maintenance stage
- Industry Foundation Classes (IFC) is a useful data exchange format
- ~~IFC represent all the data required for FM~~
- PAS 1192-3:2014 provides clear guidelines for adopting BIM in FM
- BS1192-4:2014 provides clear guidelines for populating COBie
- ~~PAS1192-3 standard and guidelines facilitate the development of EIR~~
- ~~BS1192-4 standard and guidelines facilitate the development of EIR~~
- ~~The quality of information contain in COBie is high~~
- ~~The quality of information contain in IFC is high~~

Perceived ease of use

- COBie spreadsheet is easy to ~~for facilities manager to read and understand~~ use
- COBie spreadsheet has ~~an easy interface to present information~~ user-friendly interface
- IFC is an easy format for facilities manager to use
- IFC is a user-friendly data exchange format

- PAS 1192-3 standard helps facility managers to understand how to managed information easily
- BS1192-4 standard helps facility managers to ~~populate~~ implement COBie easily

Behaviour Intention

- I have intention to adopt open BIM standards and standards guidelines in near future
- I anticipate that I will adopt open BIM standards and standards guidelines in my work
- I intent to apply open BIM standards and standard guidelines in my work
- I have adopted open BIM standards and standard guidelines

From the table above, six variables predict the behavioral intention to adopt open BIM standards (i.e. COBie and IFC) and standards guidelines (PAS1192-3 and BS1192-4) in FM. Each variables and statements was not discussed in advance with the participants, as they were adapted from a wide variety of literature reviews, informal discussions with experts and a pilot study. On the other hand, the TAM is modified to extend the external variables that affect the belief of Perceived Usefulness (PU) belief. The external variables offer a better understanding of the key factors that influence the adoption of open BIM standards and standards guidelines. The initially proposed key factors are 1) Cost, 2) Classification of BIM Data, 3) EIR, 4) Standards Guidelines 5) Interoperability, 6) Common Data Environment, 7) Technical Knowledge, and 8) Technical Support. Table 6.3 shows the list of external variables to the PU belief in TAM.

Table 6.4 Statement of Questionnaire - Key Factors

Cost
• Capturing of information in COBie may involve expensive cost in hiring specialist (e.g. computing firm, technical specialist) • The benefits of information populated in COBie are greater than its cost. • Capturing of information in IFC may involve expensive cost in hiring specialist (e.g. computing firm, technical specialist) • The benefits of using IFC are greater than its cost.
Classification of BIM Data
• The use a of classification system is useful in structuring FM data • The Uniclass/Omniclass/SFG20 standard is important ~~to~~ for defining information in COBie • The Uniclass/Omniclass/ SFG20 standard ~~helps~~ enhances the use of COBie ~~to be useful to~~ in FM systems • Information that carries Uniclass/Omniclass/SFG20 standard are readable in FM systems
Employer Information Requirement

• ~~The EIR is useful mechanism in capturing information required for FM~~ • ~~The EIR contains too much information that cannot be held within a spreadsheet~~
Standards and Guidelines
• ~~The content in standards and guidelines (i.e. PAS1192-3 & BS 1192-4) is overcomplicated~~ • ~~The content in standards and guidelines (i.e. PAS1192-3 & BS1192-4) is sufficient to facilitate the adoption of BIM in FM~~
Interoperability Data Exchange
• The COBie can easily be used to import data into FM system • The IFC format allows integration with my FM system • ~~3D model information is necessary to facilitate information management in my FM system~~
Common Data Environment (CDE)- As-built Model
• ~~AIM As-built Model is important for facility managers to coordinate and shared~~ helps facilities managers to identify the relevant information in COBie • ~~AIM As-built Model helps facilities managers to reduce redundant information in COBie~~ • ~~AIM As-built Model helps facilities managers to identify errors in COBie~~ • ~~AIM As-built Model allows collaboration with others project teams~~ helps facilities managers to identify missing information in COBie
Upskilling
• Training workshops help me to enhance my skillset in updating COBie information in FM system • Training workshops help me to enhance my skillset in using IFC data exchange format to update graphical information in FM system • ~~I'm competent in using COBie and to integrate information them into FM systems~~ • ~~I'm competent in using IFC to integrate information them into FM systems~~

As mentioned earlier, the external variables are adapted through extensive literature review, informal discussion with experts and a pilot study. From the results of the pilot study the main qualitative findings are employed to find any changes or emerging key factors to be included in the questionnaire items.

6.6.4.1.1 Cost

Cost is perceived as one of the factors that have influenced the Perceived Usefulness (PU) belief. Cost-related statements are about hiring specialists and the benefits of using COBie. However, two participants said during the in-depth interview that they are concerned about the cost in hiring highly skilled personnel, FM system implementation, and the operational savings to adopt BIM in FM. Thus, this study predicts that cost directly influences the usefulness of adopting COBie and IFC.

6.6.4.1.2 Classification of BIM Data

The external factor BIM data classification is perceived to have significant influence on the PU belief. BIM data classification-related statements are regarding the usefulness in structuring information via the classification system, the importance of defining the classification system (e.g. Omniclass, Uniclass, SFG20) in COBie, the use of classification system for COBie to be useful in FM system, and the readability of classification system for FM system. During the interview, two participants suggested that use of classification system in COBie will be useful in an FM system to identify the types of information. Classification of BIM data is an important factor for facilities manager to adopt COBie and IFC in order to identify the structure of information and the category of BIM objects they belong to. Therefore, the classification of BIM data remained as one of the variables in the questionnaire items.

6.6.4.1.3 Employer Information Requirement

EIR-related variables in the questionnaire consist of statements adapted primarily from extensive literature reviews. The EIR variable is predicted to have a positive influence on the PU belief in adopting open BIM standards and standards guidelines. The EIR variable is notably evident in the main qualitative findings as one of the important key factor. Most participants raised concerns over the interest of clients' decision in setting up the EIR, as to whether the COBie or the IFC will be used in the FM. The phrase 'client should describe in EIR the use of COBie and IFC for FM' is adapted from the main qualitative findings and before being added to the questionnaire statements. However, the EIR constructs was merged in the section 6.6.2.4 as part of the concepts and tasks to avoid redundancy of questionnaire items.

6.6.4.1.4 Standards and Guidelines

The proposed variables in the questionnaire are found to be redundant to section 6.6.5 about BIM guidelines, where the statements are merged into the section.

6.6.4.1.5 Interoperability

The interoperability variable in the proposed questionnaire item is unsuitable for targeted audience (facilities manager). The term is adapted from the extensive literature reviews. However, respondents from the pilot survey deemed to be technical and referring to those with expertise, hence it only applies to a small number of audiences. The statements related

to this variable remained in the questionnaire but the variable was changed to ‘Data Exchange’ between BIM system and FM system. The participants in the in-depth interviews suggested that the integration of both system is potentially useful in manipulating and updating information in the COBie and IFC.

6.6.4.1.6 As-Built Model

Similar to interoperability, the variable ‘Common Data Environment’ variable proposed in the questionnaire which also unsuitable. The term is adapted from the extensive literature reviews, which targets to those who have the expertise but is limited to a small number of audiences. This variable is most applicable to the design and construction team in coordinating their respective model into a single federated BIM model. The final federated BIM model would be published as Asset Information Model (AiM) to be used in the FM phase. In this case, CDE variable is replaced with the As-Built Model aims to provide long-term benefits in the use of facilities operation and maintenance.

6.6.4.1.7 Upskilling

The proposed ‘upskilling’ variable is perceived to have influenced to the PU belief in the adoption of COBie and IFC in FM. The questionnaire statements describe the competencies of a facilities manager in applying the COBie and IFC into the FM system. Likewise the other variables, the term ‘upskilling’ is adapted from the extensive literature reviews, and there is evidence in the main findings that suggests up skilling as a key factor to know-how of updating information in COBie and IFC within the FM system. The term may imply that facilities managers need to understand the underlying problems in computing software, which would be beyond their capabilities as an user but to understand on how to update information in COBie within the FM system. Up skilling is necessary for facilities managers to equip themselves on the know-how using COBie and IFC into FM system. Therefore, upskilling remained as a variable in the questionnaire items.

6.6.5 BIM Guidelines to Support Open BIM standards

The BIM guidelines in the questionnaire items focused on the PAS1192-3 and BS1192-4. Likert-scale questionnaire are used to measure the level of agreement in the statements regarding PAS1192-3 and BS1192-4. The statements are related to clarity, sufficiency, and implementation of the BIM guidelines. Several additions have been made into the statements in the questionnaire. Table 6.4 shows the statements related to PAS1192-3 and BS1192-4.

Table 6.5 Statement of Questionnaire - BIM guidelines

PAS1192-3
• PAS 1192-3 has clarified the process and procedure of information communication with FM system • PAS 1192-3 sufficiently covers the key information requirements for FM tasks • ~~PAS1192-3 adequately supports the use of COBie and IFC data format~~ has clarified the role and responsibility of managing and maintaining BIM model in operation and maintenance stage • PAS 1192-3 can support the adoption of BIM in FM on a live project
BS1192-4
• BS 1192-4 provides a comprehensive guidance to use COBie for FM • BS1192-4 provides the key information requirement for COBie • BS 1192-4 has clarified the role and responsibility of populating COBie for FM • BS1192-4 ~~adequately~~ can support the ~~use~~ adoption of COBie on live project

The main qualitative findings related to sufficiency, compliance and understanding of PAS1192-3 and BS1192-4 standards have been discussed with participants in section 6.5.4.

6.6.6 Framework of open BIM standards and guidelines

This last part of the questionnaire focuses on concepts/tasks in establishing a framework. Likert-scale questionnaire are used to measure the proposed statements, which are adapted from the extensive literature reviews. However, responses generated from the main qualitative findings are proved to be helpful in building the statements for the questionnaire. Table 6.6 provides the statements of concepts/tasks to establish a framework.

Table 6.6 Statement of Questionnaire - Key Concepts/Tasks

Concepts/ Tasks
• Reduce the content of COBie to more relevant material • A process map for BIM use in FM • ~~The~~ Early involvement of FM in EIR document • Suppliers and Manufacturers has an important factor to play in providing details for COBie data input • Reduce the cost of training in promoting the use COBie and IFC for FM • Regulatory enforcement in using COBie and IFC for FM • Communication with design and construction team to get FM information in the COBie and IFC • Assigning BIM manager with BIM to update information in COBie and IFC in the FM system

From the questionnaire, the involvement of facilities managers in the design and construction stage is one of the most notable findings. The participants from the in-depth interviews suggested that communication with the design and construction team helps to streamline COBie and IFC into the FM system. The statement is adapted from the participants' in the in-depth interviews to be part of the questionnaire items. The other notable finding was the role of BIM manager. According to the participants assigning a capable BIM manager would allow information streamlining of COBie and IFC into the FM system. Therefore, several proposed statements have been added into the questionnaire items based on the main qualitative findings.

6.7 Chapter Summary

This chapter discussed on the findings of qualitative in-depth interview with 22 key experts that involved in BIM and/or FM. The findings were discussed into five main sections; the background profile of interview participants, the relevance of key information requirement, the key factors that can influence in the adoption of open BIM standards and standards guidelines, the extend to which BIM guidelines can support the adoption of open BIM standards, and the framework that can facilitate the adoption of open BIM standards and standard guidelines. From the result, the number of the key experts proficient in BIM is twice the number of key experts that proficient in FM. A majority of BIM experts has limited knowledge of FM. On the other hand, most facilities managers that are knowledgeable in BIM have experience and proficient in IT. Various of BIM systems and FM systems are identified in the findings. Revit and Archibus being the most popular systems mentioned.

The findings of the key information requirement were found relevant to BIM-based FM includes: asset information, space information, operation and maintenance information, replacement information, and equipment information. Several key factors in the findings such awareness of BIM, classification of BIM data, cost, as-built model, data exchange and up skilling. Furthermore, the findings also discovered that inadequacy and low compliance of PAS1192-3 and BS1192-4 standards combined with the lack of understanding in the standards and guidelines create complexity and uncertainty in adopting COBie and IFC. The analysis of key concepts and task for the framework suggests the knowledge of BIM especially COBie and IFC, the value it brings to facilities managers, and communication and collaboration are the elements could facilitates to establish a framework to adopt open BIM standards and standards guidelines. The results of qualitative analysis are then use to revised the choice of words, emerging theme of questionnaire items for the main fieldwork of quantitative research. The next chapter discussed on the findings of online-survey that

includes statistical descriptive analysis of mean, median and charts as well as inferential analysis to test to the relationship between variables of the proposed framework in this study.

CHAPTER 7 QUANTITATIVE FINDINGS

7.1 Introduction

This chapter outlines the findings from the structured online survey. The online questionnaire was used as means to collect primary data and Statistical Package for the Social Science (SPSS) was selected as a tool for data analysing technique. The purpose of the quantitative data analysis was to describe and tabulate data in the form of charts and statistical measure and to examine validity and reliability of the measures and to test the correlation between variables. This chapter aims to fulfill the objectives of this study to facilitate the adoption of open BIM standards and standard guidelines and divided into five parts: a) background information, b) relevance of key information requirements, c) identification of key factors for adoption of BIM in FM, d) to what extent does BIM guidelines support the adoption of open BIM standards and e) the framework that can facilitate the adoption of BIM in FM. The quantitative findings follows with an elaboration on the purpose, classification, research approach and research strategy; an overview of key sections is presented in **Figure 7.1** below.

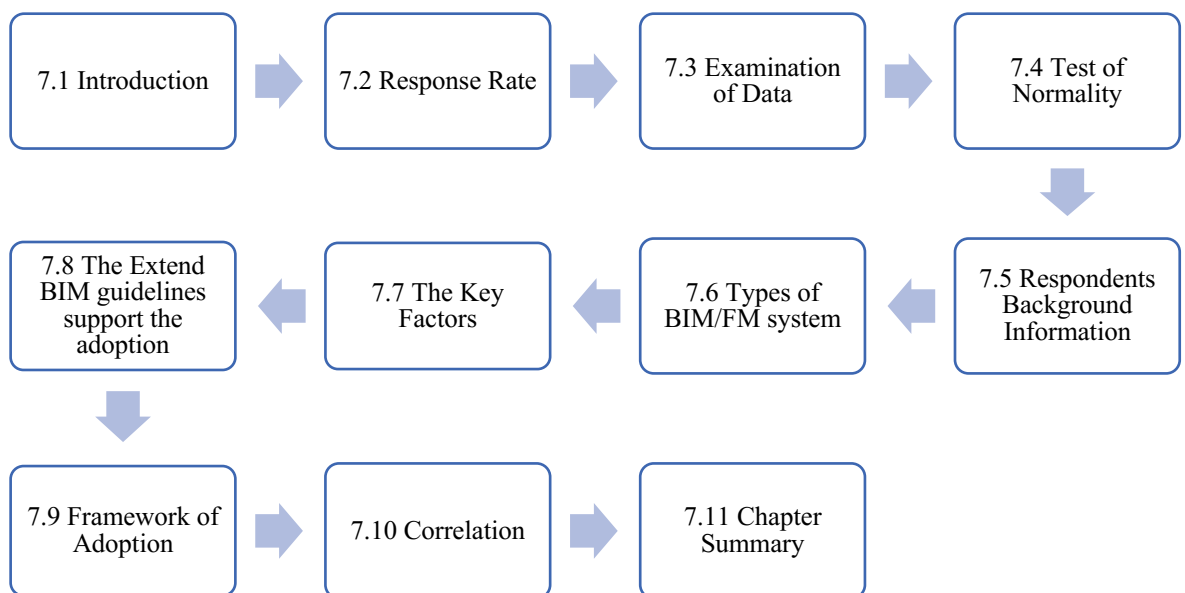


Figure 7.1 Chapter 7 Organization

7.2 Response Rate

Data was collected using a web-package online survey (SmartSurvey™) tool that posted in the closed-groups forum in the professional social media ‘LinkedIn’. The online-survey was posted in the selected groups forum that includes: BIM4FM, BSRIA, BIFM. In addition, the company email addresses that related to this study were also collected and sent individual invitation with the web link through the survey. This is due to their professional and research experience in the areas of BIM and/or FM. Apart of the UK, the online-survey were also extended to the Europe, US, Australia, Canada, New Zealand, Middle East and Asia countries due to the small number of respondents in the UK. The online-survey was conducted within 3 months (June-August, 2018). Overall ninety-seven completed responses were received and only eighty-three were valid responses were retained for data analysis process. Table 7.1 shows the response rate of the online survey respondent of the study.

Table 7.1 Response Rate

Questionnaires			
<u>Received</u>	<u>Rejected</u>	<u>Usable</u>	<u>Respond rate (%)</u>
97	14	83	85.6

7.3 Examination of Data

As the result obtained from data analysis can only be as good as the raw data entered, data screening, cleaning and verification is required to ensure quality data entry (Wang, Storey, & Firth, 1995). For this purpose, extreme care was taken in entering the data, with a check of each questionnaire entered. This process ensures that there are no mistakes in the data resulting from keystroke errors. As such, two checks for error using SPSS version 22.0 were conducted on the data before the analysis began. In the first check, data was checked for categorical variables errors (minimum and maximum values, number of valid and missing cases) and the second checking was for continuous variable errors (minimum and maximum values, means score) in the data file. Both of these methods of screening and cleaning data in the current research and obtained error free in data entry process.

7.4 Test of Normality

The research looked for a sample set, the results of which could represent population parameters and generalize the findings. The study therefore uses parametric statistics by carrying out two statistical tests, including descriptive statistics and correlations. In order to use these tests, a normally distributed data set is needed, while the use of parametric statistics

also requires a homogenous and continuous sample data. Table 7.2 shows, consistent with that interpretation and detailed analytical data, the normally distributed means and standard deviation values of the 8 variables.

Table 7.2 Test of Normality

Variables	Mean	SD	Skewness	Kurtosis	Shapiro-Wilk	Sig
Awareness of BIM	24.64	7.34	0.01	-0.50	0.99	.015
Compatibility	25.98	7.40	0.07	-0.65	0.97	.008
Observability	27.40	5.63	-0.28	-0.43	0.99	.010
Trialability	20.51	6.73	0.25	-0.58	0.97	.012
Perceived Usefulness	23.30	4.69	0.24	-0.49	0.98	.007
Classification of BIM Data	25.82	5.20	-0.23	-0.35	0.99	.011
Cost	25.70	5.52	-0.21	-0.33	0.98	.012
Data Exchange	22.15	5.01	0.27	-0.47	0.97	.017
As-Built Model	15.36	7.08	1.00	0.27	0.88	.000
Upskilling	25.58	5.16	0.21	-0.46	0.98	.009
Perceived Ease of Use	23.45	6.71	0.16	-0.59	0.99	.012
Behaviour Intention	24.32	6.34	-0.18	-0.53	0.98	.011

Note. SD = Standard Deviation

Moreover, the range of Skewness and Kurtosis between -1.96 and +1.96 was detected (Doane & Seward 2011), and rejects the highly skewed or Kurtotic data problem that can inflate the standard error bootstrapped (Chernick, 2008). In addition, Kolmogorov-Smirnov and Shapiro-Wilk tests examined the normal distribution of data in relation to the background of this study. Shapiro-Wilk test's significant higher value ($p > .05$) shows a data normalization (Pallant, 2010). Table 7.2 shows that, with the exception of variable Green Technologies policy sensibilities, $p < .05$ the data collected are normally distributed. However, these results are acceptable for SPSS use because the data set should not be too far from normal (Razali & Wah, 2011) to supply an accurate estimate with normal figures. The study therefore followed parametric methods which assume normality.

7.5 Respondents Background Information

The first section of data analysis discussed the demographic profile of the key respondents, respondents experience, types of BIM/FM system and relevance of key information requirement.

7.5.1 Demographic Profile of the Respondent

A summary of the demographic information related to the representatives of the sample is tabulated in Table 7.3 and detailed information of the analysis furnished below.

Table 7.3 Respondent's Demographic

Profile	Description	Frequency	%
Primary job function	Architect and Designer	4	4.8%
	Asset Manager	2	2.4%
	BIM Manager	4	4.8 %
	BIM Specialist	2	2.4%
	BIM Technician	2	2.4%
	BIM Coordinator	1	1.2%
	Building Services	3	3.6%
	Civil Engineer	6	7.2%
	Energy and Sustainability	2	2.4%
	Facility Managers	5	6.0%
	Health Safety and Security Officer	3	3.6%
	IT Specialist	12	14.5%
	Mechanical and Electrical Engineer	7	8.4 %
	Project Manager	11	13.3%
	Quantity Surveyor	1	1.2%
	Structural Engineer	1	1.2%
	Supply-Chain	2	2.4%
	Others (please specify):	15	18.1%
Average organization size	Small business	27	34.2%
	Small medium enterprise	30	36.6%
	Large companies	25	31.6%

Type of facilities involved	Administrative, Office, Commercial Facilities	30	17.1%
	Education, Scientific, Information, Research Facilities	19	10.9%
	Industrial Facilities	26	14.9%
	Medical Health Facilities	21	12.0%
	Protective, Correctional Service Facilities	10	5.7%
	Religious Facilities	6	3.4%
	Residential Facilities	16	9.1%
	Social, Welfare Facilities	13	7.4%
	Sport, Recreational Facilities	10	5.7%
	Utilities, Engineering Facilities	20	11.4%
	Others (please specify):	4	2.3%

Primary job function of majority respondents falls under the category of ‘others’. Surprisingly, the ‘others’ primary job functions which was not listed encompassed 18.1% majority of this survey. This could be that the positions they hold were not included in the list of options provided in the questionnaire such as academician, management, and director of asset manager. The second largest primary job function of the respondents came from IT specialist with a total of 14.5%, while the third largest were Project Manager, and Mechanical and Electrical Engineers with percentage of 13.3% and 8.4% respectively. On the other hand, the average organization size of respondents is mostly from a small medium enterprise, with percentage of 36.6% while 34.2% from small business and followed by of large companies with 31.6%%. Apart of this, majorities of respondents (17.1%) indicate that they have involved in administrative, office, and commercial facilities. Furthermore, a total of 14.9% involved in industry facilities such factories, production, plants, which the second most involved type of facilities. Meanwhile the education, scientific, information and research facilities was the third most significant type of facilities with 10.9%.

7.5.2 Respondents Experience

In regards to the rate of respondent’s experience, **Figure 7.2** describes the overall experience of the respondents in the survey. It was found that majority of the respondents rated that they have moderate experience in FM, with a total of 38.7 %. On the other hand, most respondents’ claim they have moderate to highly experience in BIM subject, which both

have the same percentage of 24.4% respectively. A total of 35.6% of respondents show they have somewhat basic experience the use BIM in FM.

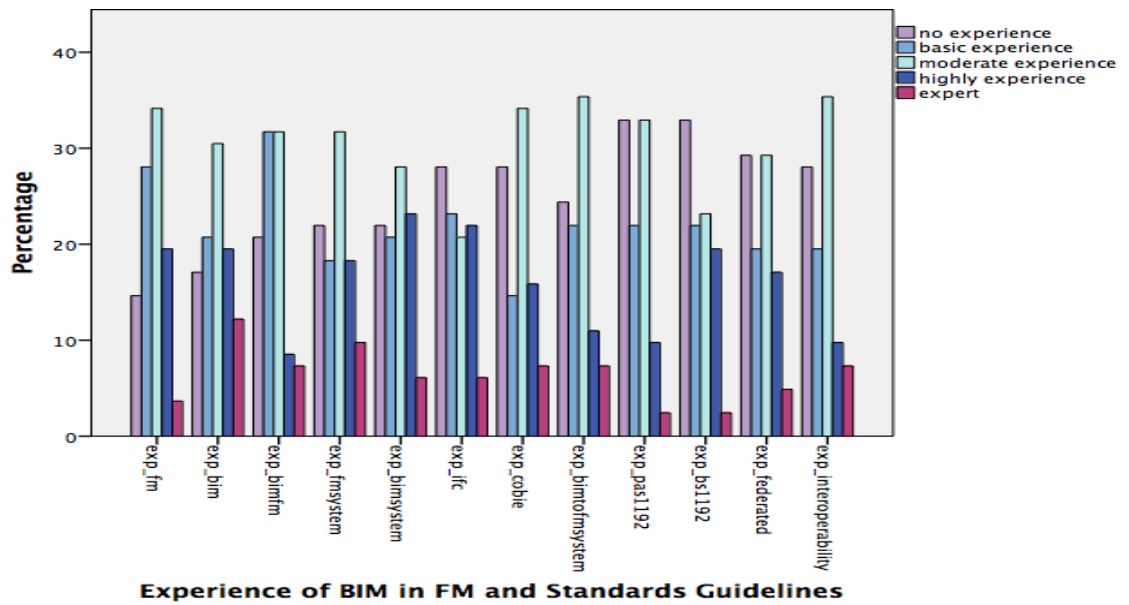


Figure 7.2 Experience of BIM in FM and Standards Guidelines

Apart of the rate of respondent's experience, Table 7.4, illustrated the rate of experience, mean and median of BIM in FM and standards guidelines.

Table 7.4 The Rate Of Experience in BIM in FM

	No experience	Basic experience	Moderate experience	Highly experience	Experts	Mean ($\bar{x}$)	Median (M)
FM	14.6% n=12	28.0% n=23	34.1% n=28	19.5% n=16	3.7% n=3	2.70	3.00
BIM	17.1% n=14	20.7% n=17	30.5% n=25	19.5% n=16	12.2% n=10	2.89	3.00
BIM for FM	20.7% n=17	31.7% n=26	31.7% n=26	8.5% n=7	7.3% n=6	2.50	2.00
FM systems	22.0% n=18	18.3% n=15	31.7% n=26	18.3% n=15	9.8% n=8	2.76	3.00
BIM systems	22.0% n=18	20.7% n=17	28.0% n=23	23.2% n=19	6.1% n=5	2.70	3.00
IFC	28.0% n=23	23.3% n=19	20.7% n=17	22.0% n=18	6.1% n=5	2.55	2.00
COBie	28.0% n= 23	14.6% n=12	34.1% n=28	15.9% n=13	7.3% n=6	2.60	3.00
BIM to FM system	24.4% n=20	22.0% n=18	35.4% n=29	11.0% n=9	7.3% n=6	2.55	3.00
PAS 1192-3:2014	32.9% n=27	22.0% n=18	32.9% n=27	9.8% n=8	2.4% n=2	2.27	2.00
BS1192-4:2014	32.9% n=27	22.0% n=18	23.2% n=19	19.5% n=16	2.4% n=2	2.37	2.00

BIM federated model	29.3% n=24	19.5% n=16	29.3% n=24	17.1% n=14	4.9% n=4	2.49	3.00
Interoperability	28.0% n=23	19.5% n=16	35.4% n=8	9.8% n=8	7.3% n=6	2.49	3.00

Table 7.4 above shows that the majority of the respondents rated that they have no experience in using FM systems (26.7%), BIM systems (31.1%), IFC (37.8%), COBie (37.8%), PAS1192-3:2014 (44.4%), BS1192-4:2014 (42.2%), BIM federated model (37.8%), Interoperability (36.6%), with exception of BIM to FM system (31.1%), which has similar percentage as those who rated moderate experience. However, the respondents who have the basic experience to expert in these areas have greater combined percentage than those who don't. Overall, the average median of experience in most area is somewhat basic (2.00), with exception of FM, BIM and BIM systems, which has a total average of 3.00 equivalent to moderate experience.

7.6 Types of BIM/FM system

7.6.1 FM system

In view of the types of BIM/FM system, **Figure 7.3** describes the type of FM systems that respondents used within their organization.

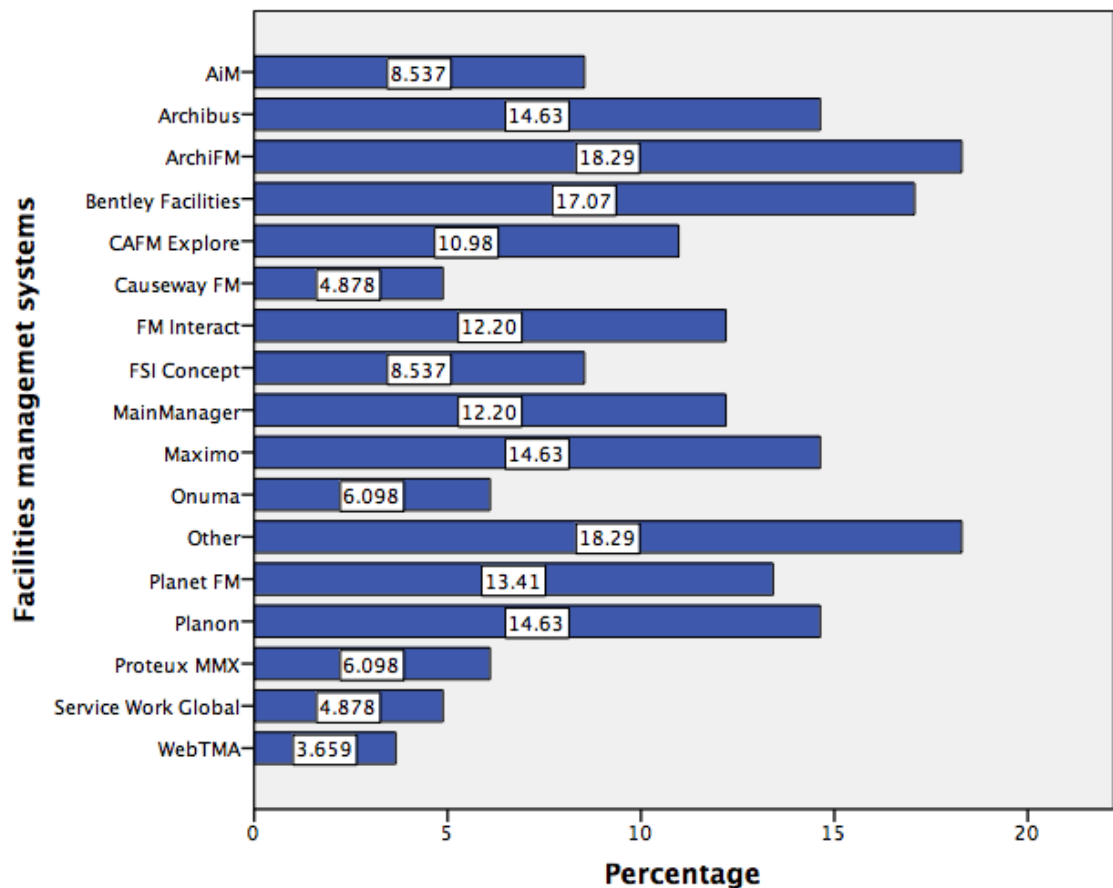


Figure 7.3 Types of Facilities Management Systems

Based on the analysis, it was found that a significant percentage of respondents rated using ArchiFM and ‘others’ FM system, which allowed respondents to leave responses/comments in the blank as to whether they do not know, none or bespoke FM system. Bentley facilities was the next frequently used FM system with a percentage of 16.13%, followed by Archibus, Planon, Maximo shared similar percentages of 14.63%, Planet FM (13.41%), MainManager and FM Interact which has similar percentage of 12.20% and CAFM Explore with 10.98%. The remaining FM with an approximate less than ten percent includes, AiM, Causeway FM, FSI Concept, Onuma Proteux MMX, Service Work Global, and WebTMA.

7.6.2 BIM systems

Pertaining to the BIM systems, **Figure 7.4** illustrated the type of BIM system that the respondents used in their organization. From the findings, 25.61% of respondents claim that they have experience in using Revit as a BIM system within their organization. Followed by, BIM 360 which represents 24.39% of respondents; Naviswork with percentage of 20.73%, ArchiCAD with 19.51% and Bentley BIM Suite–18.29%. In addition, Digital Project and others type of BIM systems share similar percentage of 10.98%. The remaining BIM systems were the least used among the respondents in the survey that includes, Bespoke BIM System, Tekla and Vectorworks.

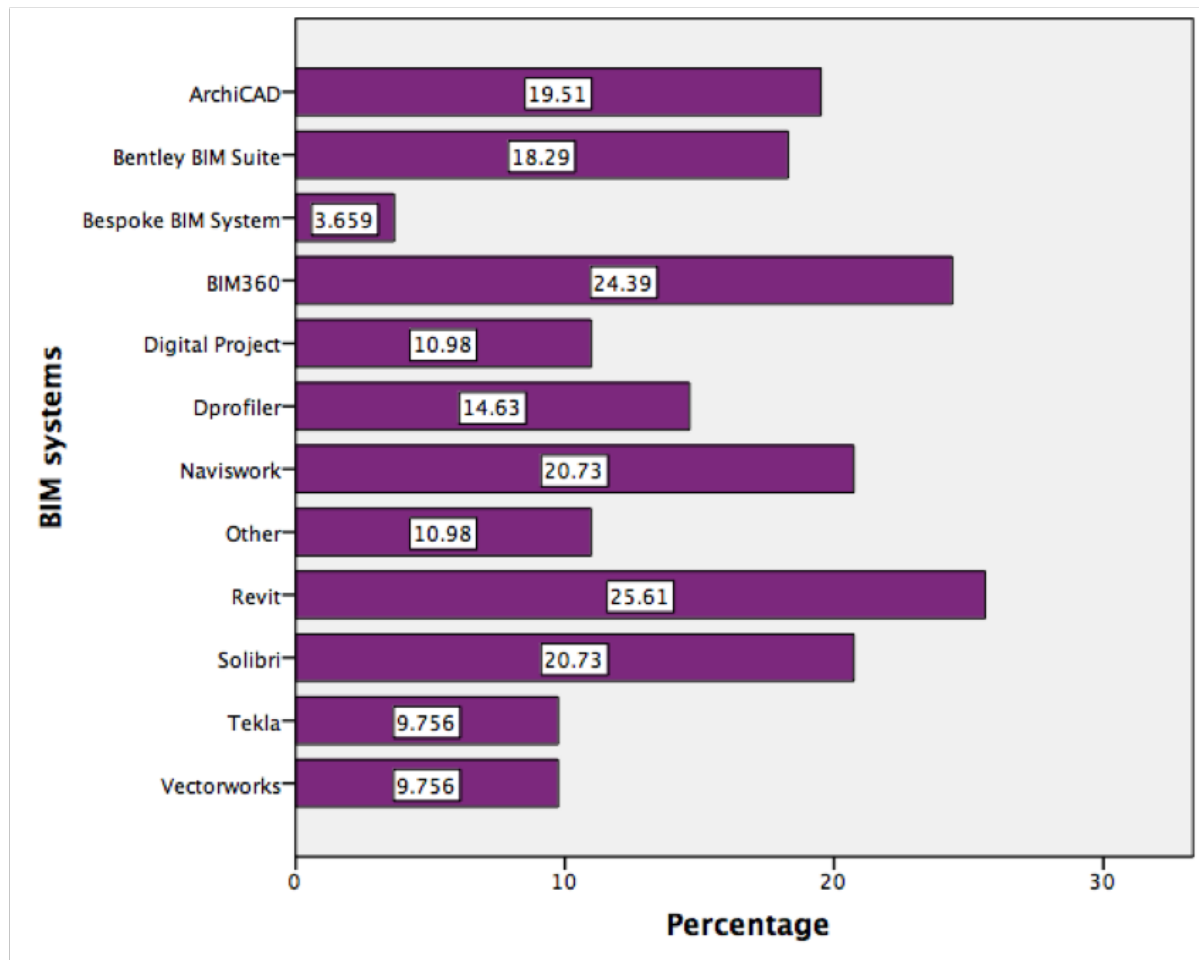


Figure 7.4 The Types of BIM Systems

7.6.3 Relevance of Key Information Requirement

In this subsection, respondents were asked to rate the relevance of key information requirements such as asset information, space information, operational and maintenance information, equipment information, replacement information according to their organization needs. **Figure 7.5** shows that generally most respondents answered neutral on asset information and operation and maintenance information, while space, equipment and replacement information mostly score relevant information in FM.

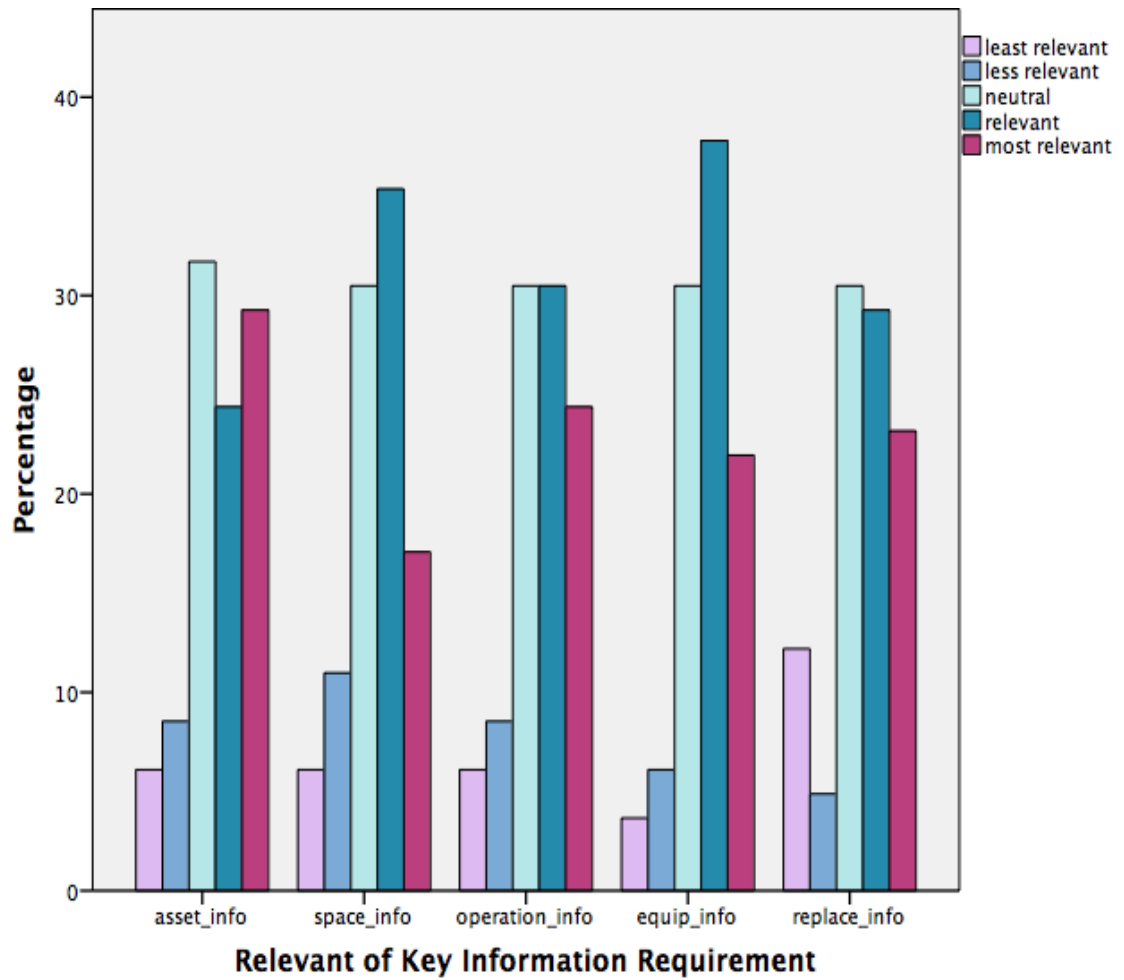


Figure 7.5 Relevant Key Information Requirement

However, on average median of all the scores, **Table 7.5** illustrated that operation, equipment, and replacement information are relevant than asset and space information.

Table 7.5 Relevant Key Information Requirement

	Least relevant	Less relevant	Neutral	Relevant	Most Relevant	Mean	Median
Asset information	6.1%	8.5%	31.7%	24.4%	29.3%	3.62	4.00
Space information	6.1%	11.0%	30.5%	35.4%	17.1%	3.46	4.00
Operation and Maintenance information	6.1%	8.5%	30.5%	30.5%	24.4%	3.58	4.00

Equipment information	3.7%	6.1%	30.5%	29.3%	23.3%	3.68	4.00
Replacement Information	12.2%	4.9%	30.5%	29.3%	23.3%	3.46	4.00

Asset information - From the **Table 7.5**, combined percentage of 53.7% of respondents indicate that asset information tends to be relevant key of the information requirement in FM use, as oppose to a combined percentage of less relevant and least relevant. Only 14.6 % respondents are likely not to think it is important, whereas, 31.7% of respondents stated neutral or don't know if asset information is the relevant for FM use.

Space information - A combined percentage of 52.5% of respondents was found space information tends to be relevant in conducting FM task, while 17.1% of combined percentage stated otherwise. However, an approximate one-third of respondents describes neutral or don't know if it is relevant information for FM task.

Operation and Maintenance information - A majority of respondents (54.9%) indicate operational and maintenance information is crucial as part of FM practice, while only 14.6% of respondents with the combined percentage stated less/least relevant information. On the other hand, a sum of 30.5% of respondents stated neutral or don't know.

Equipment information - From the result in **Table 7.5**, a total sum of relevant and most relevant percentage (52.6%) is five times greater than the percentage of less and least relevant combined (9.8%)for equipment information, while 30.5% of respondents position themselves neutral or don't know if it is relevant information in FM task.

Replacement information - The findings show a total sum of 52.6% of respondents tends to think the replacement information is relevant in FM, while 17.1% combined percentage stated less/least relevant for FM phase. Approximately, one-third of the respondents indicate neutral or don't know if it is useful.

7.7 The Key Factors that can Influence the Adoption of Open BIM standards and Standard Guidelines

In this section, the key factors that influence the adoption of BIM in FM were discussed in following sub-sections. The findings of key factors that influence the adoption of open BIM standards and standards guidelines were divided into: a) awareness of BIM, b) compatibility,

c) trialability, d) observability, e) perceived usefulness, f) perceived ease of use, g) cost, h) classification of BIM data, i) data exchange, j) upskilling and k) behaviour intention.

7.7.1 Awareness of BIM

In view of awareness of BIM, **Figure 7.6** shows the result whether the awareness of BIM can directly influence the behaviour intention. A series of statements has been constructed to evaluate the familiarity of term COBie, IFC and the standards guidelines (i.e. PAS1192-3:2014 and BS1192-4:2014). From the bar chart below, out of all the items, a majority of respondents indicate neutral in five items regarding to the awareness of BIM. Furthermore, a high percentage of agree and strongly agree scale was found in two items, while one item is on par between neutral and agree scale.

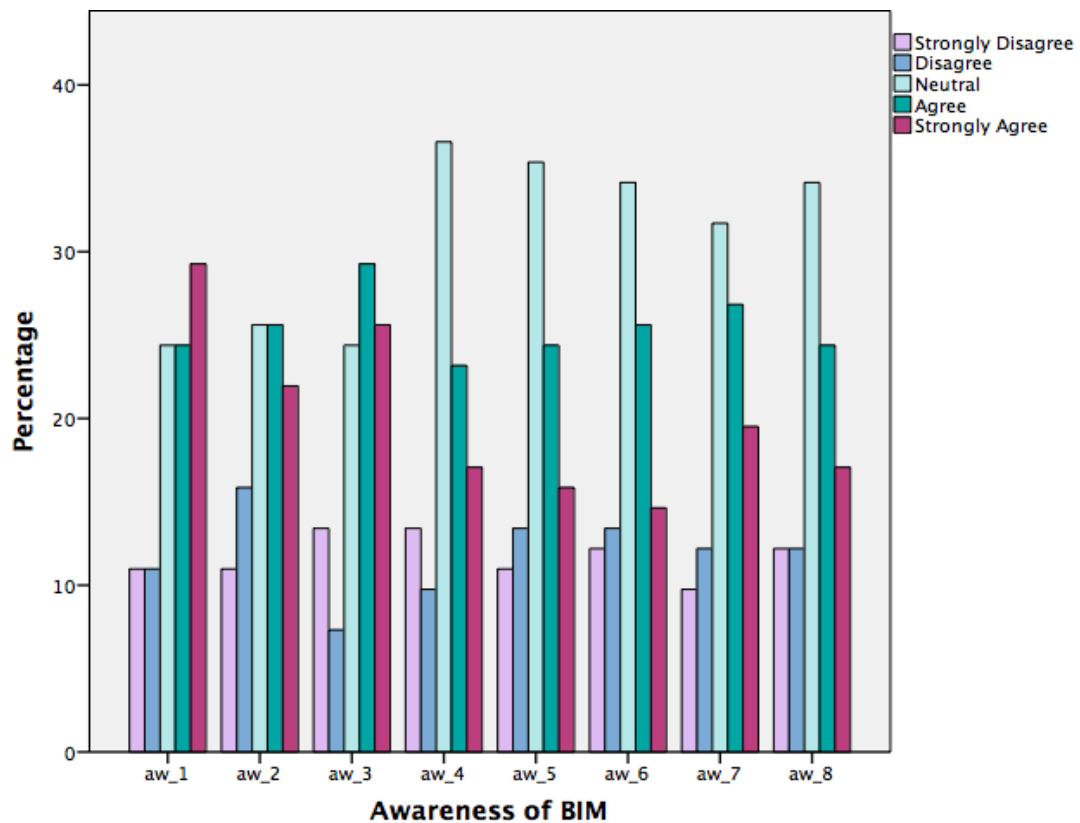


Figure 7.6 Scale of Awareness of BIM

On the other hand, in **Table 7.6**, aw_1 and aw_3 items score the highest percentage of 53.7 % and 54.9% respectively in numbers of respondents who rated both agree and strongly agree than the other six items.

Table 7.6 The Scale of Awareness of BIM

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
aw_1	11.0% n=9	11.0% n=9	24.4% n=20	24.4% n=20	29.3% n=24	3.50	4.00
aw_2	11.0% n=9	15.9% n=13	25.6% n=21	25.6% n=21	22.0% n=18	3.31	3.00
aw_3	13.4% n=11	7.3% n=6	24.4% n=20	29.3% n=24	25.6% n=21	3.46	4.00
aw_4	13.4% n=11	9.8% n=8	36.6% n=30	23.2% n=19	17.1% n=14	3.21	3.00
aw_5	11.0% n=9	13.4% n=11	35.4% n=29	24.4% n=20	15.9% n=13	3.20	3.00
aw_6	12.2% n=10	13.4% n=11	34.1% n=28	25.6% n=21	14.6% n=12	3.17	3.00
aw_7	9.8% n=8	12.2% n=10	31.7% n=26	26.8% n=22	19.5% n=16	3.34	3.00
aw_8	12.2% n=10	12.2% n=10	34.1% n=28	24.4% n=20	17.1% n=14	3.22	3.00

*aw_1: I'm familiar with the term COBie, *aw_2: I'm familiar with how COBie works for FM, *aw_3: I'm familiar with the term IFC,

*aw_4: I'm familiar with how IFC works for FM practice, *aw_5: I'm familiar with the standard guidelines PAS1192-3:2014, *aw_6: I'm familiar with how PAS1192-3:2014 helps in adopting BIM FM, *aw_7: I'm familiar with the standard guidelines BS1192-4:2014,

*aw_8: I'm familiar with how BS1192-4:2014 helps in adopting COBie in FM,

However, the remaining six items, respondents who rated agree and strongly agree score approximately two-fold in percentages than those who rated disagree and strongly disagree are combined. Respondents who rated neutral or don't know was less than one-third of the percentages of all the items. Therefore, it can be concluded that more than half of respondents are aware of the terms COBie and IFC compare to those who aware on how they worked in FM. On the other hand, the awareness of both standards PAS1192-3:2014 and BS1192-4:2014 and how they worked are higher compare to those who are not aware.

7.7.2 Compatibility

Figure 7.7 indicates the level of compatibility can directly influence the behaviour intention adoption of BIM in FM. Six items have been constructed to better describe compatibility of using COBie and IFC could improve the handing over data and effective working practice for facilities manager. A large group of respondents indicate that neutral or don't know as to whether by adopting open BIM standards could help with their productivity. From bar chart,

a high percentage of respondents rated neutral/ don't know scale in all the compatibility items.

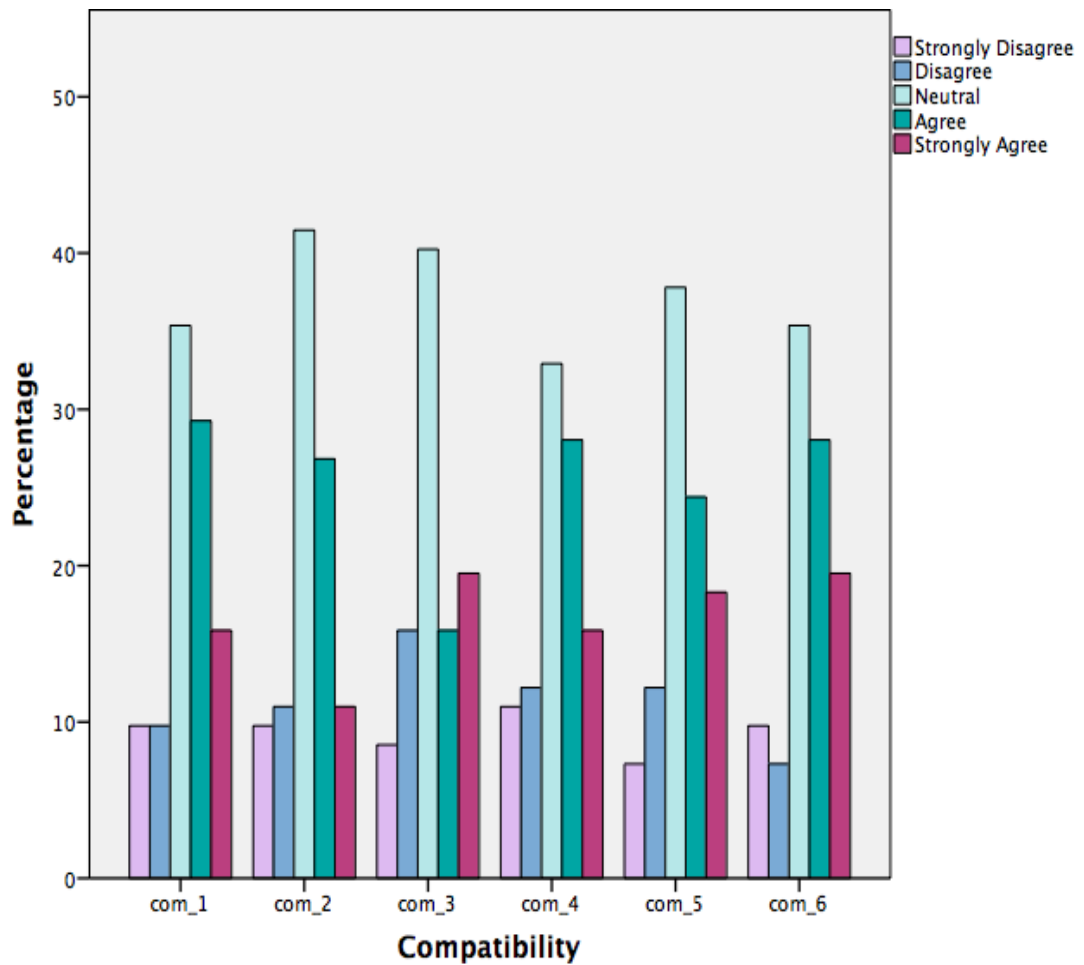


Figure 7.7 The Scale Compatibility

However, from the **Table 7.7**, nearly half of respondents score high percentages on combined scale of agree and strongly agree in four items in compatibility measure that are com_1, com_4, com_5, com_6. Meanwhile, com_2 and com_3 score less on combined scales of agree and strongly agree than respondents who rated neutral/don't know.

Table 7.7 The Scale of Compatibility

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
com_1:	9.8%	9.8%	35.9%	29.3%	15.9%	3.32	3.00
	n=8	n=8	n=29	n=24	n=13		
com_2:	9.8%	11.0%	41.5%	26.8%	11.0%	3.18	3.00

	n=8	n=9	n=34	n=22	n=9		
com_3:	8.5%	15.9%	40.2%	15.9%	19.5%	3.22	3.00
	n=7	n=13	n=33	n=13	n=16		
com_4:	11.0%	12.2%	32.9%	28.0%	15.9%	3.26	3.00
	n=9	n=10	n=27	n=23	n=13		
com_5:	7.3%	12.2%	37.8%	24.4%	18.3%	3.34	3.00
	n=6	n=10	n=31	n=20	n=15		
com_6:	9.8%	7.3%	35.4%	28.0%	19.5%	3.40	3.00
	n=8	n=6	n=29	n=23	n=16		

*com_1: The use of COBie improves the way I work, *com_2: The use of COBie facilitates effective working, *com_3: The use of COBie improves the handover data from construction to operational phase, *com_4: The use of IFC improves the way I work, *com_5: The use of IFC facilitates effective working, *com_6: The use of IFC improves the handover data from construction to operational phase

On the other hand, respondents who rated disagree and strongly disagree were less than one-fourth of the total percentage in all the items in the compatibility measure. This indicate that the use of IFC is works better in compatibility measure com_4 to com_6 as to compare to com_1 to com_3 in the use COBie in practice.

7.7.3 Trialability

Figure 7.8 shows the extent to which trialability can directly influence the behaviour intention to adopt BIM in FM. In trialability measure, four items were constructed to identify whether facilities manager is able to try out and/or have been using COBie and IFC that affect their decision in adopting open BIM standards. From the figure below, a majority of respondents rated neutral/ don't know in trialability measure of using COBie and IFC could convince facilities manager to help them in managing building operation.

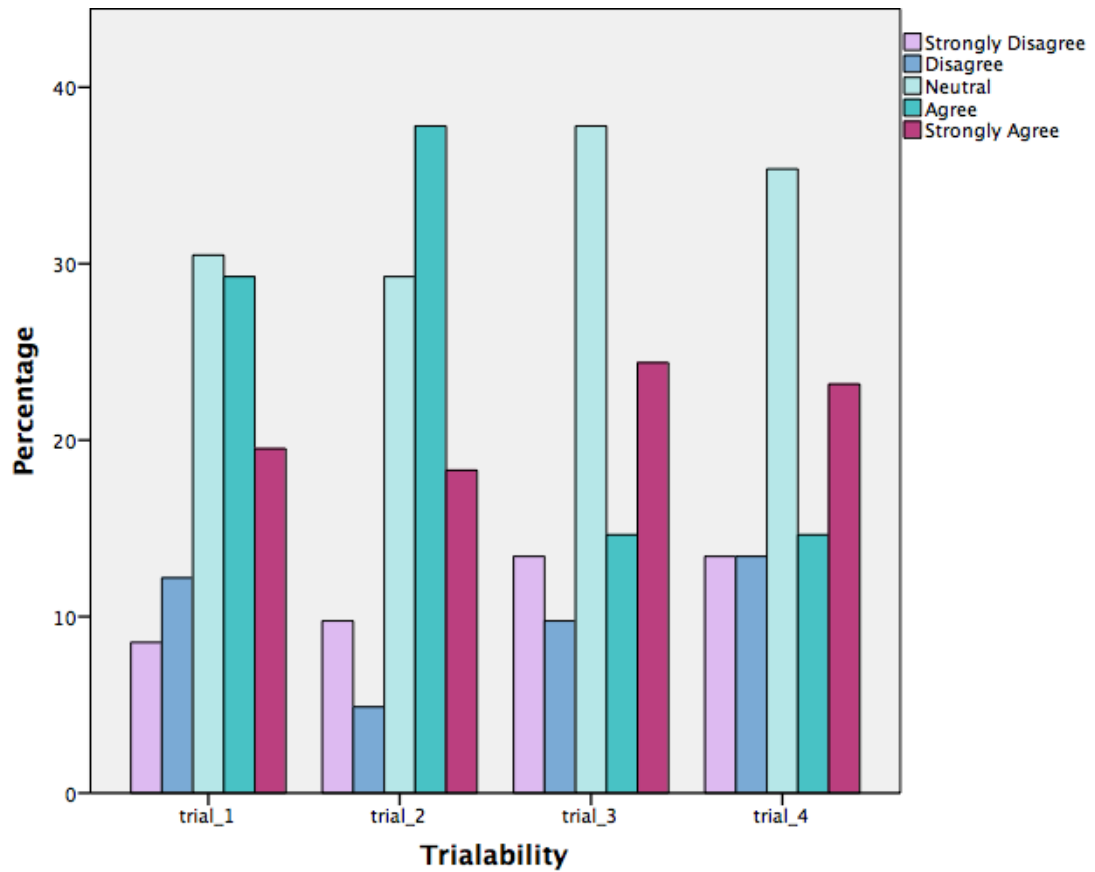


Figure 7.8 The Scale Trialability

From **Table 7.8**, trial_2 item score the highest percentage of 56.1% among other items in the total sum of agree and strongly agree scales under trialability measure.

Table 7.8 The Scale of trialability

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
trial_1:	8.5% n=7	12.2% n=10	30.5% n=25	29.3% n=24	19.5% n=16	3.39	3.00
trial_2:	9.8% n=8	4.9% n=4	29.3% n=24	37.8% n=31	18.3% n=15	3.50	4.00
trial_3:	13.4% n=11	9.8% n=8	37.8% n=31	14.6% n=12	24.4% n=20	3.27	3.00
trial_4:	13.4% n=11	13.4% n=11	35.4% n=29	14.6% n=12	23.3% n=19	3.20	3.00

*trial_1: Being able to try out COBe is important in my decision to adopts it, *trial_2: Being able to try out IFC is important, n my decision to adopts it, *trial_3: I have COBe on live projects, *trial_4: I have used IFC data exchange on live project

The trial_1 item scores nearly half of the total percentage in agree and strongly agree scales, while the remaining items, trial_3 and trial_4 score lower but not less than the total sum of percentage of those who score disagree and strongly disagree scale. On the other hand, respondents who rated neutral or don't know are more than disagree and strongly disagree scale combined, but less than agree and strongly agree scale in all items in trialability measure. This means, to able to try out IFC is important than to able to try COBie in making decision for adoption. However, using both COBie and IFC on a life projects score lower than being able to try both of them.

7.7.4 Observability

Figure 7.9 illustrates the level of observability of using COBie and IFC can influence the behaviour intention to adopt BIM in FM. Observability measure were define into four statements to predict whether facilities manager have seen case studies and demonstration of COBie and IFC used in FM. The results found out that most respondents have positioned themselves either neutral or don't know in obs_3 and obs_4 items, while obs_1 and obs_2 items score high percentage in agree and strongly agree scale respectively.

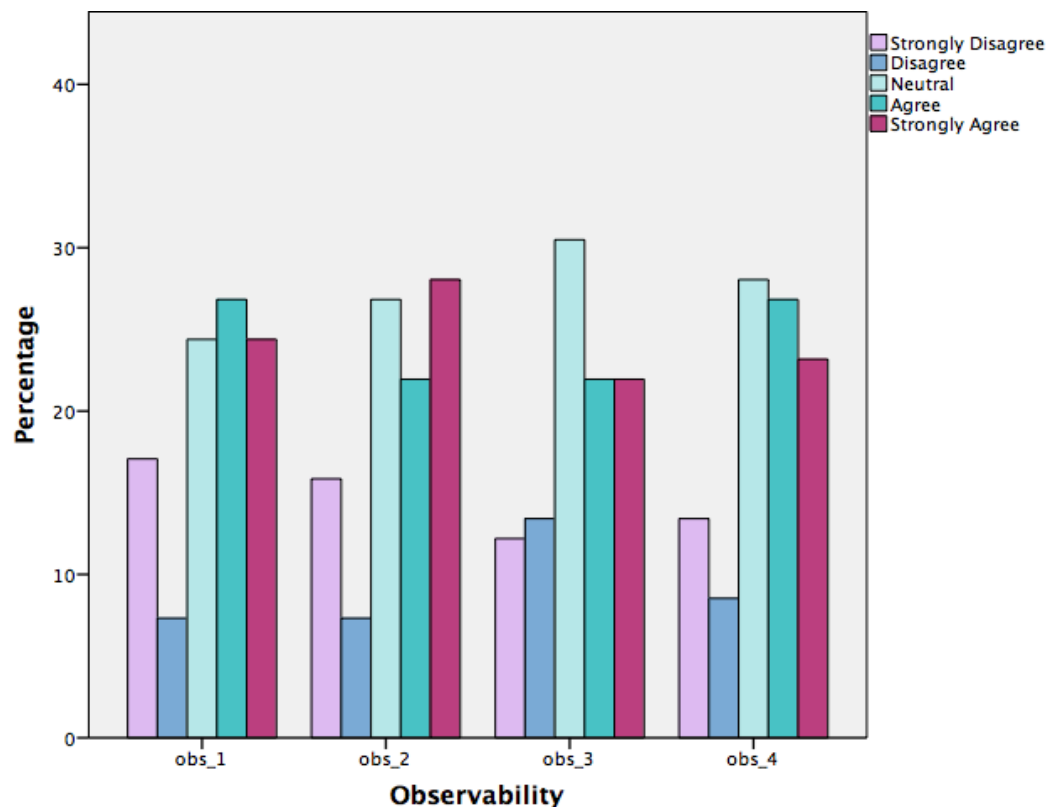


Figure 7.9 The Scale Of Observability

From the **Table 7.9**, all items score greater percentage in agree and strongly agree scale than those disagree and strongly disagree. However, out of four items that was measured, three items in observability measure –obs_1, obs_2 and obs_4 score an approximate 50% of total percentage of agree and strongly agree scale.

Table 7.9 The Scale of Observability

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
obs_1	17.1% n=14	7.3% n=6	24.4% n=20	26.8% n=22	24.4% n=20	3.34	4.00
obs_2	15.9% n=13	7.3% n=6	26.8% n=22	22.0% n=18	28.0% n=23	3.39	3.50
obs_3	12.2% n=10	13.4% n=11	30.5% n=25	22.0% n=18	22.0% n=18	3.28	3.00
obs_4	13.4% n=11	8.5% n=7	28.0% n=23	26.8% n=22	23.2% n=19	3.38	3.50

*obs_1: I have seen a case studies where COBie has been used in FM, *obs_2: I have seen demonstrations of COBie in FM, *obs_3: I have seen a case studies where IFC has been used in FM, *obs_4: I have seen demonstrations of IFC in FM

Meanwhile less than one-fourth (25%) of the total percentage of disagrees and strongly disagrees was reported in all items in observability measure. The remaining percentage score on neutral and don't know scale. The table explains that there is more observation in case studies and demonstration in using COBie in FM than it is for IFC.

7.7.5 Perceived Usefulness

Figure 7.10 illustrates the perceived usefulness of COBie and IFC can directly influence the behaviour intention to adopt BIM in FM. Six statements were constructed that include COBie, IFC and standard guidelines (PAS1192-3:2014, BS1192-4:2014) to support the perceived usefulness variable for facilities manager in adopting BIM. From the findings, a large group respondent stated neutral in to all the statements regarding the perceived usefulness of adopting open BIM standards and standard guidelines.

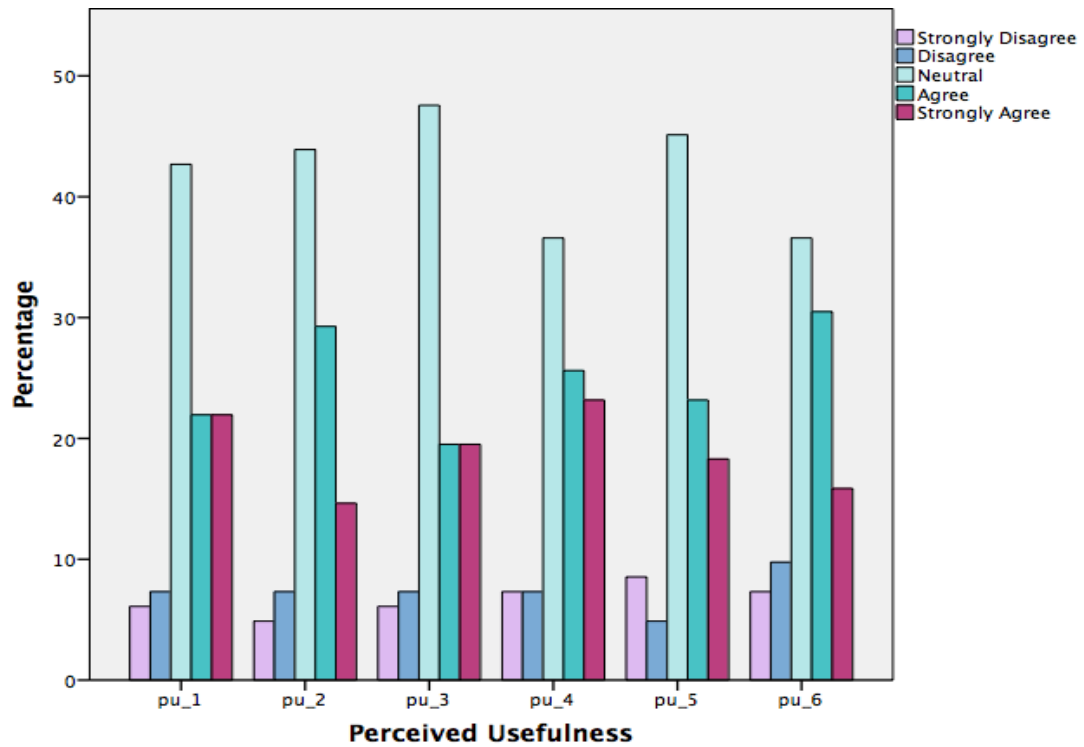


Figure 7.10 The Scale of Perceived Usefulness

From **Table 7.10**, out of six items, five items score more than 40% of total percentage of agree and strongly agree scale.

Table 7.10 The Scale of Perceived Usefulness

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
pu_1:	6.1% n=5	7.3% n=6	42.7% n=35	22.0% n=18	22.0% n=18	3.46	3.00
pu_2:	4.9% n=4	7.3% n=6	43.9% n=36	29.3% n=24	14.6% n=12	3.41	3.00
pu_3:	6.1% n=5	7.3% n=6	47.6% n=39	19.5% n=16	19.5% n=16	3.39	3.00
pu_4:	7.3% n=6	7.3% n=6	36.6% n=30	25.6% n=21	23.2% n=19	3.50	3.00
pu_5:	8.5% n=7	4.9% n=4	45.1% n=37	23.2% n=19	18.3% n=15	3.38	3.00
pu_6:	7.3% n=6	9.8% n=8	36.6% n=30	30.5% n=25	15.9% n=13	3.38	3.00

*pu_1: COBie is useful mechanism for handing over data to operation and maintenance stage, *pu_2: COBie will benefit FM practice, *pu_3: IFC has a structured information for handing over data to operation and maintenance stage, *pu_4: IFC is a useful data exchange format, *pu_5: PAS1192-3:2014 provides clear guidelines for adopting BIM in FM, *pu_6: BS1192-4 provides clear guidelines for populating COBie

pu_4 item score the highest total of percentage of 48.8%, while pu_3 score the lowest percentage of 39%. All items score greater in the total percentage of agree and strongly agree scales than the total percentage of the disagree and strongly disagree scale that score less than 20% in all items. Respondents who rated neutral or don't know score highest in the pu_3 and pu_5, and equal percentage in pu_2 compare to agree and strongly agree scales. This means more respondents believe that IFC is useful data exchange format than to believe it has structured information for handing over data to operation and maintenance stage. COBie, on the other hand, is equally useful for handing over data to operation and maintenance stage and will benefit FM.

7.7.6 Perceived Ease of Use

Figure 7.11 illustrates the PEOU of COBie and IFC can directly influence the behaviour intention to adopt BIM in FM. PEOU were constructed into six items in the questionnaire that include COBie, IFC, and standard guidelines (i.e. PAS1192-3:2014, BS1192-4:2014) to facilitate whether the measure could have significant influence to facilities manager to adopt open BIM standards. From the findings, a significant number of respondents indicate neutral or don't know that perceived ease of use.

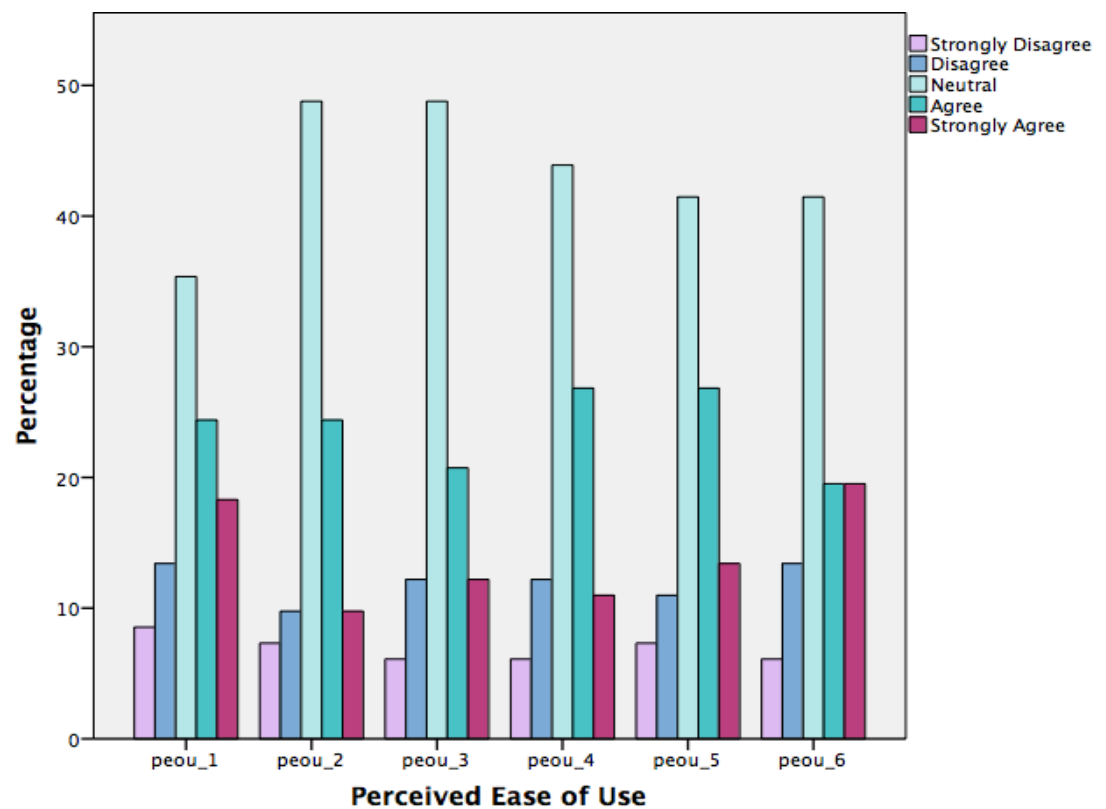


Figure 7.11 The Scale Perceived Ease of Use

Table 7.11 shows the numerical value of all six items in perceived ease of use measure. Out of all six items, peou_1 score the highest total percentage of 42.7%, while peou_3 score lowest 32.9% in total percentage of agree and strongly agree scale. On the other hand, respondents who rated disagree and strongly disagree scale are two-fold lower than agree and strongly agree scale.

Table 7.11 The Scale of Perceived Ease of Use

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
peou_1:	8.5% n=7	13.4% n=11	35.4% n=29	24.4% n=20	18.3% n=15	3.30	3.00
peou_2:	7.3% n=6	9.8% n=8	48.8% n=40	24.4% n=20	9.8% n=8	3.20	3.00
peou_3:	6.1% n=5	12.2% n=10	48.8% n=40	20.7% n=17	12.2% n=10	3.20	3.00
peou_4:	6.1% n=5	12.2% n=10	43.9% n=36	26.8% n=22	11.0% n=9	3.24	3.00
peou_5:	7.3% n=6	11.0% n=9	41.5% n=34	26.8% n=22	11.0% n=9	3.28	3.00
peou_6:	6.1% n=5	13.4% n=11	41.5% n=34	19.5% n=16	19.5% n=16	3.33	3.00

*peou_1: COBie spreadsheet is easy to use, *peou_2: COBie spreadsheet has a user-friendly interface, *peou_3: IFC is an easy format for facilities manager to use, *peou_4: IFC is a user-friendly data exchange format, *peou_5: PAS 1192-3:2014 standards helps FM to understand how to managed information easily, *peou_6: BS1192-4:2014 standard helps facility managers to implement COBie

Respondents who rated neutral and don't know has the highest percentage than any other scale in the table. Therefore, from the findings, it can be concluded that respondents found COBie is easier to use than IFC for facilities manager. Both of the standards PAS1192-3: 2014 and BS1192-4:2014 share high neutral responses as to whether it helps facilities manager to managed information easily in operation and maintenance phase and implementing COBie respectively.

7.7.7 Cost

Figure 7.12 illustrates the variable of cost can indirectly influence the behaviour intention to adopt BIM in FM. The items were constructed to support the cost measure that includes hiring specialist for capturing information using COBie and IFC and the benefits of using

both format would be greater than its cost. Most respondents rated neutral or don't know to four items related to cost measure.

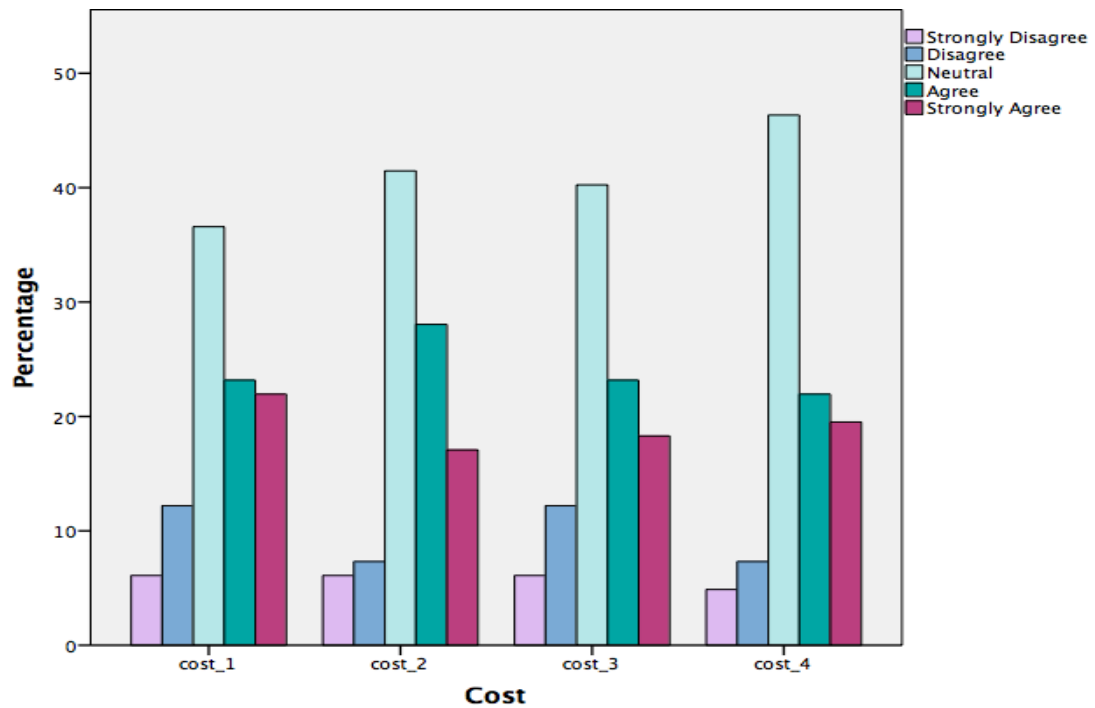


Figure 7.12 The scale cost

Table 7.12 illustrated the numerical value of respondents who rated the five-points Likert scales in all the four items in cost measure.

Table 7.12 The Scale Cost

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
cost_1:	6.1% n=5	12.2% n=10	36.6% n=30	23.2% n=19	22.0% n=18	3.43	3.00
cost_2:	6.1% n=5	7.3% n=6	41.5% n=34	28.0% n=23	17.1% n=14	3.43	3.00
cost_3:	6.1% n=5	12.2% n=10	40.2% n=33	23.2% n=19	18.3% n=15	3.53	3.00
cost_4:	4.9% n=4	7.3% n=6	46.3% n=38	22.0% n=18	19.5% n=16	3.44	3.00

*cost_1: Capturing of information in COBie may involve expensive cost in hiring specialist, *cost_2: The benefits of information populated in COBie are greater than its cost, *cost_3: Capturing of information in IFC may involve expensive cost in hiring specialist, *cost_4: The benefits of using IFC are greater than its cost.

cost_1 and cost_2 score the highest total percentage of 45.2% in both agree and strongly agree scale, while cost_3 and cost_4 score slightly lower percentage of 41.5% in the both scale. On the other hand, respondents who score both disagree and strongly disagree are

estimated two-fold lower in total percentage than both agree and strongly agree scale. However, neutral and don't know scale in all items are slightly lower percentage than both agree and strongly scale combined except for cost_4 items. This indicates that respondents tend to agree both COBie and IFC may involve expensive cost in hiring specialist than those who have the tendency to disagree. Meanwhile, respondents tend to agree that the cost will be succeeded by the benefit of information populated in COBie than IFC.

7.7.8 Classification of BIM Data

Figure 7.13 presents the extent to which classification of BIM data indirectly influence the behaviour intention adoption of BIM in FM. The items include the use of UNICLASS/OMNICLASS/SGG20 in defining, structuring, enhancing, and readable in FM system via COBie. From the findings, most respondents rated neutral or don't know scale in classification measure.

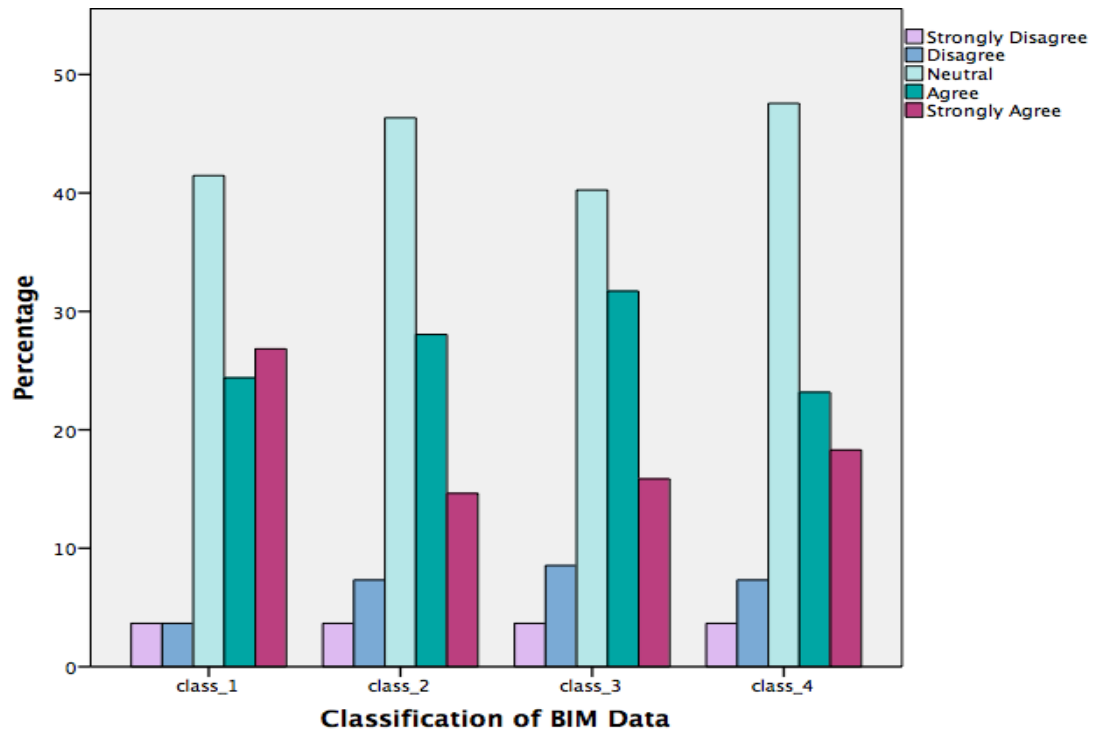


Figure 7.13 The Scale of Classification of BIM Data

From the **Table 7.13**, class_1 score the highest total percentage of 51.2% on agree and strongly agree scale. Meanwhile, class_2 score the lowest percentage of 42.6% in combined of both scale. Respondents who rated disagree and strongly disagree scale-combined score an approximate four times lower in total percentage.

Table 7.13 The Scale of Classification of BIM Data

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
class_1	3.7% n=3	3.7% n=3	41.5% n=34	24.4% n=20	26.8% n=22	3.67	3.00
class_2	3.7% n=3	7.3% n=6	46.3% n=38	28.0% n=23	14.6% n=12	3.43	3.00
class_3:	3.7% n=3	8.5% n=7	40.2% n=33	31.7% n=26	15.9% n=13	3.48	3.00
class_4:	3.7% n=3	8.5% n=7	40.2% n=33	31.7% n=26	15.9% n=13	3.45	3.00

* class_1: The use of classification systems is useful in structuring FM data, * class_2: The Uniclass/ Omniclass/SFG20 standard is important for defining information in COBie, * class_3: The Uniclass/ Omniclass/ SFG20 enhances the use of COBie in FM system, * class_4: Information that carries Uniclass/Omniclass/ SFG20 standard is readable in FM system

Out of all four items in classification measure, only an item (class_2) score highest percentage in neutral/don't know scale than combined scale has agree and strongly agree and disagree and strongly disagree. From the findings, it was found out that classification of BIM data is a significant in defining information in COBie and provide structured information and readable format in FM system.

7.7.9 Data Exchange

Figure 7.14 illustrates as to whether data exchange could have significant influence in the behaviour intention in adoption of BIM in FM. Two items were constructed to test as to whether COBie and IFC can allow integration into the FM system. A large group of respondents indicate neutral in evaluating data exchange could be useful in intending to adopt open BIM standards and standard guidelines.

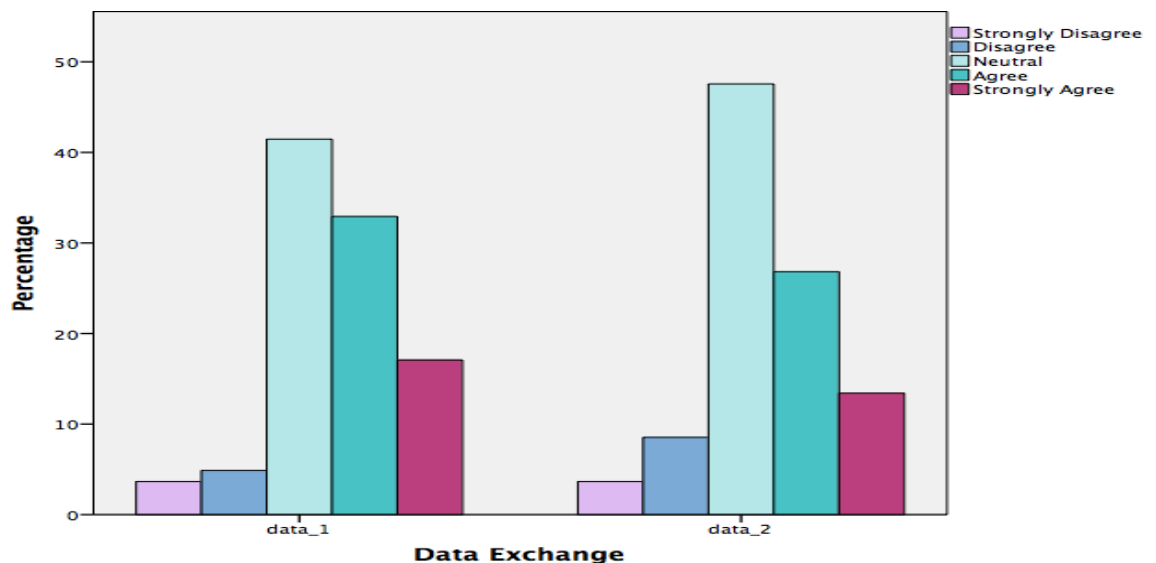
**Figure 7.14 The Scale of Data Exchange**

Table 7.14 shows numerical value of each scale in data exchange measure. data_1 score half of the total percentage of respondents who rated agree and strongly agree scale. data_2 score slightly lower total percentage of 40.2% in combination of both scales.

Table 7.14 The Scale of the Data Exchange

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
data_1:	3.7% n=3	4.9% n=4	41.5% n=34	32.9% n=27	17.1% n=14	3.55	3.38
data_2:	3.7% n=3	8.5% n=7	47.6% n=39	26.8% n=22	13.4% n=11	3.50	3.00

*data_1: COBie can easily be used to import data in FM system, *data_2: IFC format allows integration with my FM system

On the other hand, combination of both disagree and strongly disagree scale score low in both data_1 and data_2 item of 8.6% and 12.2% respectively. The neutral and don't know scale score 47.6% in data_2 items, which greater percentage than both agree and strongly agree scale, while data_1 score 41.5% that remain lower than both agree and strongly agree scale. Therefore, the findings suggest that respondents tend to agree both COBie and IFC can be integrated with FM system.

7.7.10 As-Built Model

Figure 7.15 shows the variable of as-built model could have significance influence the behaviour intention in adoption of BIM in FM. Four items of related to as-built model were constructed to help facilities manager to verify and validate the relevant, redundancy, errors or missing information in COBie. From the findings, a majority of respondents claim to have neutral stands on how as-built model could be useful in adopting open BIM standards.

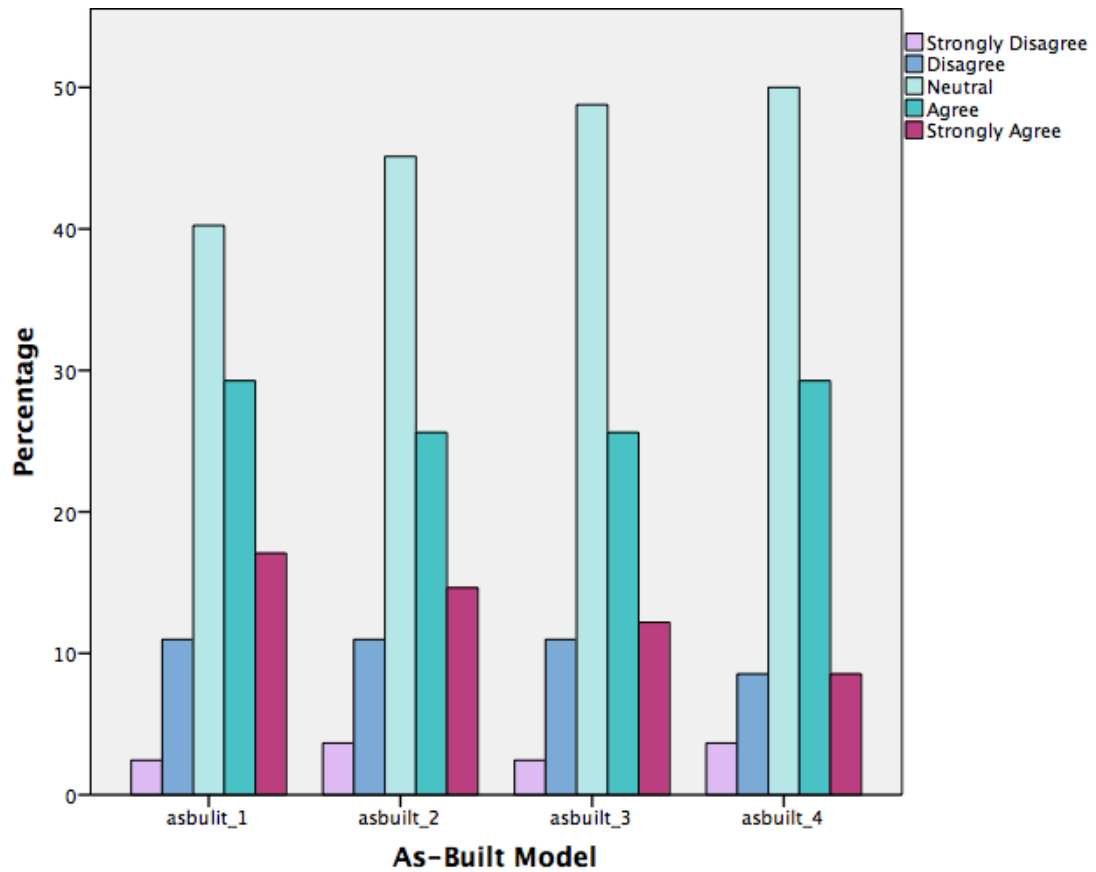


Figure 7.15 The Scale As-Built Model

Table 7.15 shows the percentages of respondents across the items under the as-built measure. The item asbuilt_1 score the highest total percentage of 46.4% of respondents who rated agree and strongly agree. Meanwhile, asbuilt_3 and asbuilt_4 share the lowest total percentage of 37.8%. All four items, however, score low of the total percentage of respondents who disagree and strongly disagree.

Table 7.15 The Scale As-Built Model

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
asbuilt_1	2.4% n=2	11.0% n=9	40.2% n=33	29.3% n=24	17.1% n=14	3.48	3.00
asbuilt_2	3.7% n=3	11.0% n=9	45.1% n=37	25.6% n=21	14.6% n=12	3.37	3.00
asbuilt_3	2.4% n=2	11.0% n=9	48.8% n=40	25.6% n=21	12.2% n=10	3.34	3.00
asbuilt_4:	3.7% n=3	8.5% n=7	50.0% n=41	29.3% n=24	8.5% n=7	3.30	3.00

*asbuilt_1:As-built model helps facilities managers to identify the relevant information in COBie, *asbuilt_2:As-Built model helps facilities managers to reduce redundant information in COBie, *asbuilt_3: As-Built model helps facilities managers to identify errors in COBie, *asbuilt_4: As-Built model helps facilities managers to identify missing information in COBie

The scale of neutral and don't know score the highest percentage compare to the level of agree and disagree scale. From the findings, it was found out that respondents tend to agree that as-built model helps facilities manager to identify the relevant information in COBie more than it can reduce redundant information, errors and missing information.

7.7.11 Upskilling

Figure 7.16 provides the variable of upskilling can have significant influence in adoption of open BIM standards and standard guidelines in FM. Two items were constructed to identify whether attending training and workshops could enhance the skillset in using COBie and IFC. Most respondents stated neutral on the need for upskilling in adopting open BIM standards.

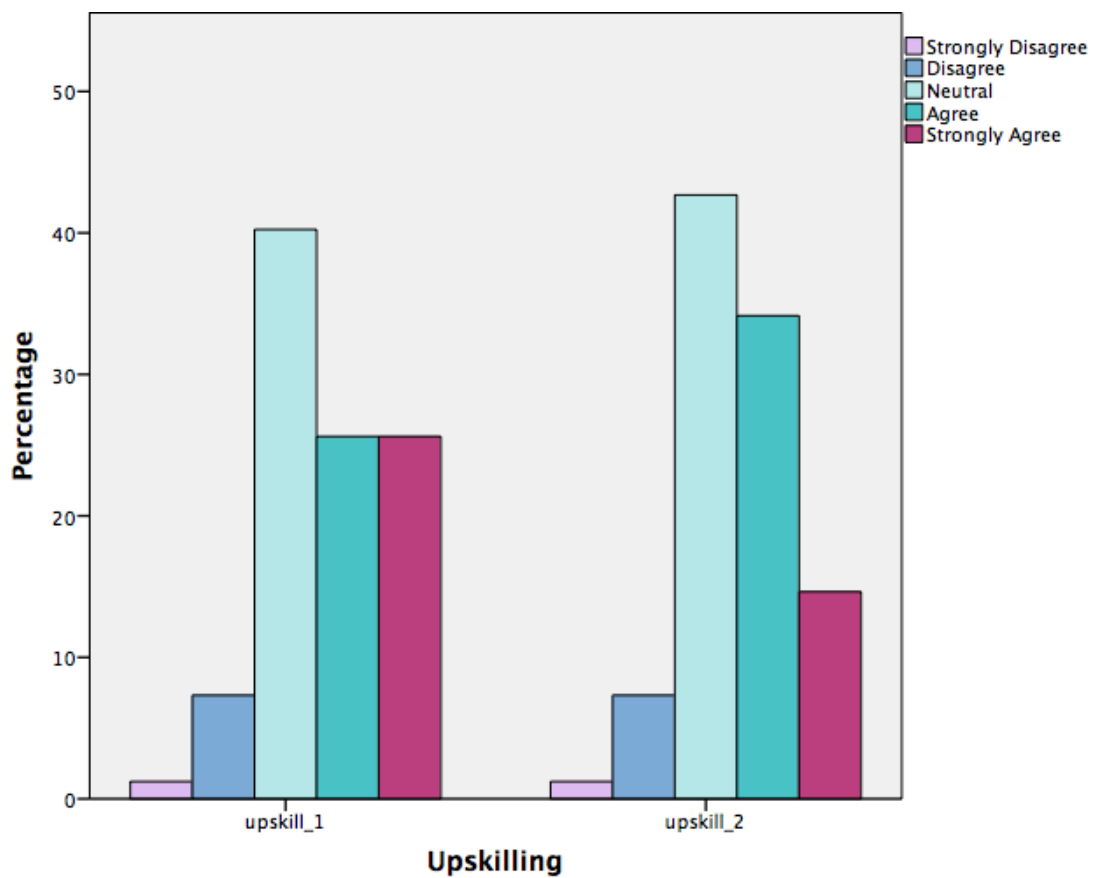


Figure 7.16 The Scale Upskilling

Under the upskilling measure in **Table 7.16**, the item upskill_1 and upskill_2 score 51.2 % and 48.7% respectively in total percentage of agree and strongly agree scale. Both items score low in total percentage of respondents who rated disagree and strongly disagree.

Table 7.16 The Scale of Upskilling

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
upskill_1	1.2% n=1	7.3% n=6	40.2% n=33	25.6% n=21	25.6% n=21	3.67	4.00
upskill_2	1.2% n=1	7.3% n=6	42.7% n=35	34.1% n=28	14.6% n=12	3.54	3.00

*upskill_1: Training workshops help me to enhance my skill set in updating COBie information in FM system, *upskill_2: Training workshops help me to enhance my skill set in using IFC data exchange format to update graphical information in FM system.

Both items score more than two-fifth in neutral and don't know scale. Therefore, the findings suggest that through training and workshops can helps facilities manager enhancing skillset in updating COBie and IFC in FM system.

7.7.12 Behaviour Intention

Figure 7.17 provides the variable of behaviour intention to predict the statistical significant in adoption of open BIM standards and standards guidelines. Four statemenst were constructed to identified the intention of adopting COBie and IFC, and the standard guidelines in practice. All four statements score high on the tendency to agree then to disagree.

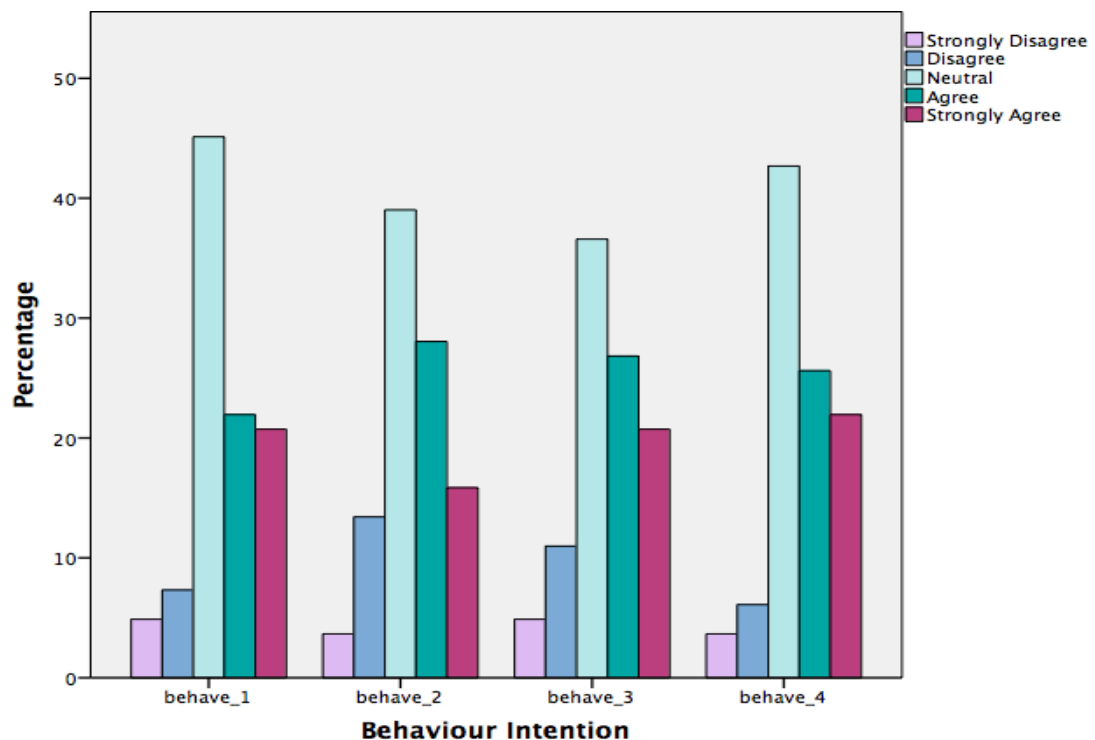


Figure 7.17 The Scale of Behaviour Intention

Table 7.17 describes the numerical value of four items under behaviour measure. From the findings, behave_3 and behave_4 score the highest total percentage of 47.6% in agree and strongly agree scale, while behave_1 score lowest total percentage in 42.7%. On the other hand, all items have low score in the total percentage of respondents who rated disagree and strongly disagree scale.

Table 7.17 The Scale of Behaviour Intention

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
behave_1	4.9% n=4	7.3% n=6	45.1% n=37	22.0% n=18	20.7% n=17	3.46	3.00
behave_2	3.7% n=3	13.4% n=11	39.0% n=32	28.0% n=23	15.9% n=13	3.39	3.00
behave_3	4.9% n=4	11.0% n=9	36.6% n=30	26.8% n=22	20.7% n=17	3.48	3.00
behave_4	3.7% n=3	6.1% n=5	42.7% n=35	25.6% n=21	22.0% n=18	3.56	3.00

* behave_1: I have intention to adopt open BIM standards, * behave_2: I anticipate that I will adopt open BIM standards and standards guidelines, * behave_3: I intent to apply open BIM standards and standard guidelines in my work, * behave_4: I have adopted open BIM standard and standard guidelines

Respondents who rated neutral and don't know score slightly higher in behave_1, but lower in other three items in behaviour intention measure. As a result, respondents tend to agree the intention to apply open BIM standards and standards guidelines in their work, and at best already adopt it.

7.8 The Extent to which BIM guidelines can support the adoption of open BIM standards

This section provides respondents to rate the extent to which BIM guidelines (i.e. PAS1192-3:2014 and BS1192-4:2014) can facilitate the adoption of open BIM standards. As can be seen in the **Figure 7.18**, the result shows that a large number of respondents rated neither agree or disagree in five out of eight items in measuring the standards and guidelines of PAS1192-3:2014 and BS1192-4:2014 that could facilitate the adoption of COBie/IFC in operation and maintenance task.

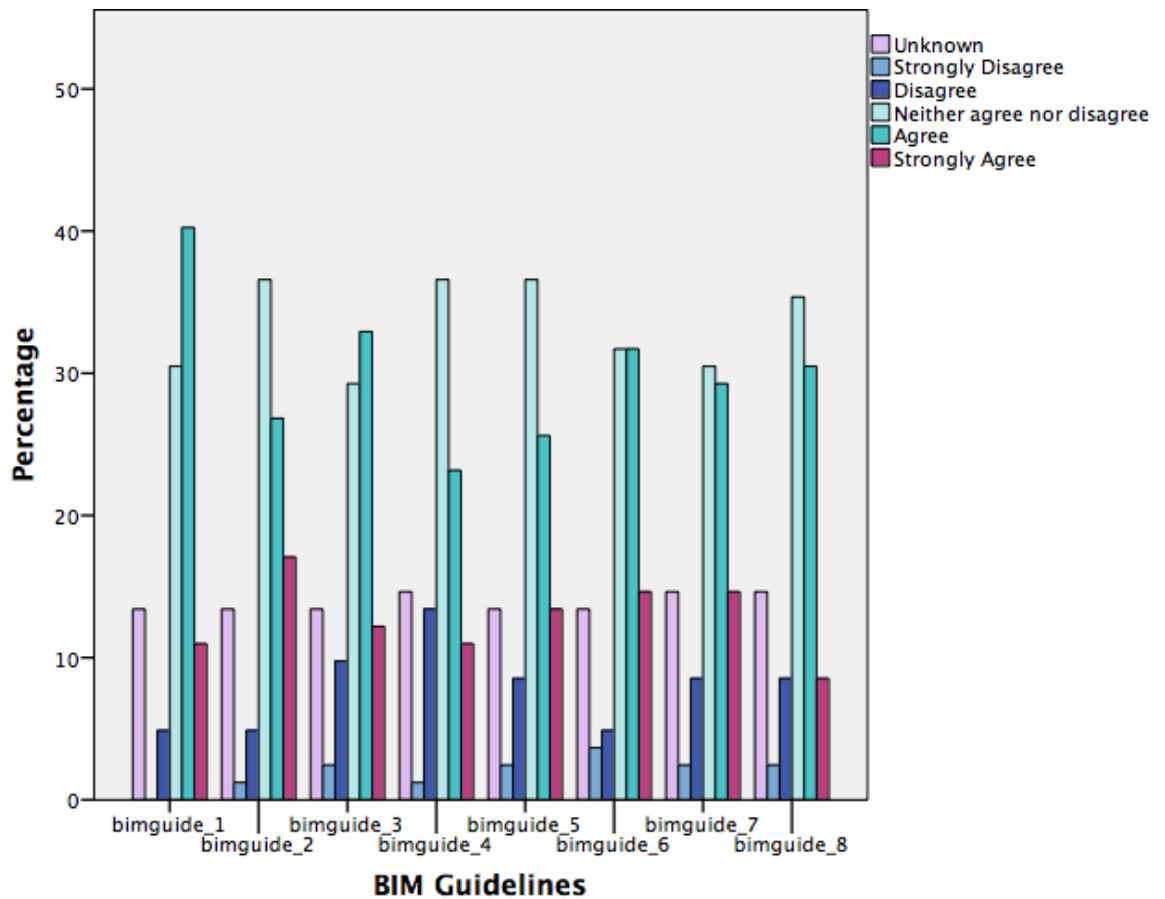


Figure 7.18 The Extent BIM Guidelines Adoption of Open BIM

The analysis of the level of agreeableness in **Table 7.18**, found that the highest total percentage of respondents who both agree and strongly agree is bimguide_1 item with 51.2% and the lowest total percentage score are bimguide_4 with 34.2%. Respondents who rated disagree and strongly disagree has low score in total percentage in all the eight items.

Meanwhile, an approximate more than one-third of the percentage score in neither agree or disagree scale. Less than 15% of respondents rated unknown scale. Therefore, the main findings reveal that more than 50% of respondents tend believe that PAS1192-3:2014 has clarified process and procedure of information communication with FM system above other statements in PAS1192-3:2014. However, the statement PAS1192-3:2014 can support the adoption of BIM in FM on a live project has the least combined percentage of agree and strongly agree scale but higher than the disagree and strongly disagree scale. The combined percentage of disagree and strongly disagree also apply to other statements including the BS1192-4:2014 statements.

Table 7.18 The Extent BIM Guidelines Adoption of Open BIM

	Unknown	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
bimguide_1	13.4% n=11	0	4.9% n=4	30.5% n=25	40.2% n=33	11.0% n=9	4.17	4.00
bimguide_2	13.4% n=11	1.2% n=1	4.9% n=4	36.6% n=30	26.8% n=22	17.1% n=14	4.13	4.00
bimguide_3	13.4% n=11	2.4% n=2	9.8% n=8	29.3% n=24	32.9% n=27	12.2% n=10	4.02	4.00
bimguide_4	14.6% n=12	1.2% n=1	13.4% n=11	36.6% n=30	23.2% n=19	11.0% n=9	3.85	4.00
bimguide_5	13.4% n=11	2.4% n=2	8.5% n=7	36.6% n=30	25.6% n=21	13.4% n=11	3.99	4.00
bimguide_6	13.4% n=11	3.7% n=3	4.9% n=4	31.7% n=26	31.7% n=26	14.6% n=12	4.09	4.00
bimguide_7	14.6% n=12	2.4% n=2	8.5% n=7	30.5% n=25	29.3% n=24	14.6% n=12	4.01	4.00
bimguide_8	14.6% n=12	2.4% n=2	8.5% n=7	35.4% n=29	30.5% n=25	8.5% n=7	3.90	4.00

*bimguide_1: PAS 1192-3:2014 has clarified the process and procedure of information communication with FM system,

*bimguide_2: PAS 1192-3:2014 sufficiently covers the key information requirement for FM tasks, *bimguide_3: PAS1192-3:2013 has clarified the role and responsibility of managing and maintaining BIM model in O&M stage, *bimguide_4: PAS1192-3:2014 can support the adoption of BIM in FM on a live project, *bimguide_5: BS 1192-4:2014 provides a comprehensive guidance to use COBie for FM, *bimguide_6: BS1192-4:2014 provides the key information requirement for COBie, *bimguide_7: BS 1192-4:2014 has clarified the role and responsibility of populating COBie in FM, *bimguide_8: BS1192-4:2014 can support the adoption of COBie on a live project

7.9 The Framework that can Facilitate the Adoption of Open BIM Standards and Standard Guidelines

The last questionnaire item in the online survey describes the recommended concepts/tasks as part of the framework to adopt open BIM standards and standards guidelines in FM. Eight items was proposed to the respondents who took part in the online-survey. In **Figure 7.19**, a high percentage of respondents rated neither agree or disagree scale in all eight items in framework measure.

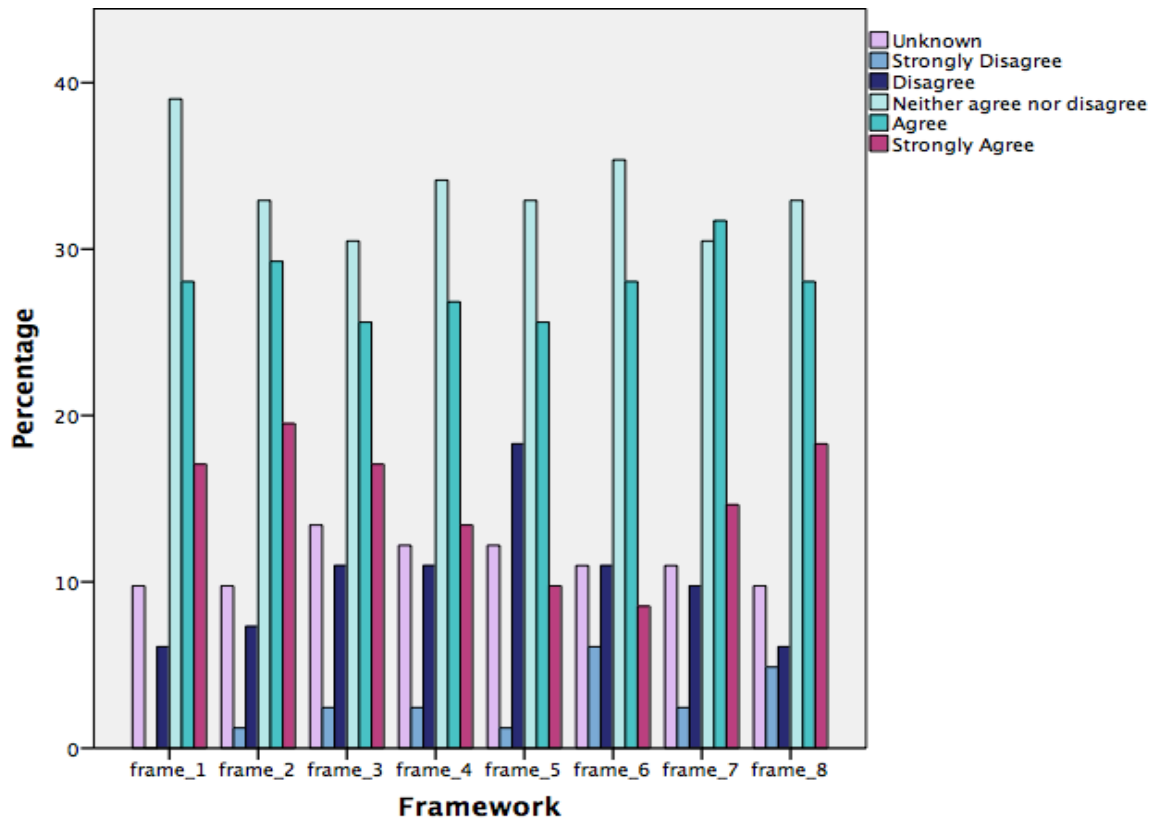


Figure 7.19 Framework facilitated the adoption of open BIM standards

From **Table 7.19**, frame_2 item is rated the highest total percentage of 48.8% of respondents who rated agree and strongly agree scale, while frame_5 item with the lowest total percentage of 35.4%. Less than one-fifth of respondents rated disagree and strongly disagree scales in all eight measures. An approximate more than one-third of responded neither agree or disagree scale in all measures.

Meanwhile, a low percentage of respondents rated unknown to all the items. The findings suggest that almost half of total respondents tend to agree on the concept of process map for BIM use in FM. On the other hand, reducing the cost of training in promoting the use COBie and IFC seems to be the least favourable among other statements but certainly higher than those rated disagree and strongly disagree.

Table 7.19 Framework facilitated the adoption of open BIM standards

	Unknown	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean ($\bar{x}$)	Median (M)
Frame_1	9.8% n=8	0	6.1% n=5	39.0% n=32	28.0% n=23	17.1% n=14	4.27	4.00
Frame_2	9.8% n=8	1.2% n=1	7.3% n=6	32.9% n=27	29.3% n=24	19.5% n=16	4.29	4.00
Frame_3	13.4% n=11	2.4% n=2	11.0% n=9	30.5% n=25	25.6% n=21	17.1% n=14	4.04	4.00
Frame_4	12.2% n=10	2.4% n=2	11.0% n=9	34.1% n=28	26.8% n=22	13.4% n=11	4.01	4.00
Frame_5	12.2% n=10	1.2% n=1	18.3% n=15	32.9% n=27	25.6% n=21	9.8% n=8	3.88	4.00
Frame_6	11.0% n=9	6.1% n=5	11.0% n=9	35.4% n=29	28.0% n=23	8.5% n=7	3.89	4.00
Frame_7	11.0% n=9	2.4% n=2	9.8% n=8	30.5% n=25	31.7% n=26	14.6% n=12	4.13	4.00
Frame_8	9.8% n=8	4.9% n=4	6.1% n=5	32.9% n=27	28.0% n=23	18.3% n=15	4.20	4.00

*frame_1: Reduce the content of COBie to more relevant material, *frame_2: A process map for BIM use in FM, *frame_3: Early involvement of facilities manager in the EIR document, *frame_4: Suppliers and Manufacturers has an important factor to play in providing details for COBie data input, *frame_5: Reduce the cost of training in promoting the use of COBie and IFC for FM, *frame_6: Regulatory enforcement in using COBie and IFC for FM, *frame_7: Communication with design and construction team to get information needed for FM in COBie and IFC, *frame_8: Assigning BIM manager to update information in COBie and IFC in the FM system

7.10 Correlation between variables in the BIM-FM Technology Acceptance Innovation Model

In **Chapter 4** discussed the predictions of proposed variables in the BIM-FM Technology Acceptance Innovation Model. The conceptual model was derived from the integration of TAM and IDT. Six main variables were used to predict the behaviour intention of facilities managers in adoption of open BIM standards and standards guidelines. On the other hand, five external variables were proposed to predict the PU belief in the conceptual model. Therefore, to explore the relationship between two variables, an associational inferential statistic –Pearson’s correlation is used to find out the strength of relationship between variables and the statistical significant is to determine the finding of p-value (probability level) between variables is statistically significant or not significant.

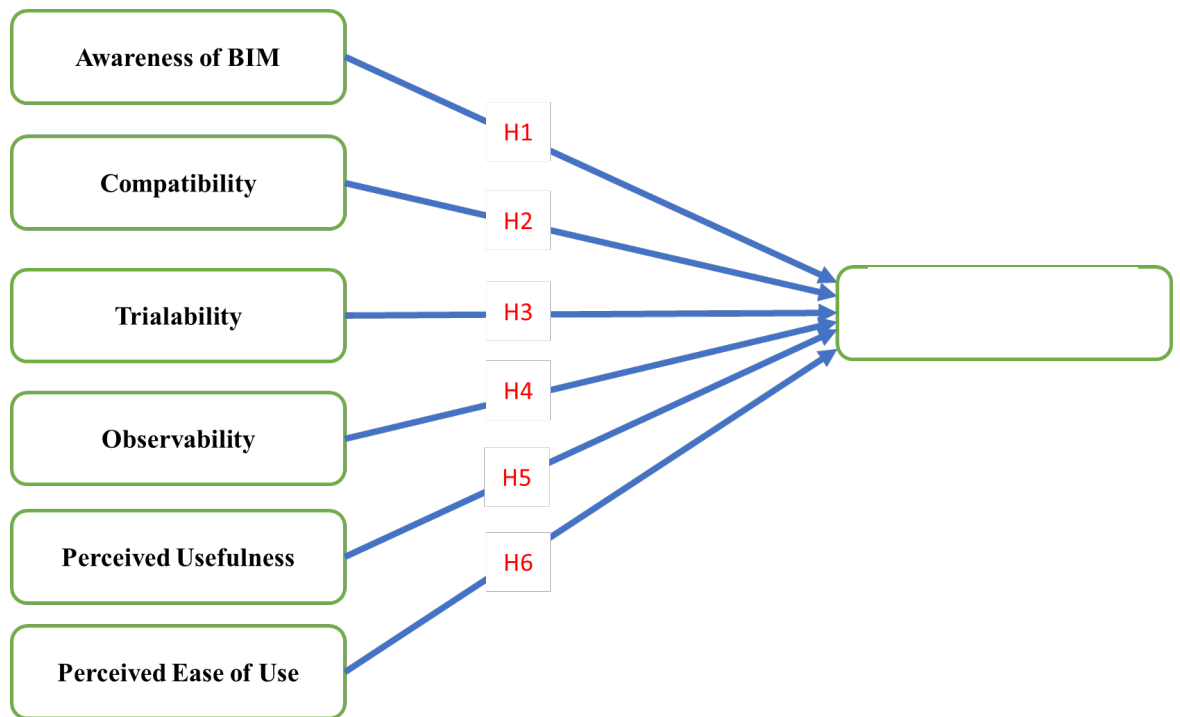


Figure 7.20 Modified model of BIM-FM TAM and IDT

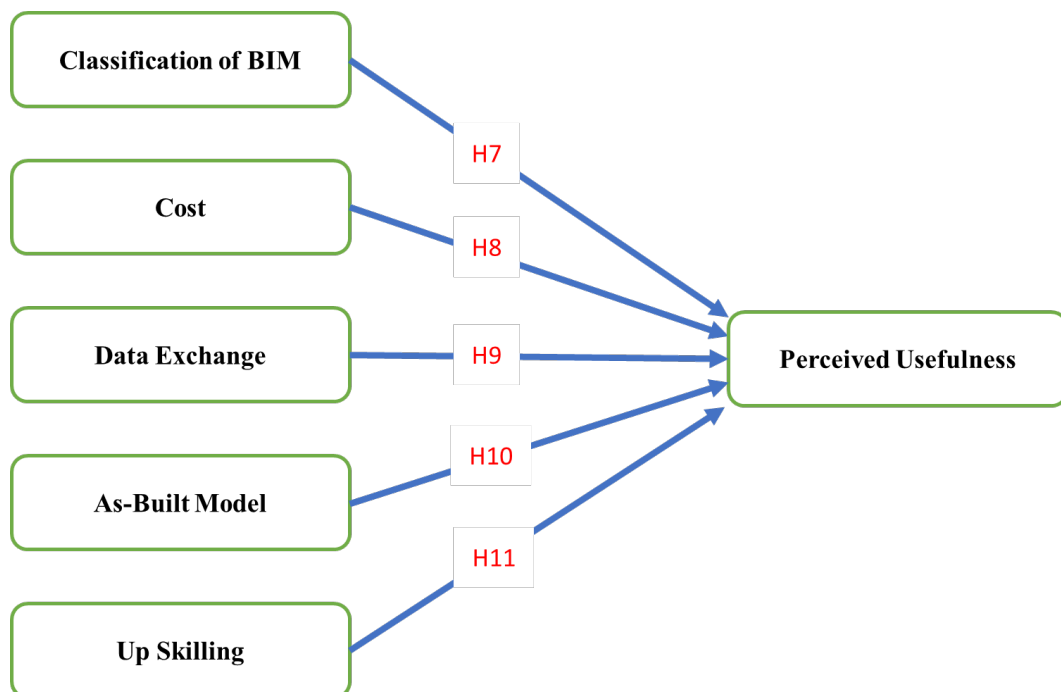


Figure 7.21 External Variables to Predict PU

To interpret the analysis of Pearson's r correlation is determined by the correlation coefficient of between two variables. The correlation coefficient can be summarised as per **Table 7.20**. On the other hand, the statistical significance can be interpreted by the p-value. If the p-value is less than or equal to 0.5 ($p \leq 0.5$), then the finding is statistically significant and if the p-value is more than 0.5 ($p > 0.5$), then the finding is not statistically significant.

Table 7.20 Strength of the Relationship Coefficient

Coefficient	Strength	Alternate descriptor
0.00	No (linear) relationship	-
0.01-0.09	Trivial (linear) relationship	Very small, insubstantial, tiny, practically zero
0.10-0.29	Low to Moderate (linear) relationship	Small, low, minor
0.30-0.49	Moderate to substantial (linear) relationship	Medium
0.50-0.69	Substantial to very strong (linear) relationship	Large, high, major
0.70-0.89	Very strong (linear) relationship	Very large, very high, huge
0.90+	Near perfect	-

7.10.1 Association between Awareness of BIM and Behaviour Intention



Table 7.21 indicates the correlation matrix between Awareness of BIM (aw) and behaviour intention (BI). The matrix also displayed the results of Pearson correlation statistical significance (Sig) among the measures to identify the strength of relationship and determine whether those measures are statistically significant. The results show the relationship between the eight measures of awareness of BIM (aw_1-aw_8) and the four measures of behaviour intention (behave_1-behave_4) are statistically significant with p-value less than or equal to 0.5 ($p \leq 0.5$). On the other hand, the notable Pearson correlation that shows very strong coefficient more than 0.60 in four measures in the above table.

Table 7.21 Correlation Matrix Between Awareness and Behaviour Intention

		behave_1	behave_2	behave_3	behave_4
aw_1	Pearson Correlation	.470**	.420**	.331**	.496**
	Sig. (2-tailed)	.000	.000	.002	.000
aw_2	Pearson Correlation	.591**	.438**	.507**	.541**
	Sig. (2-tailed)	.000	.000	.000	.000
aw_3	Pearson Correlation	.545**	.595**	.549**	.632**
	Sig. (2-tailed)	.000	.000	.000	.000
aw_4	Pearson Correlation	.503**	.558**	.595**	.691**
	Sig. (2-tailed)	.000	.000	.000	.000
aw_5	Pearson Correlation	.647**	.356**	.520**	.532**
	Sig. (2-tailed)	.000	.001	.000	.000
aw_6	Pearson Correlation	.626**	.474**	.538**	.494**
	Sig. (2-tailed)	.000	.000	.000	.000
aw_7	Pearson Correlation	.522**	.378**	.390**	.434**
	Sig. (2-tailed)	.000	.000	.000	.000
aw_8	Pearson Correlation	.558**	.401**	.502**	.522**
	Sig. (2-tailed)	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).					

The relationship between items– (aw_3–behave_4), (aw_4 and behave_4), (aw_5–behave_1), and (aw_6–behave_1) are explained as below:

aw_3–behave_4: Familiarity with the term IFC has strong relationship with those who had already adopted it

aw_4–behave_4: Familiarity with how IFC works for FM practice has a significant relationship with those who had adopted it.

aw_5–behave_1: Familiarity with the standard guidelines PAS1192-3:2014 has a strong relationship with the intention to adopt open BIM standards and standards guidelines in near future

aw_6-behave_1: Familiarity with how PAS1192-3:2014 helps in adopting BIM in FM has a substantial relationship with the intention to adopt open BIM standards and standards guidelines in near future

This indicate that the likelihood of participants who familiar with the term IFC and know how it works in FM practice is those who have already adopted open BIM standards and standards guidelines. Meanwhile, respondents who familiar with PAS1192-3:2014 and know how to use it in FM have a higher possibility in adopting it in near future. In contrast, none of items in the above table show low relationship and mostly the strength fall between 0.3 to 0.6 correlation coefficient that indicate moderate to strong relationships.

7.10.2 Association Between Compatibility and Behaviour Intention



Table 7.22 indicate the correlation matrix between Compatibility (Com) and behaviour intention (BI). The results show the relationship between measures of compatibility (com_1-com_6) and behaviour intention (behave_1-behave_4) is all statistically significant. The result shows that there are very strong relationship in item com_2 against behave_1, behave_3 and behave_4. The following Table elaborates the relationship between items.

Table 7.22 Correlation Matrix Between Compatibility and Behaviour Intention

		behave_1	behave_2	behave_3	behave_4
com_1	Pearson Correlation	.516**	.488**	.497**	.529**
	Sig. (2-tailed)	.000	.000	.000	.000
com_2	Pearson Correlation	.622**	.431**	.601**	.606**
	Sig. (2-tailed)	.000	.000	.000	.000
com_3	Pearson Correlation	.489**	.516**	.586**	.581**
	Sig. (2-tailed)	.000	.000	.000	.000
com_4	Pearson Correlation	.433**	.501**	.568**	.661**
	Sig. (2-tailed)	.000	.000	.000	.000
com_5	Pearson Correlation	.412**	.435**	.485**	.504**
	Sig. (2-tailed)	.000	.000	.000	.000

com_6	Pearson Correlation	.505**	.554**	.571**	.531**
	Sig. (2-tailed)	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).					

com_2—behave_1: *the use of COBie facilitates effective working has a strong relationship with intention to adopt open BIM standards and standards guidelines in near future.*

com_2—behave_3: *the use of COBie facilitates effective working has a strong relationship with anticipation in adopting open BIM standards guidelines.*

com_2—behave_4: *the use of COBie facilitates effective working has a significant relationship with respondents who had already adopted open BIM standards and standards guidelines.*

This shows that participants who think that the use of COBie facilitates effective working is either those who have already adopted COBie or those who anticipated to apply it in their work and near future. Apart from that, in the item com_4 against behave_4 also show a strong relationship in correlation coefficient.

com_4—behave_4: *the use of IFC improves work has a strong relationship with those who already adopted open BIM standards and standards guidelines.*

This indicates that the respondents who believe that IFC improves their work is those who already adopted it. However, none of items appear to show low relationship but mostly show a moderate to strong correlation coefficient more than 0.4.

7.10.3 Association Between Trialability and Behaviour Intention



Table 7.23 indicate the correlation matrix between Trialability (trial) and behaviour intention (behave). The results show the relationships between measures of trialability (trial_1-trial_6) and behaviour intention (behave_1-behave_4) are all statistically significant. The result shows that there are very strong relationships between item trial_3 against behave_1, trial_4 against behave_2 and behave_4. The following items elaborate on the notable relationship between items.

trial_3—behave_1: *I have used COBie on live projects has a strong relationship with intention of adopting open BIM standards and standards guidelines in near future.*

trial_4-behave_2: *I have used IFC data exchange on live projects has a significant relationship with anticipation in applying open BIM standards and the standards guidelines in working practice.*

trial_4-behave_4: *I have used IFC data exchange on live projects has a strong relationship with respondents who already adopted open BIM standards and standards guidelines.*

Table 7.23 Correlation Matrix Between Trialability and Behaviour Intention

		behave_1	behave_2	behave_3	behave_4
trial_1	Pearson Correlation	.555**	.553**	.514**	.522**
	Sig. (2-tailed)	.000	.000	.000	.000
trial_2	Pearson Correlation	.479**	.545**	.479**	.581**
	Sig. (2-tailed)	.000	.000	.000	.000
trial_3	Pearson Correlation	.616**	.418**	.542**	.525**
	Sig. (2-tailed)	.000	.000	.000	.000
trial_4	Pearson Correlation	.500**	.617**	.594**	.604**
	Sig. (2-tailed)	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).					

The above result can be inferred that respondents who have used COBie on live project has the tendency to adopt it in near future, while respondents who have used IFC data exchange on live projects are those who has the intention to apply in their work or have already adopted open BIM standards and standards guidelines.

7.10.4 Association Between Observability and Behaviour Intention



Table 7.24 shows the correlation matrix between Observability (obs) and behaviour intention (behave). The results show the relationships between the measures of observability (obs_1-obs_4) and behaviour intention (behave_1-behave_4) are all statistically significant. It was also found out that almost all of the items have somewhat strong relationships against each other with the correlation coefficient more than 0.6. The following describe the relationship between items.

Table 7.24 Correlation Matrix Between Observability and Behaviour Intention

		behave_1	behave_2	behave_3	behave_4
obs_1	Pearson Correlation	.491**	.497**	.497**	.476**
	Sig. (2-tailed)	.000	.000	.000	.000
obs_2	Pearson Correlation	.626**	.438**	.627**	.603**
	Sig. (2-tailed)	.000	.000	.000	.000
obs_3	Pearson Correlation	.574**	.616**	.518**	.640**
	Sig. (2-tailed)	.000	.000	.000	.000
obs_4	Pearson Correlation	.580**	.617**	.541**	.573**
	Sig. (2-tailed)	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).					

obs_2–behave_1: *demonstrations of COBie in FM has strong influence in the intention in adoption of open BIM standards and standards guidelines in near future*

obs_2–behave_3: *demonstrations of COBie in FM has a strong relationship with anticipation in applying open BIM standards and standards guidelines in work.*

obs_2–behave_4: *demonstrations of COBie in FM has a significant relationship with those who had already adopted open BIM standards and standards guidelines*

obs_3- behave_2: *case studies where IFC has been used in FM has a high correlation with anticipation in applying open BIM standards and standard guidelines in working practice.*

obs_3-behave_4: *case studies where IFC has been used in FM has a strong association with those who had already adopted open BIM standards and standards guidelines*

obs_4–behave_2: *demonstrations of IFC in FM has a significant relationship with anticipation in adoption of open BIM standards and standard guidelines in working practice.*

The above relationships suggest that respondents who have seen the demonstration of COBie in FM will likely to have the intention in adopting open BIM standards and standards guidelines and apply it as part of their work, and also those who at best already adopted it.

In addition, respondents who have seen case studies where IFC have been used in FM have the tendency to be expected to apply as part of their work or those already adopted. Furthermore, it is also noted that respondents who have seen the demonstration of IFC used in FM will likely to anticipate applying it. On the other hand, other items show moderate to strong relationships and none of the items fall below than 0.4 in correlation coefficient.

7.10.5 Association Between Perceived Usefulness and Behaviour Intention



Table 7.25 shows the correlation matrix between perceived usefulness (pu) and behaviour intention (behave). The results show the relationships between the measures of perceived usefulness (pu_1-pu_6) and behaviour intention (behave_1-behave_4) are all statistically significant. The findings indicate that there are very strong relationship between the item pu_2 against behave_1 and behave_3.

Table 7.25 Correlation Matrix Between Perceived Usefulness and BI

		behave_1	behave_2	behave_3	behave_4
pu_1	Pearson Correlation	.513**	.362**	.461**	.414**
	Sig. (2-tailed)	.000	.001	.000	.000
pu_2	Pearson Correlation	.627**	.553**	.647**	.584**
	Sig. (2-tailed)	.000	.000	.000	.000
pu_3	Pearson Correlation	.589**	.531**	.629**	.598**
	Sig. (2-tailed)	.000	.000	.000	.000
pu_4	Pearson Correlation	.469**	.482**	.518**	.581**
	Sig. (2-tailed)	.000	.000	.000	.000
pu_5	Pearson Correlation	.598**	.531**	.493**	.641**
	Sig. (2-tailed)	.000	.000	.000	.000
pu_6	Pearson Correlation	.572**	.437**	.436**	.581**
	Sig. (2-tailed)	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).					

pu_2-behave_1: *COBie will benefit FM practice has a strong relationship with intention in adopting open BIM standards and standards guidelines in near future*

pu_2-behave_3: *COBie will benefit FM practice has a substantial relationship with the intention to adopt open BIM standards and standards guidelines in work.*

The above indicate that participants who think COBie will benefit FM are likely to adopt open BIM standards and standards guidelines in near future and intent to apply it in their work. On the other hand, other items have shown a consistent correlation coefficient between 0.4 to 0.6 that indicate moderate to strong relationships.

7.10.6 Association between Perceived Ease of Use and Behaviour Intention



The results show the relationships between perceived ease of use (peou_1- peou_6) and behaviour intention (behave_1-behave_4) in **Table 7.26**. From the findings, all measures are found statistically significant and, however, notable strong relationships are found in the following item;

Table 7.26 Correlation Perceived Ease of Use and Behaviour Intention

		behave_1	behave_2	behave_3	behave_4
peou_1	Pearson Correlation	.552**	.535*	.493**	.526**
	Sig. (2-tailed)	.000	.000	.000	.000
peou_2	Pearson Correlation	.416**	.430**	.446**	.449**
	Sig. (2-tailed)	.000	.000	.000	.000
peou_3	Pearson Correlation	.566**	.608**	.411**	.590**
	Sig. (2-tailed)	.000	.000	.000	.000
peou_4	Pearson Correlation	.447**	.346**	.486**	.571**
	Sig. (2-tailed)	.000	.001	.000	.000
peou_5	Pearson Correlation	.430**	.371**	.498**	.590**
	Sig. (2-tailed)	.000	.001	.000	.000
peou_6	Pearson Correlation	.432**	.529**	.516**	.570**

	Sig. (2-tailed)	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).					

peou_3–behave_2: *IFC is an easy format for facilities manager to use has a strong relationship with anticipation to adopt open BIM standards and standard guidelines as part of work.*

This means participants who believed IFC is an easy format for facilities managers to use has the tendency to anticipate in applying in their work. Apart from that, none of other measures seem to fall below than moderate relationships.

7.10.7 Association between Cost and Perceived Usefulness



Table 7.27 indicate the result of correlation between cost (cost_1-cost_4) and perceived usefulness (pu_1-pu_6). All measures appear statistically significant in the table. Several notable findings were found in the following relationships between items;

Table 7.27 Correlation Matrix Between Cost and Perceived Usefulness

		pu_1	pu_2	pu_3	pu_4	pu_5	pu_6
cost_1	Pearson Correlation	.478**	.592**	.505**	.466**	.427**	.392**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
cost_2	Pearson Correlation	.561**	.654**	.658**	.577**	.696**	.564**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
cost_3	Pearson Correlation	.483**	.529**	.423**	.414**	.546**	.521**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
cost_4	Pearson Correlation	.476**	.573**	.627**	.537**	.603**	.555**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).							

cost_2–pu_2: *The benefit of information populated in COBie is greater than its cost has strong relationship that COBie will benefit FM*

cost_2–pu_3: *The benefit of information populated in COBie is greater than its cost has a significant relationship that IFC has a structured information for handing over data to operation and maintenance stage.*

cost_2–pu_5: *The benefit of information populated in COBie is greater than its cost has a high correlation with PAS1192-3:2014 provides clear guidelines for adopting BIM in FM.*

This indicate that respondents who think that the benefit of information populated in COBie are greater that its cost has a tendency to believe it will benefit FM and IFC has a structured information for handing over data to operational and maintenance phase. Also, it appears PAS1192-3:2014 provide some clear guidelines for operation and maintenance phase. Meanwhile, it also appear that cost_4 has a high correlation coefficient against pu_3 and pu_5 as found in the following;

cost_4–pu_3: *Capturing information in IFC may involve expensive cost in hiring specialist has a strong relationship that IFC has a structured information for handing over data to operation and maintenance stage.*

cost_4–pu_5: *Capturing information in IFC may involve expensive cost in hiring specialist has a strong relationship that PAS1192-3:2014 provides clear guidelines for adopting BIM in FM*

The correlation suggests that respondents who think the benefit of using IFC are greater that its cost has the tendency to think IFC has a structured information for handing over data to operation and maintenance phase and PAS1192-3:2014 provide clear guidelines to adopt BIM in FM. On the other hand, none of the measures fall on the categories of low relationships.

7.10.8 Association between Classification of BIM and Perceived Usefulness



From the **Table 7.28**, the external variable of classification of BIM (class) was predicted to have influence to the perceived usefulness (pu) in conceptual model. The results show all measures are statistically significant. The following are the relationships between items that appear to have strong relationships.

Table 7.28 Correlation Matrix Between Classification of BIM Data and PU

		pu_1	pu_2	pu_3	pu_4	pu_5	pu_6
class_1	Pearson Correlation	.549**	.509**	.441**	.538**	.467**	.461**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
class_2	Pearson Correlation	.571**	.630**	.605**	.535**	.475**	.492**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
class_3	Pearson Correlation	.614**	.629**	.616**	.563**	.637**	.644**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
class_4	Pearson Correlation	.505**	.582**	.618**	.600**	.504**	.487**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000

The item class_3 was found to have a very strong relationship with almost all items in PU with correlation coefficient more 0.6.

class_3–pu_1: *The use of UNICLASS/OMNICLASS/SFG20 standard enhances the use of COBie in FM system has a strong relationship with COBie is useful mechanism for handing over data to operational and maintenance stage.*

class_3–pu_2: *The use of UNICLASS/OMNICLASS/SFG20 standard enhances the use of COBie in FM system has a strong relationship with COBie will benefit FM practice.*

class_3–pu_3: *The use of UNICLASS/OMNICLASS/SFG20 standard enhances the use of COBie in FM system has a strong relationship with IFC has a structured information for handing over data to operation and maintenance stage.*

class_3–pu_5: *The use of UNICLASS/OMNICLASS/SFG20 standard enhances the use of COBie in FM system has a strong relationship with PAS1192-3:2014 provides clear guidelines for adopting BIM in FM.*

class_3–pu_6: *The use of UNICLASS/OMNICLASS/SFG20 standard enhances the use of COBie in FM system has a strong relationship with BS1192-4:2014 provides clear guidelines for populating COBie.*

From the above statements, it shows that respondents who believe the use Uniclass/Omniclass/SFG20 standard enhances to use of COBie in FM systems are likely to believe COBie is useful and benefit in FM practice and IFC has a structured information for handing over data to operation and maintenance stage. In addition, those participants also are found to believe that PAS1192-3 and BS1192-4 provide clear guidelines in adoption of COBie and IFC in FM. Apart from that, item class_2 is found to have a very significant relationship against item pu_2 and pu_3.

class_2–pu_2: *The Uniclass/Omniclass/SFG20 standard is important for defining information in COBie has a strong relationship with COBie will benefit FM practice.*

class_2–pu_3: *The Uniclass/Omniclass/SFG20 standard is important for defining information in COBie has a significant relationship with IFC has a structured information for handing over data to operation and maintenance stage*

This means respondents who believe that Uniclass/Omniclass/SFG20 standard is important in defining information in COBie has high possibility to believe that COBie will benefit FM practice and IFC has structured information for handing over. Furthermore, it is also noted that item class_4 also have a very significant relationship with items pu_3 and pu_4 in the following statements;

class_4–pu_3: *Information that carries Uniclass/Omniclass/SFG20 standard is readable in FM system has a strong relationship with IFC has a structured information for handing over data to operation and maintenance stage.*

class_4–pu_4: *Information that carries Uniclass/Omniclass/SFG20 standard is readable in FM system has a significant relationship with IFC is a useful data exchange format*

It is suggested that respondents who believe that information that carries Uniclass/Omniclass/SFG20 standard is readable in FM system also tend to believe that IFC has a structured information and useful for handing over data to operation and maintenance

stage. Meanwhile, the correlation coefficient of other measures falls between moderate-strong relationships.

7.10.9 Association between Data Exchange and Perceived Usefulness



From the **Table 7.29**, the external variable of data exchange (data) was predicted to have influence to the PU in conceptual model. The result reveals that all measures are statistically significant. The following describe the significant of relationships found between items;

Table 7.29 Correlation Matrix Between Data Exchange And Behaviour Intention

		pu_1	pu_2	pu_3	pu_4	pu_5	pu_6
data_1	Pearson Correlation	.727**	.692**	.557**	.601**	.629**	.647**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
data_2	Pearson Correlation	.549**	.695**	.603**	.583**	.718**	.643**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).							

data_1–pu_1: COBie can be easily to be used to import data into FM system has a high correlation with COBie being a useful mechanism for handing over data to operational and maintenance stage

data_1–pu_2: COBie can easily be used to import data into FM system has a significant relationship with COBie will benefit FM practice

data_1–pu_4: COBie can easily be used to import data into FM system has a substantial relationship with IFC being a useful data exchange format.

data_1–pu_5: COBie can easily be used to import data into FM system has a strong relationship with PAS1192-3:2014 provides clear guidelines for adopting BIM in FM

data_1–pu_6: COBie can easily be used to import data into FM system has a significant relationship BS1192-4:2014 provides clear guidelines for populating COBie

The findings suggest that most of the items in data exchange and PU has presented very strong relationships. This suggest respondents tend to believe COBie can be easily to be used to import data into FM system will makes COBie and IFC and the standards guidelines being useful and benefit in FM practice. Meanwhile, a significant relationship also found in item data_2 as following;

data_2–pu_2: *IFC format allows integration with FM system has a strong relationship with COBie will benefit FM practice*

data_2–pu_3: *IFC format allows integration with FM system has a significant relationship with IFC has a structured information for handing over data to operation and maintenance stage.*

data_2–pu_5: *IFC format allows integration with FM system has strong relationship with PAS1192-3:2014 provides clear guidelines for adopting BIM in FM*

data_2–pu_6: *IFC format allows integration with FM system has a substantial relationship with BS1192-4:2014 provides clear guidelines for populating COBie*

As for item data_2 suggest those who believe IFC format allows integration with FM system tend to agree COBie, IFC and the standard guideline PAS1192-3:2014 and BS1192-4:2014 provide clear guidelines for operation and maintenance phase and adopting COBie.

7.10.10 Association Between As-Built Model and Perceived Usefulness



The results show the relationships between as-built model (asbuilt) and PU in **Table 7.30**. From the results, all measures are statistically significant. The analysis found out that item as-built_1 against pu_2, pu_3, and pu_6 has a high correlation. Similarly, asbuilt _2 against pu_2 and pu_5, and asbuilt_4 against pu_2 has a high correlation. In following relationships provide the description between items.

asbuilt_1–pu_2: *As built model helps facilities managers to identify the relevant information in COBie has a high correlation with COBie will benefit FM practice*

asbuilt_1–pu_3: *As built model helps facilities managers to identify the relevant information in COBie has a strong relationship with IFC has a structured information for handing over data to operation and maintenance stage.*

asbuilt_1–pu_6: *As built model helps facilities managers to identify the relevant information in COBie has a significant relationship with BS1192-4:2014 provides clear guidelines for populating COBie*

Table 7.30 Correlation Matrix Between As-Built Model and Perceived Usefulness

		pu_1	pu_2	pu_3	pu_4	pu_5	pu_6
asbuilt_1	Pearson Correlation	.557**	.629**	.605**	.574**	.592**	.621**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
asbuilt_2	Pearson Correlation	.557**	.649**	.539**	.578**	.617**	.578**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
asbuilt_3	Pearson Correlation	.402**	.587**	.426**	.504**	.490**	.410**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
asbuilt_4	Pearson Correlation	.448**	.669**	.575**	.554**	.524**	.478**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).							

It appears that there is a potential that as built model helps facilities managers in identifying the relevant information COBie has a potential being useful as well as IFC in FM practice. Furthermore, there are significant relationship found in as-built_2 as describe in the following:

asbuilt_2–pu_2: *As built model helps facilities managers to reduce redundant information in COBie has a strong relationship with with COBie will benefit FM practice*

asbuilt_2–pu_5: *As built model helps facilities managers to reduce redundant information in COBie has a significant relationship with PAS1192-3:2014 provides a clear guidelines for adopting BIM in FM*

asbuilt_4–pu_2: *As built model helps facilities managers to identify missing information in COBie has a strong relationship with COBie will benefit FM practice.*

This suggests that as-built models help facilities managers to reduce redundant information in COBie tend to believe it will benefit FM practice and also believe PAS1192-3:2014 provides a clear guidelines. On the other hand, it was found out that respondent who believe

as built model helps facilities manager to identify missing information in COBie tends to believe it will benefit FM practice. From the **Table 7.28**, none of the items fall in the categories of low and insignificant relationships.

7.10.11 Association Between Up skilling and Perceived Usefulness



The results show the relationships between up skilling (upskill) and PU in **Table 7.31**. From the results, all measures are statistically significant and both items in up skilling variable are found to have very significant relationship against perceived usefulness variable. The following statement describes the significant relationships between up skilling and perceived usefulness.

Table 7.31 Correlation Matrix Between Upskilling and Perceived Usefulness

		pu_1	pu_2	pu_3	pu_4	pu_5	pu_6
upskill_1	Pearson Correlation	.508**	.686**	.533**	.554**	.650**	.610**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
upskill_2	Pearson Correlation	.557**	.691**	.639**	.650**	.640**	.659**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).							

upskill_1–pu_2: *Training workshops help me to enhance my skill set in updating COBie information in FM system has a significant relationship COBie will benefit FM practice.*

upskill_1–pu_5: *Training workshops help me to enhance my skill set in updating COBie information in FM system has a strong relationship with PAS1192-3:2014 provides clear guidelines for adopting BIM in FM*

upskill_1–pu_6: *Training workshops help me to enhance my skill set in updating COBie information in FM system has a high correlation with BS1192-4:2014 provides clear guidelines for populating COBie.*

In item upskill_1 suggest respondents who consider training workshops can enhance the skill to update COBie in FM system believe COBie will benefit FM practice and the PAS1192-3: 2014 and BS1192-4 provide clear guidelines in adopting BIM in FM and COBie. Meanwhile, it was found in item upskill_2 has positive correlation to all items in pu_1 to pu_6, however, only notable strong correlations are discussed in the following;

upskill_2–pu_2: *Training workshops help me to enhance my skill set in using IFC data exchange format to update graphical information in FM system has a strong relationship with COBie will benefit FM practice.*

upskill_2–pu_3: *Training workshops help me to enhance my skill set in using IFC data exchange format to update graphical information in FM system has a significant relationship with IFC has a structured information for handing over data to operation and maintenance stage.*

upskill_2–pu_4: *Training workshops help me to enhance my skill set in using IFC data exchange format to update graphical information in FM system has a substantial relationship with IFC being a useful data exchange format.*

upskill_2–pu_5: *Training workshops help me to enhance my skill set in using IFC data exchange format to update graphical information in FM system has high correlation with PAS1192-3:2014 provides clear guidelines for adopting BIM in FM*

upskill_2–pu_6: *Training workshops help me to enhance my skill set in using IFC data exchange format to update graphical information in FM system has a strong relationship with BS1192-4:2014 provides clear guidelines for populating COBie*

Similarly, item upskill_2 suggest that respondents who consider training workshops enhance their skill set in using IFC in FM system are those who are also tend to believe COBie and IFC are useful format and will benefit FM practice, and the standards PAS1192-3:2014 and BS1192-4:2014 provide clear guidelines in adopting BIM in FM and populating COBie. Other items appear to show moderate to strong relationships.

7.11 Chapter Summary

This chapter discussed on the findings from the structured online-survey. The data was collected using a web-package online survey (SmartSurvey™). This survey was posted in a closed group forum in the professional social media ‘LinkedIn’ includes BIM4FM, BSRIA, BIFM, and company email addresses that related to this study via web link. The findings are then discussed into five parts; a) respondents’ demographic, b) relevance of key information

requirements, c) identification of key factors for adoption of BIM in FM, d) to what extent does BIM guidelines support the adoption of open BIM standards and e) the framework that can facilitate the adoption of BIM in FM. The collected data are then analysed using the SPSS statistical software for descriptive statistics analysis such frequency, median and mean in forms of tables and charts. Bivariate analysis is also conducted using the Pearson's correlation to understand the significance of relationship between variables in the conceptual framework. The correlation matrixes were produced in tables for discussion.

The result of respondents' demographic shows that '*others*' categories of job function score the highest percentage of 18.1%, followed by IT specialist and Project Manager with percentage of 14.5% and 13.3% respectively. Small medium enterprise is the majority groups of organization that took part in this survey with score of 36.6%. The highest percentage of type of facilities involved is administrative, office, commercial facilities with 14.9%. Proficiency of those who experience in BIM is higher than FM and BIM for FM. ArchiFM and '*others*' FM score the highest percentage of 18.29%. Meanwhile, Revit score highest in the use BIM system. In addition, all the key information requirement (i.e. asset, space, operation and maintenance, replacement, equipment) scores majority in combined percentage of relevant and most relevant with operation and maintenance being the highest score. 12 key variables were analysed in the key factors that adoption of open BIM standards and standards guidelines. It was found out that most respondents are aware of COBie, IFC and the standards guidelines (i.e. PAS1192-3 and BS11924) but unsure how it works. It was also found out that IFC is more compatible than COBie and trying to use IFC is more familiar than COBie. A large number of respondents also suggest that demonstration in using COBie in FM affect their decision to adopt compare to IFC. COBie is preferable than IFC in handing over data to operation and maintenance stage, and also being easier to use compare IFC.

Meanwhile, it is also suggest that both standards guidelines (PAS1192-3 and BS1192-4) share high neutral/ don't know responses as whether it helps facilities managers managed information easily. The cost of adopting COBie will be succeeded by the benefit of information. Majority of respondents agree that classification of BIM data is significant in COBie for FM systems. Also, respondents believe both COBie and IFC can be integrated into the systems. As-built model helps FM to identify relevant information in COBie and Through training and workshop can enhance facilities managers skillset in updating COBie and IFC in FM system. Furthermore, most respondents are likely to apply open BIM standards (i.e. COBie and IFC) and standards guidelines and already adopting it.

On the other hand, the extent to which BIM guidelines can support the adoption open BIM standards, it was found out that a majority of respondents believe PAS1192-3:2014 has clarified process and procedure of information communication with FM system. Meanwhile, most respondents think the concept of process map for BIM use in FM is preferable as part of the framework that can facilitate the adoption of open BIM standards and standards guidelines.

CHAPTER 8 DISCUSSION OF KEY FINDINGS

8.1 Introduction

The objective of this chapter is to reflect the debate on the importance of the results in respect of current qualitative and quantitative analysis information. An overview of the research is provided in the first section. It reaffirms the research background, goals and approaches adopted in this study. The second section responds to the four research goals by summarizing the significant differences between what has been implemented and what are literature according to BIM standards. The third section deals (a) with regard to the relevance of the key information requirements, (b) with the important factors which can influence the adoption of open BIM standards or standards directives, (c) with regard to the extent to which BIM guidelines can support the adoption of open BIM Standards. Finally, this chapter concludes with a new conceptual framework proposed for open BIM standards and guidelines for standards. Figure 8.1 provides an overview of the key sections.

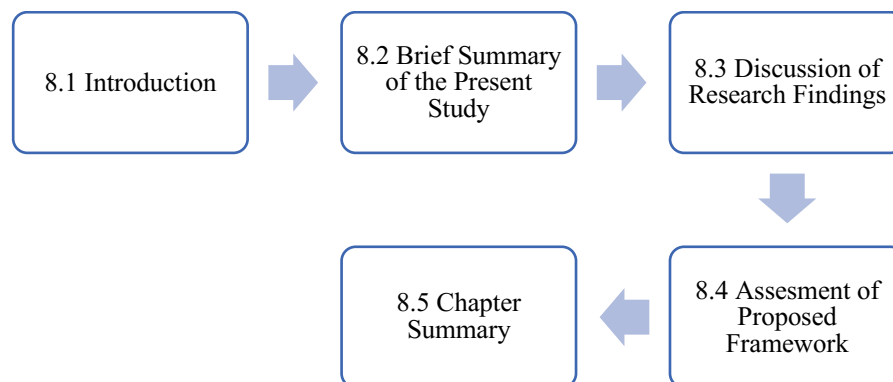


Figure 8.1 Chapter 8 Organization

8.2 Brief Summary of the Present Study

This study revolves around the United Kingdom (UK) construction industry. In the architectural, engineering and construction phases, the Building Information Modeling (BIM) is widely applied, but the process is slow for professionals involved in the facility management (FM) phase. In more specific respect, this study focuses on the application of BIM, which supports building components, enabling real-time data access, visualization and commercialization, maintenance checks, updating digital assets, space management, refurbishment and renovation work, emergency management, energy control and monitoring, and staff training and devement. Moreover, BIM as a "Digital Representation of

a facility's physical and functional properties" provides a shared knowledge resource for information on a facility that is a reliable basis for decision-making during the life cycle’.

Despite the promising benefit that facilities manager could envision, the adoption of BIM poses multiple challenges in the areas of people, processes and technology (Kassem et al., 2015; Parsanezhad and Dimyadi, 2014). The challenges with ‘people’ in adopting BIM is due to cultural barrier, organisation resistance, knowledge gap and lack of real world evidence. Meanwhile ‘process’ challenges are related to roles and responsibilities, data specification, collaboration, and changes in practice in FM. Lastly, technological challenges are related to software tools, interoperability between systems and readiness of software vendors. Therefore, this study investigates the cultural barrier on low adoption of BIM among facilities manager and second, the integration of TAM and IDT employed to establish a framework that can better facilitate the adoption of open BIM standards and standards guidelines in FM.

The objectives of the study were:

- RO1: To determine the key information requirements for BIM-driven FM
- RO2: To identify the key factors that influence the adoption of open BIM standards and standards guidelines
- RO3: To investigate the extent to which BIM guidelines support the adoption of open BIM standards (COBie and IFC) for FM
- RO4: To establish a framework that can facilitate the adoption of open BIM standards and standards guidelines in FM

The present study employed Exploratory Sequential Mixed Methods approach using in-depth interview (qualitative phase) and online structured survey to collect data and to establish a framework to better facilitate the adoption of BIM in FM. Furthermore, expert phone interview was conducted with the construction industry expert to confirm the information collected from the key in-depth interview participants about the BIM implementation strategy. The following sections illustrated the framework of analysis and discuss each research objective and its contributions in more depth.

8.3 Discussion on Research Findings

The key findings for the four research objectives are summarised and explained within the context of current academic knowledge.

8.3.1 Research Objective 1

The first research objective is to determine the key information requirement for BIM-based FM. A number of discussions can be drawn from the findings of Chapter Six and Seven as well as extensive literature review. The findings identify the vast array of key information requirement for FM but uncertain the relevance of those information served for BIM. From the literature, the information requirement was identified for FM use that aggregated to asset information, maintenance information, financial information, property information, geometric information and supplementary information (i.e. environment analysis information, legal information, procurement and supplier information, and geographical information).

8.3.1.1 Discussion of Qualitative Findings

The qualitative phase findings suggest a more specific and direct to the key information required to BIM-enabled FM as oppose in broad categories of information proposed in the literature. The main findings reveal that operation and maintenance, equipment information, space information, asset information, replacement information and miscellaneous information (i.e. health and safety and product information, geometric information). However, some of findings especially in miscellaneous information were obscure and may overlapped or fall under the same categories with others theme of key information requirement. Prior investigations (for example, Parsanezhad, 2015) showed that specific and direct key information needed to be efficient and must be built on sustained, multidisciplinary information gathering, analysis, and flow throughout the building asset life cycle. In order to confirm the design of the items in this questionnaires the list of key information requirements are confirmed (i.e. operation and maintenance, equipment information, space information, asset information, substitution); Furthermore, the effective use of the information enabled by BIM guarantees a continuous performance with minimal maintenance costs during building life cycle (Liu and Issa, 2012).

8.3.1.2 Discussion of Quantitative Findings

The findings in the quantitative structured survey indicate all measure in five key aspects of key information requirement score slight majorities in tendency to rate relevant and most relevant scales. As operation and maintenance information scores the highest among other key information requirement. The mean scores of 4.00 in all aspects of key information requirement indicate to be relevant. Despite the small majority of the five key aspects of the

important information requirements, challenges based on how and where the data can be updated, whether they're in the native BIM or in the CAFM system, are suggested. FM must identify essential areas that can't be ignored and re-introduce this in the design process. But the underlying ethos appears to be that the degree of knowledge blindness, yet the full picture of how to identify the key information requirements for BIM-driven FM as long-term operational efficiency, are revealed in all of the collaborative projects. Recent studies (e.g. Akinade et al. 2018; Niu et al. 2019) have suggested that FM use the Internet of Things (IoT) for its role in the BIM chain, given that IoT will play an important role in FM in the future. However, organization should leverage BIM and build a solid information management platform as the starting point. On the other hand, when it comes to IoT for FM, the organisation should know where and when to deploy IoT and how to leverage that to progressively generate information, insights and knowledge.

This research has identified the key information requirements for BIM and FM processes in an efficient and effective way. This is achieved by introducing the application areas of BIM-enabled processes, with the seamless flow of information as a pre-condition. In addition, existing challenges and obstacles to BIM's successful employment and implementation are identified and the solution is laid down in Chapter 6 as an action plan. Comprehension of conventional FM practice allows a performance gap, mainly due to inefficiencies in information management across the life cycle of construction assets and a lack of cooperation among industry actors. Furthermore, BIM is important to bridge the gap identified earlier as a collaborative process that facilitates the continued flow of key data. Moreover, the first step towards BIM based FM awareness is to develop awareness of the FM application areas for BIM enabled processes. Although cultural changes and interoperability are the main barriers which are difficult to address, the latter is continually developing and hence the technological progress (i.e. cloud-based application) and government efforts (e.g., BIM development communities) are believed to be in line with these research findings.

8.3.2 Research Objective 2

Subsequently, the second objective investigates the key factors that can facilitate the adoption of open BIM standards and standards guidelines. Initially, extensive literature review and informal discussion with experts and pilot studies identifies the key factors as a) awareness of BIM, b) as-Built Model, c) classification of BIM data; d) cost; e) employer information requirement; f) interoperability, and g) up-skilling as proposed external

variables to support the establish a framework. The qualitative in-depth interviews were conducted and analysed to confirm the key factors proposed before embedded into designing the questionnaire in conducting the quantitative structured survey. The following sections discussed extensively on qualitative findings followed by the quantitative findings.

8.3.2.1 Discussion of Qualitative Findings

In objective 2, the findings in qualitative in-depth interviews are discussed on the a) compliance of standards and guidelines, b) strategy in capturing information for FM use and finally, c) the key factors that influence the adoption of open BIM standards and standard guidelines.

8.3.2.1.1 Compliance to Standards and Guidelines

In the compliance of standards and guidelines, it was found out that PAS1192-2:2013 and BS1192-4:2014 are the most notable complied standard guidelines in adopting BIM. The former standard is mostly used in guiding implementation of BIM in design and construction stage, while the latter is a guiding in adoption of COBie. However, few participants complied to PAS1192-3:2014 in implementing BIM in operational and maintenance phase. This is because most of the interview participants are knowledgeable in BIM in construction project than BIM in FM. The standards BS1192-4:2014 support in guiding both design and construction team as well as FM team in understanding the information delivery via COBie. In addition, as a part of the IFC schema and BIM literature, COBie captures information for both spatial and physical assets in the facility (Karlshøj et al., 2017). This consistent in the NBS survey report in 2017 indicating PAS1192-2:2013 is predominantly complied standards than both PAS1192-3:2014 and BS1192-4:2014. Therefore, in this study, it can be inferred that low compliance of both PAS1192-3 and BS1192-4:2014 are still prevalent for FM due to the limited knowledge and experience from the interview participants in BIM-FM project. Furthermore, the discussion of the compliance to the standards and guidelines were a pre-requisite interview question to elicit deliberately in achieving objective 2. Therefore, this section is discussed independently in qualitative findings found in chapter six.

8.3.2.1.2 Strategy in Capturing Information for FM use

The discussion on strategy in capturing information for FM use was group into people, process, and technology due the various points of views in the analysis. In discussion of 'people' aspect, it was found out that client requirement and assigning BIM coordinator were the main strategy. Client Requirement or EIR is part of strategy for facilities manager in

setting the key information requirement in assisting client briefing whilst informing the design and construction team. In addition, the assignment of the BIM coordinator can help mediate the exchange of information between the two parties during the handover period. This is in line with Arayici et al. (2011) studies that implementing BIM effectively calls for major changes to the way in which building companies operate at almost every level of the building process. This means not only learning new software applications, but also how you can reinvent the workflow, train employees and assign tasks and change the way the construction is modeling.

Meanwhile, the ‘process’ aspect involves the categorization of information in classification system, communication and sharing information, early phase involvement of FM, standard and guidelines, and COBie delivery. To able to capture information for FM use, early involvement of facilities manager is favourable to advise client the sort of information requirement that valuable in the operation and maintenance phase of building. Past studies (e.g. Talamo and Bonanomi, 2015; Yalcinkaya and Singh, 2015) argued that communication and sharing information between project team and FM needs to establish to acquire the information needed in structured and understandable format. The use COBie delivery enable facilities manager to read the types and categories of information in the define classification system. Furthermore, on-site building survey method requires capturing any missing information in as-built building information.

On the other hand, in terms of the ‘technology’ aspect includes using model viewer application, data capturing tools, and digital twin concepts as strategy. The use of model viewer application is to assist in visualizing in the BIM model for understanding the location and specification about facilities information. While, data-capturing tools such as laser scanning involves in capturing the as-built information model in supporting facilities manager’s task (Ghaffarianhoseini et al., 2017). On the other hand, the digital twins are also found in the findings of the highly complex virtual model that, however, the findings could be one of strategy rather than using the BIM in future research in the FM context in combination with a physical object, in real time data via connection sensors. BIM technology in the implementation of buildings is supported in recent years by past studies (such as Azhar, 2011; Ghaffarianhoseini et al., 2017), which have been essential to facilitate the design, realization and use procedures. The improvement and development of new models enables efficient control of building processes using BIM and eliminates sensitive processes.

Similar to the preceding section a), the discussion of strategy in capturing information for FM use were a pre-requisite interview question to elicit deliberately in achieving objective 2. Therefore, this section is discussed independently in qualitative findings found in Chapter six.

8.3.2.1.3 The Key Factors Influence Adoption of Open BIM Standards

In the discussion of the key factors that influence the adoption open BIM standards and standards guidelines in FM. Eight main key findings appeared to support with literature in the qualitative analysis include; value of BIM, simplicity, awareness of BIM, success stories, cost of BIM adoption, up-skilling, development of UNICLASS, accessibility of data. The key findings share parallel meaning with the literature and integrated theoretical framework.

Value of BIM (PU) - The value of BIM to facilities manager has been debated in the literature to the extent to which of the benefit that BIM could potentially support streamlining in operation and maintenance task. Under TAM's PU, this study adapt its definition that predict the extends to which open BIM standards could improve the job performance of facilities manager. As the benefit of BIM seems promising in the future prospect (Becerik et al., 2012), the challenges of BIM remain persisting especially to convince facilities manager in adopting open BIM standards and standard guidelines.

Simplicity(PEOU) - In the literature, simplicity is conceived to share similar meaning with TAM model 'perceived ease of use' – the extend to which open BIM standards (COBie and IFC) can easily be used without complication. User-friendliness of COBie and IFC does not limited to the technology aspect, but also in the process includes communication of exchanging information between project team and FM team is substantial. However, previous study point out both COBie and IFC poses challenges in terms of instability, suffer from loss, error-prone data (Shen et al., 2010; Fallon et al., 2016).

Awareness of BIM - In the literature, participation in BIM activity has been low and seems disinterested (BIM4FM, 2013). The reason of the lack of awareness is because the meaning of BIM to FM has been specifically about the technology instead of the processes and people aspect on what sort of skillset facilities manager requires and opportunity in enhancing the productivity in conducting operation and maintenance task (Lewis, 2013). The study of perception of facilities managers towards open BIM standards and standard guidelines has been sceptical and on-going challenge for adoption.

Successful stories - (Observability) In the literature, the challenges in providing the evidence and proof of return on investment in real world has been long debated (Kassem et al., 2015; Becerik-Gerber et al., 2012). The period of adoption of BIM in operation and maintenance may take long before to actually reports its return of investment (ROI) and operational saving. Under Rogers (2003) IDT's, 'observability' variable supported the key finding of successful stories that demonstrate the adoption COBie ad IFC in FM is viable and practical to convince facilities manager.

Cost of BIM adoption - Cost of BIM adoption is one the main findings that supported by the literature in take into consideration of cost of implementation of BIM-based FM system, hiring highly skilled personnel (i.e. BIM Manager) and proof return of investment. Becerik et al. (2012) and Williams et al. (2014) argue the lack of evidence in reducing operation and maintenance cost and return on investment has been the gap for both owner and facilities manager to assess its feasibility on the overall financial resources of an organization.

Development of UNICLASS - The development of UNICLASS is to support the function of COBie and IFC into the FM system. In the literature, the difficulty of using UNICLASS in FM system has been a challenge to its difficulty to use (Afsari & Eastman, 2016). In order to support the use of COBie and IFC to be useful in FM system, classification system play in important role in assigning information in the BIM model.

Up skilling - In the literature, enhancing skillset and knowledge of know-how in using COBie and IFC has been gap to facilities manager. Kassem et al. (2015) and Becerik-Gerber et al. (2012) argue the lack of knowledge, know-how and unclear the use of BIM are among the shortcoming in evaluating the value of BIM. Up skilling is essential as part key factor to determine the adoption of COBie and IFC. To able to handle information contained in COBie and IFC requires training and attending workshops to acquire necessary knowledge to understand the different types of information exchange format and integration with FM system.

Accessibility of Data (Compatibility) - In the literature, information is in the heart of facilities core function. To able to access data is readily and intuitively drive facilities manager to likely adopt information exchange via COBie and IFC. Traditionally, handover information delivered in paper-based document that stored in the storage room or manually

key-in into the FM system that inherently toilsome (Patacas et al., 2015; Teicholz, 2013). Using digital format COBie and IFC readily capture information about facilities to reduce the amount of workload in order to begins operation of building once completed. On the other hand, among other emerging themes that lead to the gap of this research includes; adoption of software vendors, assigning BIM manager, level of details, sub-contractor and supply chain, communication with design and construction team, regulation and policy and willingness to change could be potential theme as part of establishing the framework.

Adoption of facilities managment software vendors - Compatibility in information exchange format in COBie and IFC is one of the underlying factor that leads to adoption. As seen in **Figure 3.6**, only handful of FM software vendors have been developing format to map the information contained in COBie and IFC into their system.

Assigning BIM manager - allows information exchange in COBie and IFC to be coordinate and verify in a gradual manner. To ease the task of facilities manager, appointing BIM manager with knowledge and experience can facilitate the adoption of COBie and IFC into the FM system without troubling the normal routine of managing operation and maintenance task. Skill gap and knowledge gap in FM in adopting BIM can impede the adoption further without any support.

Level of Details - To set the extend of the level of details about facility information in the outset of BIM project can greatly support to the relevant information requirement in COBie or IFC into FM system.

Sub-contractor and supply chain capability - play an important role to supply information about the building information. The capability to work in the BIM environment influence the information and specification needs in COBie and IFC. Therefore, information handover to facilities manager may not entirely delivered in the digital format but paper-based document and may need to make request for information.

Communication with Design and Construction Team - allows facilities manager to engage in reviewing and checking the information requirement in COBie and IFC. To able to assess validity and quality of information, rigorous effort in reviewing as-built information allows facilities managers to liaise with designer and construction team in timely manner to raise any sort of problem or missing information in the building information.

Regulation and Policy.- Government initiative in funding small to medium-scale BIM-FM project to demonstrate the use COBie and IFC and setting practical professional guidelines for FM could enhance the likelihood in adoption. Although the UK government announcement of mandating BIM level 2 in all centrally public funded project, the effort in adopting BIM to FM remains low.

Willingness to change - willingness in adapting new technologies and practice could face with resistance among facilities managers. The process of changing in workplace may involve a certain degree iteration and re-working in normal daily routine task for facilities manager. Also, as supporting the non-core business of client organization, change proposition within the organization may not easily adapted especially investing in establishing a new IT infrastructure to facilitate the adoption COBie and IFC in FM department.

8.3.2.2 Discussion of Quantitative Findings

From the extensive literature, informal discussion and findings in qualitative analysis, the proposed variables in the framework that were confirmed are compatibility, trialability, observability, perceived ease of use, perceived usefulness, awareness of BIM, classification of BIM data, cost, data exchange, as-built model, up skilling and behaviour intention. The discussions of 12 key variables are described as follows:

Awareness of BIM - The result reveals the term COBie and IFC is more familiar than how it works. However, there are strong relationships between respondents who familiar with IFC and those who are already adopt it. Also, the adoption PAS1192-3 in FM is likely for those who intent to apply in near future.

Compatibility - The finding shows using both COBie and IFC improves the way respondents work, however, it also found that using of IFC is more compatible than using COBie. In correlation analysis, there are strong relationship between COBie facilitates effective working and intention to apply in work and/or have already adopted. Also, there appears strong relationship between IFC improves respondents work and respondents who have already adopted open BIM standards and standard guidelines.

Trialability - The result reveals that trying out IFC is more than trying out COBie. However, being able trying out both COBie and IFC in live project has yet to be adopted. Meanwhile, the result in correlation analysis found out that the use of COBie on live project has strong relationship with respondent who will adopt it in near future. Moreover, the use IFC on live projects are those who either has the intention to apply in their work or have already adopted open BIM standards and standards guidelines.

Observability - The finding indicates that there are tend to be more case studies and demonstration using COBie in FM than IFC. There is strong relationship in the demonstration of COBie in FM and intention to apply in work in the near future and/or already adopted it. On the other hand, the demonstration of IFC used in FM has a strong relationship in anticipation applying as part of their work.

Perceived Usefulness - The result shows that COBie is a useful for handing over data to operation and maintenance stage and will benefit FM. On the other hand, more respondents tend to believe IFC is useful data exchange format than it had structured information for handing over data to operation and maintenance stage. As for the standard guidelines, BS1192-4 tends to provide clear guidelines for populating COBie and there appears uncertainty for PAS1192-3: 2014 that it could provides guidelines for adopting BIM in FM. In the correlation analysis, there appears a very strong relationship that COBie will benefit FM are likely to adopt open BIM standards and standards guidelines.

Perceived Ease of Use - The finding reveals that COBie is tend to be easier to use than IFC for facilities manager. However, both PAS1192-3:2014 and BS1192-4:2014 poses uncertainty in supporting facilities managers task. In terms of relationship, it shows that there are a strong relationship that IFC is an easy format for facilities managers and anticipation in applying in their work.

Cost - The result shows that both COBie and IFC may involve expensive cost in hiring specialist and also COBie will be succeeded by the benefit of information populated rather than IFC. In correlation analysis, the benefits of information populated in COBie are greater than its cost has the tendency to believe COBie will benefit FM. Meanwhile, the benefit of using IFC are greater than its cost has a strong relationship with structured information for handing over data to operation and maintenance phase and the standard PAS1192-3:2014 in providing clear guidelines to adopt BIM in FM.

Classification of BIM Data - is significant in defining information in COBie and provide structured information and readable format in FM system. In correlation analysis it appears the use of classification system (Uniclass/Omniclass/SFG20) enhances the use of COBie in FM system has a strong relationship with COBie being useful and benefit in FM practice and IFC in structuring information for handing over data to operation and maintenance stage. Subsequently, there is also strong relationship between the use of classification system (Uniclass/Omniclass/SFG20) enhances the use of COBie in FM system PAS1192-3 and BS1192- 4.

Subsequently, classification standard is important in defining information in COBie has tendency to believe that COBie will benefit FM practice and IFC has a structured information for handing over. In addition, Information classified into standard is readable in FM system also tend to believe that IFC has a structured information and useful for handing over data to operation and maintenance stage.

Data Exchange - The result indicates both using COBie and IFC can be integrated with FM system. In correlation between data exchange and behaviour intention, it appears that there is a strong relationship with COBie can be easily used to import data into FM system tend to believe COBie, IFC and the standard guidelines are useful. Similarly, it also found out that IFC format allows integration with FM system tend to agree COBie will benefit and IFC has structured information for FM. Also, a strong relationship to PAS1192-3:2014 and BS1192-4:2014 that provide clear guidelines for operation and maintenance phase.

As-built Model - The finding reveals that as-built model tend to helps facilities manager to identify relevant information in COBie more than reducing redundant information, errors and missing information. It was also found out that there is a strong relationship that as-built model helps facilities manager to identify the relevant information in COBie and it will benefit FM practice. Also, a strong relationship that IFC has structured information to handing over to operation and maintenance stage, similarly to the standard BS1192-4: 2014 provide clear guidelines for populating COBie. Meanwhile, as-built model helps facilities manager to reduce redundant information in COBie tend to agree COBie will benefit FM practice and PAS1192-3:2014 standards provide clear guidelines for adopting BIM in FM. Furthermore, it is also noted that a strong relationship between as-built model helps facilities managers to identify errors in COBie and benefit FM practice.

Upskilling - by attending training and workshops can help facilities manager enhance skillset in updating COBie and IFC in FM system. From the correlation analysis, it was noted that training workshops can enhance the skill to update COBie in FM system tend to agree COBie will benefit FM practice and both PAS1192-3:2014 and BS1192-4:2014 provide clear guidelines for adopting BIM in FM and COBie. In addition, training workshops enhance their skill set in using IFC in FM system are those who are tend to agree COBie and IFC are useful format and will benefit FM practice, and also for both of the standards PAS1192-3:2014 and BS1192-4:2014 that provide a clear guidelines in adopting BIM in FM and populating COBie.

8.3.3 Research Objective 3

Objective 3 discusses the extent to which BIM guidelines can support the adoption of open BIM standards. From the literature findings, the lack of standards guidelines for FM has been a challenge for a proper adoption (Williams et al., 2013). The PAS1192-3:2014 and BS1192-4:2014 standards are both guidance to support the adoption of BIM in operation and maintenance phase as well as the adoption of COBie. However, from the NBS reports in 2017 only 27 % actually use PAS1192-3: 2014 standards and 18% use BS1192-4 standards for adoption of BIM. This suggests there is a low uptake of these standards that pertinent for facilities manager in guiding the adoption of BIM for facilities managers.

8.3.3.1 Discussion of Qualitative Findings

In objective 3, the findings in qualitative in-depth interviews are discussed in three areas; a) sufficiency of standard and guidelines, b) compliance of standards guidelines (PAS1192-3:2013 and BS1192-4:2014), c) understanding of standards guidelines in adoption of open BIM standards and standards guidelines.

8.3.3.1.1 Sufficiency of standard and guidelines

In discussion of sufficiency of standard and guidelines, it is noted that inadequacy of standard and guidelines influence the adoption of open BIM standards. The underlying reason is due to unclear roles, lack of accessibility of information to facilities manager and heavily focuses on design and construction team. In the literature, the lack of standards and guidelines was supported in Williams et al. (2013) that impede facilities manager from adopting BIM. This exacerbates that facilities managers are unclear how to use BIM and limited knowledge that they make BIM data accessible to FM use.

8.3.3.1.2 Compliance of PAS1192-3:2014 and BS1192-4:2014 Standard

Compliance to either or both PAS1192-3:2014 and BS1192-4:2014 are highlighted in the main findings suggest that the standards guidelines that are readily to accessible for adopting BIM in FM. In the NBS reports, there seems to have increase in the number of compliance of both PAS1192-3: 2014 and BS1192-4: 2014.

8.3.3.1.3 Understanding Guidelines in Adoption Open BIM Standards

Majority of interview participants agree that facilities managers do not understand the standards and guidelines in adopting open BIM standards. This suggests that facilities managers may received limited knowledge COBie and IFC, but unclear set of information requirements limits their ability to understand the potential of managing a building operation. In the literature, Kassem et al (2015), Patacas et al (2015) , Parsanezhad & Dimyadi (2014) and Kassem et al (2015) agrees that the lack of knowledge and understanding in assessing to use BIM in FM is the main barrier to the likelihood to adopts COBie and IFC.

8.3.3.2 Discussion of Quantitative Findings

In the main quantitative findings, the discussion includes in evaluating the extend to which PAS1192-3:2014 and BS1192-4:2014 can support the adoption of open BIM standards. It was found that respondents tend to agree that PAS1192-3:2014 guide the process and procedure of information communication with FM system. On the contrary, PAS1192-3:2014 also score the least majority among other statements in believing it could help in adoption of BIM in FM on the live project. Meanwhile, as for BS1194:2014 standards, it was found that BS1192-4:2014 provides the key information requirement for COBie score highest among other statements. However, both PAS1192-3:2014 and BS1192-4:2014 scores higher in total percentage in agree and strongly agree than its counterpart. However, the adoption of both standards on live project remains questionable.

8.3.4 Research Objective 4

The last objective discuss on the framework that can facilitate the adoption of open BIM standards and standards guidelines. From the literature findings, two theories of TAM and IDT are adapted to underpin the research and to better predict the behaviour intention to adopt open BIM standards and standards guidelines. By anchoring TAM model of perceived usefulness and perceived ease of use and IDT characteristics of innovation ; compatibility, observability, trialability. Both theories were integrated to reinforced the framework and

extended the conceptual model by combining the external variables that represent the key factors that influence the adoption to predict behaviour.

8.3.4.1 Discussion of Qualitative Findings in Objective 4

In objective 4, the main qualitative findings is discussed in two parts: a) concepts/tasks to exploits open BIM standards and standards guidelines, b) comments and recommendation.

8.3.4.1.1 Concepts/Tasks to exploit open BIM standards

In the discussion on the concepts/tasks to exploit open BIM standards and the standards guidelines, seven main findings are discovered that consistent with the literature, informal discussion and pilot study that includes; a) Accessibility of Data, b) Awareness of BIM, c) Cost, c) Simplicity d) Success stories/Case Studies, e) Value of BIM

Accessibility Data - As discussed in the section 8.3.1.3, accessibility of data to facilities manager is crucial to able to conduct operation and maintenance phase. The concept of accessibility of data is consistent in the framework with compatibility. This means the extend to which adoption of COBie and IFC enable FM to access and acquire the set of relevance of key information that improves the normal daily routine of facilities manager task and productivity. Therefore, accessibility of data interprets compatibility variable in establishing the framework.

Awareness of BIM - align with the discussion in section 8.3.1.3 as part of tasks to exploit open BIM standards and standards guidelines. Awareness of BIM is important to understand the terms BIM in FM might mean and entails especially in the use COBie and IFC and the standards guidelines before deciding for adoption . Therefore, the awareness of BIM variable is confirmed as part of the framework in exploiting open BIM standards and standards guidelines.

Cost - As previously discussed in the section 8.3.1.2.3, the overall cost of adoption BIM to facilitate the use of COBie and IFC is one of the determining concepts to evaluate the capability of investing on implementation of BIM is worthwhile to facilities manager and align in overall organization goal. Hence, the cost variable is consistent as part of establishing a framework.

Simplicity - is suggested as one of the tasks that can exploit open BIM standards. user-friendliness of using COBie and IFC and transitioning to FM system allow to facilitate better adoption. As per discussion in section 8.3.1.3, simplicity is inferred as the perceived ease of use as part of the important variable that influence the behaviour intention of facilities manager in adoption of open BIM standards and standards guidelines. Therefore, the key variable is confirmed as part of integration of theories in establishing a framework.

Success story/Case studies - is inferred as observability variable under the Rogers' IDT five innovative characteristics. Evidence in that adoption of COBie and IFC can successfully adopted in FM can inspire the benefits and challenges that involves in the BIM-FM project. Lesson learnt in success story/case studies allow FM to assess the feasibility and viability in adopting COBie and IFC into the FM organization. Therefore, it is confirm that success stories is inferred as observability as part key variable or concepts in determining to exploit the adoption open BIM standards and the standards guidelines.

Value of BIM - as extensively discussed in earlier section 8.3.1.3, is supported in literature, informal discussion with expert, pilot study and the main qualitative and quantitative findings as an important concept in exploiting open BIM standards and standards guidelines. The value of BIM is inferred as 'perceived usefulness' variable under the TAM model that influence the behaviour intention of facilities manager. The prospect of the adoption of COBie and IFC would be beneficial in facilities a manager is remains as important factor in assessing the increase in productivity and efficiency in conducting operation and maintenance task. Thus, the theme value of BIM interprets the 'perceived usefulness' in establishing a framework to exploit open BIM standards and the standard guidelines.

Other emerging concepts and tasks that was found in the qualitative analysis includes; a) Early Involvement in BIM, b) Employer Information Requirement, c) Government standardisation, d) Hands-on Experience, e) Level of Details (LOD), f) Knowledge of BIM. The discussion of each themes are elaborate as the following:

Early Involvement in BIM - is one of the emerging themes in the findings as a task that can potentially support the adoption of COBie and IFC in FM. This suggest that facilities manager should take part in the early involvement in outset of BIM project to discuss the key information needed in the format they could access during the handing over of information. In conjunction, facilities manager could advise and assist client as part of

defining the Employer Information Requirement (EIR) and influence the adoption of COBie and IFC and BIM-based FM system to accommodate the better adoption later in the operation and maintenance phase.

Government standardisation - Active role in government initiative in providing BIM-FM procurement, incentive and professional guidance can drive the adoption COBie and IFC better in FM. Standardisation in BIM-FM processes could provide a exemplary to convince facilities manager that the adoption of COBie and IFC in FM is feasible.

Hands-on Experience - emerge as theme in the qualitative analysis as the key task that could exploit open BIM standards. The hands-on experience share similarities in Rogers' IDT 'trialability' variable in trying out the use of COBie and IFC and how it works in FM system allow facilities manager to decide in adopting them. The experience to able to use COBie and IFC in live project influence the adoptions in future project in refurbishment or renovation. Therefore, the hands-on experience interprets 'trialability' as part of key variable that influence the behaviour intention to adopts open BIM standards and standards guidelines.

Level of Details - As previously discussed in the preceding section 8.3.1.3 as an emerging key factors that influence the adoption of COBie and IFC. The level details entail the extend to which the details of non-graphical information required by facilities manager and the owner needs. The key concept of specifying the level of details in COBie and IFC is vary from different FM organization information needs. However, acquiring **knowledge of BIM** and FM in strategic planning in setting Asset Information Requirement (AIR), Organization Information Requirement (OIR) helps facilities manager to align their goal to informs client Employer Information Requirement (EIR) in the process to obtain sufficient information to manage building operation.

8.3.4.1.2 Comments and Recommendation

In discussion of comments and recommendation, it was found out that four main areas emerged in qualitative analysis. Again re-emphasize in the preceding section, knowledge of BIM, value of BIM, Collaboration and Communication appear to be key points in supporting the framework that can facilitate the adoption of open BIM standards and standard guidelines.

8.3.4.2 Discussion of Quantitative Findings

In the discussion of main qualitative findings, eight main frameworks were constructed from the literature review, informal discussion with the key experts, and pilot study. It was found out that the key concept/task that preferable in exploiting the adoption of open BIM standards are establishing a process map for implementing BIM in FM. The process map is useful outline to guide to role facilities managers in a set of sequential activities or workflow as part of implementation of BIM in FM. Although in the standards PAS1192-3:2014 is to guide implementation of BIM in operation and maintenance phase, however, the extend to which that it could be understood for adoption raise a question of compatibility and knowledge that it can support for its use.

8.4 Assessment of Proposed Conceptual Framework of TAM and IDT

TAM and IDT framework is proposed to investigate the obstacles to further BIM adoption in the building industry. The primary purpose of this research is a comprehensive literature review on key BIM, FM, TAM, IDT and informal expert discussions has developed the framework. The framework has been developed. The conceptual framework has been tested and validated by expert review in order to attain Chapter 1's fourth research objective.

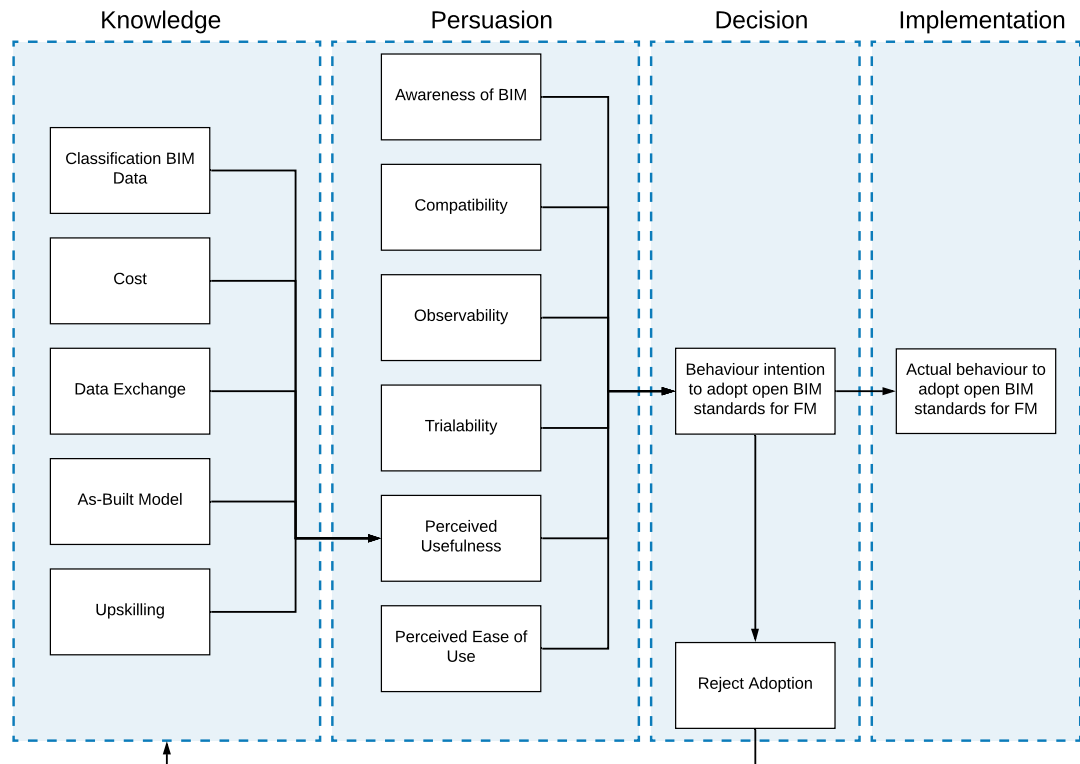


Figure 8.2 Proposed Conceptual Framework of TAM and IDT

From the discussion of both main findings in qualitative and quantitative finding, the revised framework has omitted with variable Employer Information Requirement (EIR) due to the similarities in objective 1 in identifying the key information requirement for BIM-based FM. Meanwhile, 'interoperability' variable has change the term to data exchange as the external key factor because of language use in management term. Technical knowledge and technical support has combined into a single variable 'upskilling' to avoid any redundancy in the framework.

There are therefore five variables in the domain of knowledge (BIM classification, cost, data exchange, model-built and skill upgrades) that have a direct impact on PU and six of the persuasion variables (BIM awareness, CAFM compatibility, observability, triability, PU and PEOU) that directly affect the actual BIM adoption. In-depth interviewees and data collected from online structured surveying across organizational borders in the construction industry were used to validate the model empirically. The analysis of quantitative phase data correlation showed that the proposed effects of all the eleven variables considered important in BIM acceptance were supported.

A brief and clear summary of the literature pertaining to factors which affect adoption of BIMs and the experience of various case studies under TAM and the framework of IDT is a wide-reaching background in BIM (e.g. Succar and Kassem, 2015; Singh and Holmström, 2015; Hosseini and al. 2016, Chen et al., 2019). However, the testing and relationship analysis are seldom integrated into a framework. This study provides proof that BIM's intention to adopt can be explained through the proposed TAM and IDT framework. Moreover, this study offers a different perspective on BIM adoption factors. Five of the variables have a direct effect on the actual adoption of BIM. In addition, all five dimensions seem to be having more effect on the PU, and PU mainly determines intention of adoption and actual behaviour, as demonstrated in Chapter 4, in order to adopt open BIM standards for FM. The key factors influencing BIM adoption and helpful in promoting its further development for potential and current users and achieving dramatic productivity improvements in the construction industry are clearly understood. TAM is used to explain the behavior of users in using IT. IDT is a technique that understands the incentives for innovation use and focuses on the forming and eventual adoption of attitudes (motivators) (Ahuja et al., 2018).

In recent years, BIM adopted studies have proliferated, most of them innovation-oriented with the studied innovation as finite, not multifaceted, innovation (such as new learning or communication technology) and conduct (e.g. the use of information technology). This research calls for new and tailored studies on BIM adoption. (1) BIM is a varied innovation (i.e. product, processes and policies) involving several implementation steps aimed at various stages of capacity (i.e. modelling, cooperation, integration); (2) BIM implementation also covers the project network subjects that are affected by interdependences of supply chains (Papadonikolakis et al., 2016). This need is supported by these observations: In many countries, BIM national policies for facilitating BIM adoption across their respective markets are being studied and developed (Kassem and Succar, 2017) and a number of strategic documents, adoption reports, data exchange standards, and collaboration protocols are being increasingly published (Kassem and Succar 2015). In the systemic literature previously presented, current study on BIM adoption has seldom seen the simultaneous potential impact on BIM adoption and diffusion by multiple stakeholders on the market, supply chain and project environment. The aim is therefore to carry out holistic BIM adoption investigations, in line with the specific characteristics of BIM, by introducing the proposed TAM and IDT framework.

8.5 Validation of the Framework

The method of validation of the framework was conducted using member checking from the in-depth interview participants, through which the researcher found ways to improve the credibility, validity and accuracy of the key findings of research interviews (Creswell, 2007; Lincoln and Guba, 1985). The method involved the researcher preparing a summary of key findings and information and then getting feedback from the interview participants to reflect their thoughts, feelings, and experiences to determine the accuracy and credibility of the key findings (Creswell, 2007; Lincoln and Guba, 1985). In this study, three returning interview participants agreed to take part in the validation of the framework via telephone interviews and their comments and feedback were audio recorded, transcribed and analysed accordingly in revising the proposed framework. From the analysis, two emerging key factors, an awareness of the CAFM system and the level of details, were found to support the facilitation of the framework, as shown in Figure 8.3.

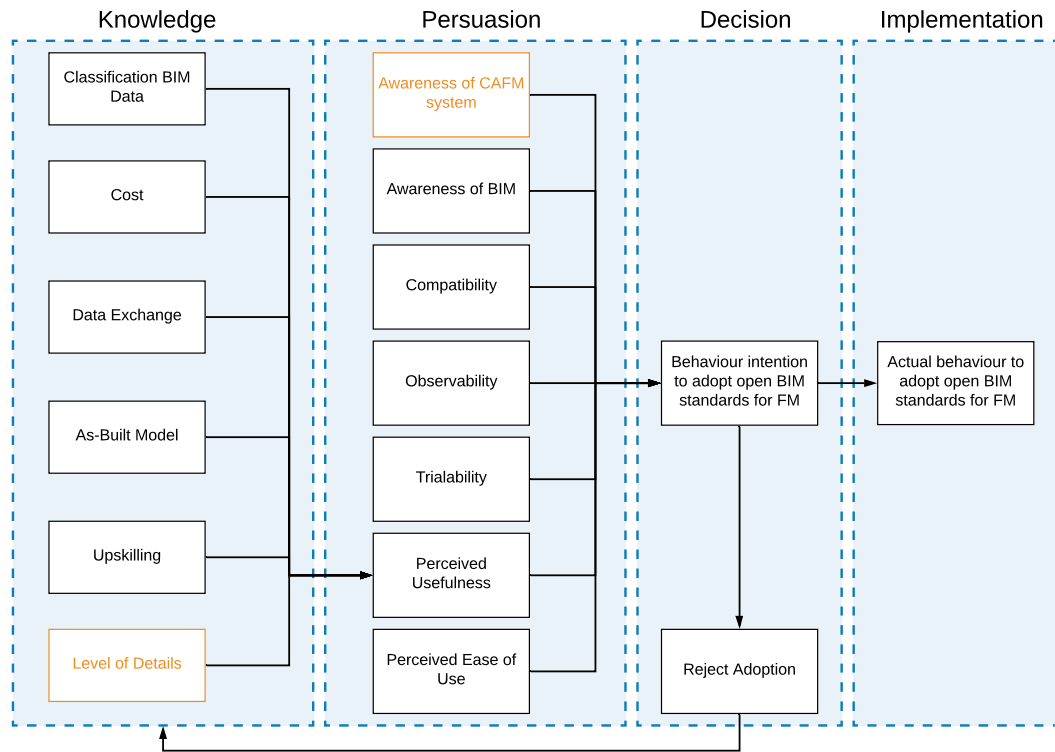


Figure 8.3 Revised conceptual framework of TAM and IDT

The findings in two out three interview participants indicate that an ‘awareness of the CAFM system’ is essential in understanding the function organizing and managing asset within the facilities such as space management, operation and maintenance. Interview participant ID01 commented on the awareness of the CAFM system for facilities managers in terms of whether they understood the function of the CAFM system in managing facilities operation and compatibility to feed the COBie dataset. Meanwhile, ID15 argued for the adoption of the CAFM system as a prerequisite of background understanding of handling digital information and its function working with various data types and requirements to suit the needs of clients. Therefore, an ‘awareness of the CAFM system’, highlighted in the orange box, is shown as a key factor that directly influences the behaviour intention to adopt open BIM standards and standards guidelines.

On the other hand, the level of details emerged as a key factor already discussed previously in section 8.3.4.1.1. Two out three interview participants argued that the level of details is important in order to inform the design team at the start of the project to specify the information requirement for facilities management to avoid unnecessary cost and time consuming in populating COBie dataset in the later stages of construction. Interview participant ID01 pointed out that the level of definition could be split into two parts – the

level of details for the BIM model and the level of information for the COBie dataset – to be able to specify the extent to which the information required, such as additional information for components (e.g. performance data) should be included in COBie. Apart from that, interview participant ID15 was also concerned about the responsibility in delivering the level of details during the project phases to verify the accuracy and quality of the dataset. As a result, the ‘level of details’ is highlighted in the orange box to suggest the external variables that influence the perceived usefulness in adopting open BIM standards and standards guidelines.

Overall, all three interview participants agreed on the key findings in the proposed framework. Interview participant ID01 argued that there is a lack of ability to use and a lack of understanding as to what to do with COBie/IFC once facilities managers received it during the handover stage. In addition, interview participant ID03 mentioned the framework adequately covered some of the aspects (i.e. As-built model, data exchange, cost) that overlap with the design team in adopting COBie/IFC. On the other hand, interview participant ID15 raised a question involving whose responsibility in providing information contained in COBie/IFC and at what given time in the project phases in order to make the framework to be useful towards the adoption.

8.6 Summary of Discussion of Key Findings

This chapter discuss the main finding in both qualitative and quantitative study respectively. The discussion of key findings aim to achieve the objectives of this research that includes; a) the relevance of key information requirement, b) the key factors that can influence the adoption of open BIM standards and standards guidelines, c) the extent to which BIM guidelines can support the adoption of open BIM standards, and d) the framework that can facilitate the adoption of open BIM standards and standards guidelines. The discussion reveals that asset, space, operation and maintenance, equipment, and replacement information are the relevance of key information requirement. It also found that key factors that that influence the adoption of open BIM standards and standards guidelines were consistent in both studies include: value of BIM–perceived usefulness, awareness of BIM, success stories–observability, cost of BIM adoption, up-skilling, development of UNICLASS and accessibility of data–compatibility. On the other hand, the discussion also highlights that insufficiency of standards guidelines and limited knowledge in both PAS1192-3:2014 and BS1192-4:2014 are the main challenge that impeded the adoption of COBie and IFC in FM. Furthermore, the key concepts/task that exploits open BIM standards

and standards guidelines suggest that the knowledge of BIM, Early involvement in EIR, Value of BIM and Success stories/ Case studies were found to support in a framework that can support facilities manager in adoption of COBie and IFC, and the standards guidelines.

8.7 Chapter Summary

The qualitative and numerical evidence of BIM adoption was presented in this chapter. In addition, the main findings to achieve the objectives of this research are discussed in this chapter. Finally, this section ends by proposing a new conceptual BIM adoption TAM and IDT framework. The next chapter provides the theoretical, methodological and managerial implications for the practice of the findings which may be of interest to academic researchers

CHAPTER 9 CONCLUSION AND IMPLICATIONS

9.1 Introduction

The debate, implication and conclusion of this thesis are provided in this chapter. The chapter begins with the theoretical contribution and discussion of the adoption in FM of open BIM standards and standards guidelines. It also outlines the consequences for the practice of findings that may interest academics, policy makers and practitioners. The present study provides a limitation and the recommendation for further research. Finally, the chapter summarizes the contribution of this study to the existing knowledge of BIM standards and standards guidelines in FM. Figure 9.1 provides an overview of key sections.

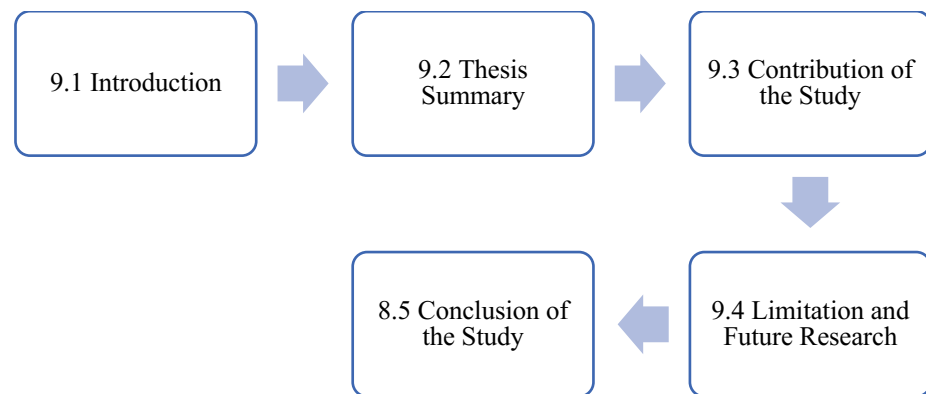


Figure 9.1 Chapter 9 Organization

9.2 Thesis Summary

This study focuses on the adoption of open BIM standards and standards guidelines in FM. Emerging open BIM standards such as Industry Foundation Classes (IFC) and Construction Operations Building information exchange (COBie) can greatly facilitate the handing over of data and information to the facilities managers in a gradual and structured way. Recent efforts to facilitate the use of COBie have been noted in the British Standards (BS 1192-4: 2014) and Publicly Available Specification (PAS 1192-3: 2014) guide to implement BIM in operation and maintenance stage. However, the adoption open BIM standards and standards guidelines among facilities managers are still low. Therefore, a better understanding on the reluctance of adoption is needed and a conceptual framework was formulated from the extensive literature review, informal discussion with experts to understand the key factors that influences the adoption of open BIM standards and standards guidelines and behavioural intention to use open BIM standards and standards guidelines. The research introduced an integrated model of TAM and IDT as a set to test the simultaneous effect on the behaviour

intention in adoption of open BIM standards and standards guidelines in FM. The articulation of the proposed TAM and IDT framework leads to the research design of a mixed method approach. The data collections conducted through in-depth interviews and structured online-survey.

Through the pre-test study, the proposed conceptual framework and variables for the key factors were identified and modified. Six main variables with nine external variables were adopted from the extensive literature review and informal discussion with experts, then revised after conducting pilot study. The results of pilot study show that the adoption of open BIM standards and standard guidelines is formed by integrated TAM and IDT; perceived usefulness, perceived ease of use, compatibility, trialability, observability and newly introduced awareness of BIM. The external variables for perceived usefulness includes; classification of BIM data, EIR, role of subcontractor and suppliers, cost, As-built model, up skilling, interoperability. Thereafter, the main qualitative data were evaluated and analyse in NViVO to consolidate the external variables in the conceptual framework in order to formulate questionnaire items through online-survey. The findings of in-depth interview were discussed into five main sections; the background profile of interview participants, the relevance of key information requirement, the key factors that can influence in the adoption of open BIM standards and standards guidelines, the extend to which BIM guidelines can support the adoption of open BIM standards, and the framework that can facilitate the adoption of open BIM standards and standard guidelines. From the result, the number of the key experts proficient in BIM is twice the number of key experts that proficient in facilities management. A majority of BIM experts has limited knowledge of facilities management. On the other hand, most facilities managers that are knowledgeable in BIM have experience and proficient in IT.

In addition, the findings of the key information requirement were found relevant to BIM-based facilities management includes: asset information, space information, operation and maintenance information, replacement information, and equipment information. Several key factors in the findings such awareness of BIM, classification of BIM data, cost, as-built model, data exchange and up skilling. Furthermore, the findings also discovered that inadequacy and low compliance of PAS1192-3 and BS1192-4 standards combined with the lack of understanding in the standards and guidelines create complexity and uncertainty in willingness to adopt COBie and IFC. The analysis of key concepts and task for the framework suggests the knowledge of BIM especially COBie and IFC, the value it brings to

facilities managers, and communication and collaboration are the elements could facilitate to establish a framework to adopt open BIM standards and standards guidelines. The results of qualitative analysis are then use to revised the choice of words, emerging theme of questionnaire items for the main fieldwork of quantitative research.

On the other hand, the quantitative data was generated from the online-survey from the closed-group discussion of professional social media LinkedIn. This data was examined the impact of six main variables on the behavioural intention to adopt open BIM standards and standards guidelines. SPSS was employed to validate the model. The findings are then discussed into five parts; a) respondents' demographic, b) relevance of key information requirements, c) identification of key factors for adoption of BIM in FM, d) to what extent does BIM guidelines support the adoption of open BIM standards and e) the framework that can facilitate the adoption of BIM in FM. The collected data are then analysed using the SPSS statistical software for descriptive statistics analysis such frequency, median and mean in forms of tables and charts. Bivariate analysis is also conducted using the Pearson's correlation to understand the significance of relationship between variables in the conceptual framework. The correlation matrixes were produced in tables for discussion.

The findings identified five key information requirements for BIM-based FM. Moreover, findings of the data concluded that the behaviour intention in adoption of open BIM standards and standard guidelines among facilities managers are influence by several key factors, such as awareness of BIM, cost, classification of BIM data, interoperability, as-built model and up skilling. Finally, this research contributes to literature on the adoption open BIM standards and standards guidelines in FM. The proposed TAM and IDT framework is the most important outcome of this research in term of both contribution to knowledge and practice and can be used to support the adoption of open BIM standards and standards guidelines in FM. In summary, this study facilitates the understanding and knowledge of open BIM standards i.e. COBie and IFC and standards guidelines in FM and the future direction of BIM and ICT implementation and policy in UK.

9.3 Contribution of the Study

The research findings have several important implications for researchers and practitioners. This chapter distinguishes research contributions and implications for theoretical, methodological, management and publication output contributions.

9.3.1 Theoretical Contributions

Theoretical contribution can be summarized in two-fold. First, this study explores the key factors that influence the adoption of open BIM standards and standard guidelines in FM. Second, the validation of the proposed TAM and IDT framework integration. This study has contributed to the growing body of knowledge that is related to the adoption of open BIM standards and standards guidelines through the lens of social behaviour perspective. First, the study makes a theoretical contribution in highlighting the relationship among BIM, COBie and IFC and standards guidelines among facilities managers. Researches such as Eastman et al. (2011) and Teicholz (2013) have explored on the adoption of COBie and IFC and standards guidelines among facilities managers. Extant research is largely focused on the case studies and literature reviews journal articles and very limited attention has been given to understand the reluctance of facilities manager in adopting BIM specifically COBie and IFC. The research showed, therefore, that facility management and coordination to maximize efficiencies and avoid numerous problems created through fragmented and disjointed approaches is a critical factor for the successful introduction of open BIM standards and standard guidelines in FM. Such leadership should be primarily driven by governmental entities but needs the support and cooperation of key players in industry, such as industry clients, contractors and professional associations.

The above findings enrich the understating of interrelationships between TAM and IDT related to the adoption of open BIM standards and standards guidelines in FM. This is because, as of yet, no empirical analysis was conducted to investigate the adoption of open BIM standards and standards guidelines in FM and simultaneously incorporate the TAM and IDT. By doing so, this research contributes to the existing literature by providing new and differentiated insights on the possible interrelationships between the adoption of open BIM standards and standards guidelines in FM with the TAM and IDT.

9.3.2 Methodological Contributions

The methodological contributions in this study can be notice by the measures all variables are verified empirically, thus, presenting valuable information for future studies. On the other hand, this study employs sequential exploratory mixed methods techniques that conduct qualitative in-depth interviews followed by quantitative online survey. This study is important in term of measurement revision of the key variables constructs as the statements of items required meticulous understanding and amendments to capture features of BIM,

COBie, IFC and the standards guidelines of PAS1192-3:2014 and BS1192-4: 2014. Although most of the key variables were adapted from the previous literature and guidelines, several attempts have been made to assess the reliability and validity and revised the statements according to characteristics of behaviour intention in adoption of open BIM standards and standards guidelines during the pre-test study.

Secondly, this study also contributes by addressing the knowledge gap and integrating theories of TAM and IDT, this study fulfils the information gap by exploring the key factors that can influence the adoption of open BIM standards and standards guidelines in FM. The key factors that identified are awareness of BIM, classification of BIM data, cost, data exchange, as-built model and upskilling. The key factors are proposed to support in the framework to identified the usefulness of COBie, IFC and the standard guidelines PAS1192-3:2014 and BS1192-4:2014. In spite of this, the conceptual framework is introduced and tested by integrating the TAM model and IDT's five innovative characteristics (compatibility, observability, trialability, perceived usefulness and perceived ease of use) in predicting the behaviour intention in adoption of open BIM standards and standards guidelines in FM. To best of knowledge and extensive literature review, this is the first time the integrated model of TAM and IDT being introduced as a set to test the simultaneous effect on the behaviour intention in adoption of open BIM standards and standards guidelines in FM.

This is, on the other hand, the first attempt at TAM and IDT scales to examine user adoption of BIM technology. Very few scientific contributions related to the introduction of BIM in FM as the majority of the literature contributions of TAM and IDT in IT and mobile adoption to consumer behavior can be found to the best of the knowledge. For example, Mutai (2009) combined TAM, IDT and Task Technologies Approach (TTF) to examine factors which could affect BIM's usage in the United States of America's leading construction companies. BIM technology diffusion in builders is influenced by the research research results, grouped into three categories of human, technological and risk factors.

Although the above-mentioned technology assessment theories provide a sound theoretical basis for investigating the factors influencing the use of BIM, the primary objective of this study is to study the application of open BIM standards and how use is improved. This study's theories framework is similar to the model Mutai (2009), but TTF has in this study been deleted because TTF shows how well the functionality of the technology meets or

meets the needs of the task. It has been designed to evaluate the overall IT system of an organization and assumes that the IT can only improve job performance. This research, TAM and IDT integrated with additional variables identified from extensive literature reviews and in-depth expert interviews in order to examine and analyze barrier factors for BIM adoption in order to support broad adoption. Furthermore, this research the considered the first research employed qualitative in-depth interview with key experts and a quantitative online structured-survey through closed group discussion in the professional social media LinkedIn in reaching wider respondents with the proposed TAM and IDT framework.

9.3.3 Managerial Implications

First implications of the study are the approach of facilities managers to access and examine information about buildings and further increase the potential for collaboration and efficiency gains. The facilities managers leadership behavior needs to be nurtured through changes in their mindsets, practices and decision-making activities. It should be proactive in managing the issues of BIM, COBie, IFC, and the PAS1192-3:2014 and BS1192-4:2014 Standard Guidelines. It should innovate in the promotion and support of new ideas. In competition with local and global construction actors they must be more aggressive but constructive.

Secondly, this study contributes to the present understanding of BIM's business case attributes for all building industry players. If there is no proper communication of business value and return on investment (RIO) from the adoption of open BIM standards and FM standards, this will create a barrier. In the final analysis, the adoption and implementation of BIM is still inhibited by companies with cynical and negative opinions on the value of investing in the required BIM technology and training, mainly due to problems with articulating the business case for these businesses. A good example of what is needed to communicate benefits to enterprises was the McGraw Hill (2014) Report on the BIM business value in the major global building market. In their major survey, they found that 75% of firms have had a positive return on investment in BIM with lower errors and omissions, less workmanship, and lower construction costs, cited as the main benefits. The articulation of the business case is probably even more important for the construction industry, because it will be the main driving forces behind the adoption of open BiM and FM standards. Evidence studies show that the use of BIM generates significant value for the organization through management of facilities, which eventually improves the exchange of

information, reduces design mistakes, improves the design quality, enhances productivity and reduces construction and costs (NIBS 2013; McGraw Hill 2014; Wong et al., 2018).

Thirdly, the role of networking is concerned. In addition to the relevant government agencies and / or institutions, the facility managers must establish, establish, strengthen and sustain their networking efforts. The organization is gaining preferential access, according to Luo, Sun, & Wang (2011), to valuable market information, better opportunities for government monetary and non-monetary stimulus, and contributes to reducing bureaucratic delays. The next logical step for building owners and operators is facility managers also need to take advantage of networking opportunities to achieve the integration of IT infrastructure and building systems. The majority of the costs associated with construction and maintenance are not in the design phase, but the ongoing maintenance costs. By means of advanced construction technology like BIM and smart integration, the building can offer enormous cost savings throughout the lifetime of the building and make it comfortable place to live or work.

The fourth implication is the preparation of the organization. In order to sustain the features of BIM, COBie, IFC and standard guidelines of PAS1192-3: 2014 and BS1192-4: 2014, the organization should develop its managerial capabilities and firm competences in the long term. The company management team should not only have diverse technical, business, interpersonal and communications skills, but must always be prepared to work hard, to be attentive to any changes of technology, to be able to anticipate global market behavior, to make fast, precise choices and especially to identify the direction in the future for BIM and ICT.

9.3.4 Contribution in Terms of Publication Output

The outcome from this research project was mainly this thesis, including the methodology, empirical data and key findings of the influencing factor to adopt open BIM standards; a copy of summary was offered to the participating interviewees in return for their participation. Meanwhile, two publications of paper were made as follows:

Paper 1: ‘Developing BIM-FM Innovation Technology Acceptance Framework’, Journal of Building Performance, Volume 9 Issue 2, 2018, submitted for 3rd Malaysia-Europe FM Conference, 26 September 2017, Kuala Lumpur, Malaysia

Paper 2: ‘Assessment of open BIM standards in FM’ at the International Conference on Innovative Production and Construction (IPC 2017), 30 Nov-1 December 2017, Perth Western, Australia

9.4 Limitations and Future Research

Several limitations have been identified and recommendations for future studies have to be discussed in this section.

There are several reasons why the first limitation is to interpret the results of this study with caution. This study first used users as interviewees and conducted a survey and expert interview. Thus, the sample may be partial because the user experience in the UK included the sample. Secondly, only numerical relations can be provided by statistical analysis. The interpretation of these figures depends on the authors' and users' subjective evaluation. However, the results are consistent with other theories and studies, which enhances trust in the results. The results of this study could therefore be further researched using a qualitative method for ethnography to confirm and understand the results more thoroughly.

The second restriction was the study examined only the TAM and IDT factors and incorporated some additional literature variables on a broader BIM context. More predictors such as work size, liability, law and insurance issues can be conceivable, which can affect BIM adoption. In order to better understand the adoption and application of BIM applications, future research should therefore examine the influence of this additional variables.

The third restriction was the problem of finding suitable literature information pertaining to the field of study, since only limited work on the use and implementation of BIM organizations was available. Moreover, the lack of BIM experts and a limited number of BIM-specific cases was a fundamental limit since the adoption criteria developed were based on the experience of just some experts and not generally considered in a larger study population. Although this is regarded as a limitation, this research has also made a contribution towards the present literary context, as the limited literature adds to the small breadth of knowledge available already. Therefore, in the near future, the scientists should stress the contribution of knowledge to adopting open BIM standards and standard guidelines in FM.

9.5 Conclusion of the Study

This chapter summarized the thesis and provided an overview of its aims, contributions to research knowledge, restrictions and future directions. This study addressed the study's objective, identified BIM adoption factors and proposed a TAM and IDT framework in order to address opportunities for BIM work. It also contributed to knowledge which will support the organization through awareness that BIM's value is necessary for understanding and aligning macro-and micro-level values within the organization. When considering the demands of facilities management, in terms of both the technical requirement for undertaking the work, such as the specific technicalities of maintaining buildings, and the information requirements for that work, a flexible approach to developing ideas and priorities is beneficial. BIM offers an opportunity to explore the ideals of, and application within, facilities management, and simulate innovative practices without any negative implication on either cost or time. The advanced use of information, created and exchanged in a timely manner, not only allows facilities management to be brought to the forefront of design decisions, but also does so in a way that forces disparate parties to collaborate, discover, and share.

With the facility in operation and live data continually being captured – whether through rudimentary processes such as pen on paper, or advanced input within the model database – the future for further optimisation is one of occasion and thrilling opportunity. This research has highlighted the opportunities for innovative project development within the field of construction, when mandating the adoption of open BIM standards and standards guidelines in FM and utilising the process of BIM for Facilities Management. Through the exploration of this research, it has concluded that although there are numerous benefits from BIM such as heightened collaboration and advanced awareness of long-term processes, there are still areas for progression and refinement. BIM for FM is a subject matter that has only recently begun to be explored. It is clear, however, that only by learning from a range of case examples will FM be able to develop future state-of-the-art solutions to achieve the long-term saving requirements of building assets.

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APPENDICES

Appendix A- Participant Information Sheet



Participant Information Sheet – In-depth Interview

Study title

The adoption of Building Information Modelling (BIM) in Facilities Management (FM)

Invitation paragraph

You are being invited to take part in a research study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

What is the purpose of the study?

The aim of this study is to investigate the adoption of open BIM standards and standard guidelines in facilities management. Buildings have very long lifespans and decisions made before and during construction have long-term consequences. A significant portion of life cycle cost is incurred during the operational and maintenance phase of a building. More often than not, clients and investors often focus on the capital cost, with less or no consideration of future operation, maintenance and/or replacement costs. Thus, data and information are left until the building is completed before being handed to the facilities managers in typically non-suitable, manual/paper-based or non-digital formats. With the late delivery of non-digital data, it is challenging for facilities managers to assess the quality of information and whether the information they need is contained in the handover data.

Emerging open Building Information Modelling (BIM) standards such as Industry Foundation Classes (IFC) and Construction Operations Building information exchange (COBie) can greatly facilitate the handing over of data and information to the facilities managers in a gradual and structured way. However, facilities managers are still very reluctant to adopt open BIM standards in their practices due to many uncertainties such as cultural barrier towards adopting new technology, lack of collaborations between stakeholders, fragmentation and competition among different software vendors and interoperability issues. Recent efforts that facilitate the use of COBie have been noted in the Publicly Available Specification (PAS 1192-3: 2014) and British Standards (BS 1192-4: 2014). PAS 1192-3: 2014 specifies how information can be managed in the operational phase while BS 1192-4: 2014 defines a methodology for the transfer between parties of structured information relating to facilities, including buildings and infrastructure. A recent report by UK National Building Specification revealed that only 26% and 18% of the UK construction professionals surveyed used PAS 1192-3:2014 and BS 1192-4:2014 respectively.

This study will investigate why there is a low adoption of open BIM standards amongst professionals and why BIM guidelines have not entirely unlocked this challenge. To achieve this, two main theories – the Technology Acceptance Model (TAM) and Innovation Diffusion Theory (IDT) widely used for investigating the reluctance of people in adopting new technologies will be used in this study. The integration of both theories will be adopted to establish a framework that can better facilitate the adoption of open BIM standards and standard guidelines in facilities management.

This fieldwork will be run for six months from 1st of July 2017 to 31st of July 2018. Final results will be a PhD thesis and summary report of findings for participants. There is also a possibility that the findings will be published in conference paper/ academic journal papers.

Why have I been invited to participate?

You have been invited to participate because of your knowledge or experience in the area of BIM and facilities management topics and you are;

1. A BIM proponent group (i.e. BIM Task Group) or a BIM expert/ consultant.
2. A member of BIM4FM, BIM Experts, BSRIA group in LinkedIn professional social media
3. A facilities management software vendors/ facilities manager/ facilities management service provider.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

If you decide to take part in the study, you will be one of the key participants to be interviewed. You will not be asked to provide any sensitive information. You will be asked about your background, position, experiences, knowledge and skill related to BIM-compliant projects and practices. The interview will take approximately 45-60 minutes (you will decide the length of time) discussing about the key factors that influence the adoption of open BIM standards (COBie, IFC) and standard guidelines (PAS1192-3, BS1192-4) in facilities management. The meeting will take place at a location of your choice and on a date of your convenience between the 1st of July 2017 and 31st of July 2018. If you give your consent, an audio of the interview will be recorded. Otherwise, authorized notes will be taken. If you decide to withdraw from this study, the researcher will not include any information that has been recorded.

What are the possible benefits of taking part?

This study will give you an opportunity to reflect on the adoption of BIM in facilities management in the near future. This study aim to investigate the adoption of open BIM standards and standard guidelines in facilities management

Will what I say in this study be kept confidential?

All information collected in this research will be kept strictly confidential but anonymity cannot be completely guaranteed (as it is subject to legal limitations). Confidentiality, privacy and anonymity will be ensured in the collection, storage and publication of research material. Data generated by the study will be retained in accordance with the University's policy on Academic Integrity and kept securely in electronic form for a period of ten years after the completion of this research project.

What should I do if I want to take part?

Please take time to read the participant information sheet and decide whether to take part in this research. If you would like to take part in this study after this period, please send a reply to sheikh.ali.sh.said-2015@brookes.ac.uk

What will happen to the results of the research study?

The research will be submitted to Oxford Brookes University, and graded as part of a requirement for completion of a Doctor of Philosophy (PhD) degree. Interviewees may have access to a summarized version of the findings upon their request. The anonymity of participants will be ensured in the publication of research material in any form. The data generated in the course of the research will be retained in accordance with the University's policy of Academic Integrity and must be kept securely in paper or electronic form for a period of ten years after the completion of research study. Participants should be aware that there are legal limitations on data confidentiality and anonymity.

Who is organising and funding the research?

The research is being organised and undertaken by Sheikh Ali Azzran, a PhD student in the School of the Built Environment, Faculty of Technology, Design and Environment, Oxford Brookes University, UK. This research has been supervised by Professor Joseph H.M.Tah, Director of Studies and Dr. F. Henry Abanda as the main supervisor. The research is a PhD studentship sponsored by Majlis Amanah Rakyat (MARA); a Malaysian government agency, Malaysia.

Who has reviewed the study?

This research has been approved by the University Research Ethics Committee, Oxford Brookes University. If you have any concerns about the way in which the study has been conducted, you should contact the Chair of the University Research Ethics Committee on ethics@brookes.ac.uk

Contact for Further Information

For further information you can contact Sheikh Ali Azzran at sheikh.ali.sh.said-2015@brookes.ac.uk

Thank you for taking time to read the information sheet.

Sheikh Ali Azzran
March 2018

Prof. Joseph H.M.Tah
Oxford Brookes University
Headington Campus
Oxford
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Dr. Henry Abanda
Oxford Brookes University
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Appendix B – Consent Form



CONSENT FORM

The Adoption of Building Information Modelling (BIM) in Facilities Management

The research will be submitted to Oxford Brookes University, and graded as part of a requirement for completion of a Doctor of Philosophy (PhD) degree.

Principal Researchers

Professor Joseph H.M.Tah, jtah@brookes.ac.uk

Dr. F. Henry Abanda, fabanda@brookes.ac.uk

Sheikh Ali Azzran, PhD Research Student, sheikh.ali.sh.said-2015@brookes.ac.uk

School of the Built Environment, Faculty of Technology, Design and Environment
Oxford Brookes University

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.
3. I agree to take part in the above study.

☐
☐
☐

Please initial box

4. I agree to the interview being audio recorded
5. I agree to the use of anonymised quotes in publications
6. I agree that my data gathered in this study may be stored (after it has been anonymised) in a specialist data centre and may be used for future research.

Yes	No
☐	☐
☐	☐
☐	☐

Name of Participant

Date

Signature

Sheikh Ali Azzran

Name of Researcher

Date

Signature



The Adoption of Building Information Modelling (BIM) in Facilities Management (FM)

1. The Adoption of Building Information Modelling (BIM) in Facilities Management (FM)

You are kindly invited to contribute towards this study. It is important to note that participation is voluntary. Before deciding whether to participate in this survey it is important to know why it is being conducted. This research aims to establish a framework that can facilitate the adoption of open BIM standards and standard guidelines in facilities management. The purpose of this survey is to investigate the level of awareness and knowledge in open BIM standards; COBie (Construction Operations Building Information Exchange) and IFC (Industry Foundation Classes) and standard guidelines (e.g. PAS 1192-3 and BS1192-4). This survey will take approximately 20 minutes to complete. Your answers will be kept strictly confidential and anonymous and will be used for academic purposes only. Any information you provide will be managed in accordance with Oxford Brookes University's policies of academic integrity and in particular confidentiality. Thank you for your support. If at any one moment you have any concerns do not hesitate to contact me at: sheikh.ali.sh.said-2015@brookes.ac.uk

I have read and understood the background information about the research in the preceding section, and I consent to participate in this study. Completing the questionnaire is voluntary but your participation will be greatly appreciated. *

☐ Yes

☐ No

2. Section 1: Background Information

The purpose of this section is to collect demographic data about participants and preliminary facilities management information. This will inform the analysis within the context of information quality based on the information provided. For further information about the surveys visit: <https://www.gov.uk/service-manual/user-centred-design/user-research/survey-design.html>

Which of the following best describe your primary job function? (Please select all that apply) *

- ☐ Architect and Designer
- ☐ Asset Manager
- ☐ BIM Manager
- ☐ BIM Coordinator
- ☐ BIM Technician
- ☐ BIM Specialist
- ☐ Building Services Manager
- ☐ Civil Engineer
- ☐ Energy/ Sustainability Manager
- ☐ Facilities Manager
- ☐ Health, Safety and Security Officer
- ☐ IT Specialist
- ☐ Mechanical and Electrical Engineer
- ☐ Project Manager
- ☐ Quantity Surveyor
- ☐ Structural Engineer
- ☐ Supply-Chain
- ☐ Other (please specify):

What is the average size (total number of staff) of your organization *

- ☐ Small Businesses (0-49)
- ☐ Small Medium Enterprise (50-249)
- ☐ Large Companies (250- above)

Which of these facilities are you or your organisation involved with? (Please select all that apply) *

- ☐ Administrative, Office, Commercial Facilities (Office Buildings, Shopping Malls, etc.)
- ☐ Education, Scientific, Information, Research Facilities (Universities, Schools, Institutes, Libraries, etc.)
- ☐ Industrial Facilities (Factories, Production Plants, etc)
- ☐ Medical Health Facilities (Hospitals, Health Centres, Ambulance, etc)
- ☐ Protective, Correctional Service Facilities (Police, Fire, Prisons, etc)

☐ Religious Facilities
 ☐ Residential Facilities
 ☐ Social, Welfare Facilities (Care Homes, Nursing Homes, Children and Youth Centres etc.)
 ☐ Sport, Recreational Facilities
 ☐ Utilities, Engineering Facilities
 ☐ Other (please specify):

How would you rate your experience of: *

	No experience	Basic experience	Moderate experience	Highly experience	Expert
Facilities management	☐	☐	☐	☐	☐
BIM	☐	☐	☐	☐	☐
The use of BIM for facilities management	☐	☐	☐	☐	☐
Facilities management systems (e.g. CAFM, CMMS)	☐	☐	☐	☐	☐
BIM systems (e.g. Revit, ArchiCAD, Tekla)	☐	☐	☐	☐	☐
Industry Foundation Classes (IFC)	☐	☐	☐	☐	☐
Construction Operation Building information exchange (COBie)	☐	☐	☐	☐	☐
Exporting models from BIM authoring software to facilities management system	☐	☐	☐	☐	☐
The use of PAS 1192-3:2014- Specification for information management for the operational phase of assets using BIM	☐	☐	☐	☐	☐
The use of BS1192-4:2014- Collaborative production of information – Fulfilling employer's information exchange requirements using COBie	☐	☐	☐	☐	☐
BIM Federated Model	☐	☐	☐	☐	☐
Interoperability and utility tools (i.e. Solibri, Ecodomus)	☐	☐	☐	☐	☐
Others (Please specify):					

Which of the following FM systems do you or your organisation used? (please select all that apply) *

☐ AiM
 ☐ Archibus

- ☐ ArchiFM
- ☐ Bentley Facilities
- ☐ CAFM Explorer
- ☐ Causeway FM
- ☐ FM: Interact
- ☐ FSI (Concept)
- ☐ Maximo
- ☐ MainManager
- ☐ Onuma
- ☐ Planet FM
- ☐ Planon
- ☐ Proteus MMX
- ☐ Service Works Global
- ☐ WebTMA
- ☐ Other (please specify):

Which of the following BIM systems do you or your organisation used? (please select all that apply) *

- ☐ ArchiCAD
- ☐ Bentley BIM Suite
- ☐ BIM 360°
- ☐ Digital Project (DP)
- ☐ Dprofiler
- ☐ Naviswork
- ☐ Revit
- ☐ Solibri
- ☐ Tekla Structure
- ☐ Vectorworks
- ☐ Bespoke BIM system
- ☐ Other (please specify):

3. The extent to which BIM guidelines can support the adoption of open BIM standards

Preliminary information: The aim of this section is to investigate the extent to which BIM guidelines can support the adoption of open BIM standards (COBie and IFC) in facilities management. The acronyms as used in the section are defined for clarity purposes.

BIM – Building Information Modelling

BIM is defined as a process of generating, storing, managing, exchanging and sharing information about facility and asset in the operational phase of a building.

COBie – Construction Operation Building information exchange

COBie is a means of sharing and exchanging information about facility. It is created purposely for information exchange and creation between BIM systems and FM systems; and it can be created and exchanged using a simple spreadsheet

IFC- Industry Foundation Classes

The Industrial Foundation Classes is an open standard to facilitate the digital information exchange of BIM object data. It is act as a platform of exchanging information of project object data from design and construction to facilities management.

PAS1192-3:2014 – Specification for information management for the operational phase of assets using building information modelling

PAS 1192-3:2014 is a standard that focus on using **BIM** to capture information in the operational phase of the building and/or assets.

BS1192-4:2014 – Collaborative production of information – Fulfilling employer's information exchange requirements using COBie

BS1192-4:2014 is a methodology for the transfer between parties of structured information relating to facilities, including buildings and infrastructure

EIR – Employer Information Requirements

The **EIR** is a document defined by owner to specifies information requirements for all the construction players involved in the development of project using **BIM** and the management of the building throughout its lifecycle

Compatibility

The adoption of open BIM standards (**COBie** and **IFC**) and standard guidelines (**PAS1192-3:2014** and **BS1192-4:2014**) is perceived as consistent with values, past experience and needs of facilities managers.

Trialability

The opportunity to experiment and test open BIM standards and standard guidelines before deciding to adopt it in facilities management.

Observability

The result of adopting of open BIM standards and standard guidelines demonstrate a clear understanding for facilities managers to follow before they decide to adopt it.

Data Exchange

The ability to manage and exchange information between software systems (e.g. BIM systems and FM systems)

As-Built Model

A single validated and approved model that contain information related to assets, spaces, operation and maintenance, replacement, and equipment information for facilities management.

4. Relevance of key information requirement

Using a scale of 1=most relevant to 5=least relevant, please rate the following key information requirement in your facilities management tasks? *

	5 - Most relevant	4	3- Neutral/ Don't know	2	1- Least relevant
Asset information (Asset registers/records, life expectancy, commissioning dates, etc)	☐	☐	☐	☐	☐
Space information (Space coding, room numbering, etc)	☐	☐	☐	☐	☐
Operation and Maintenance information (O&M manual, maintenance schedule, frequencies of maintenance, etc)	☐	☐	☐	☐	☐
Equipment information (MEP equipment list, equipment life expectancy, etc)	☐	☐	☐	☐	☐
Replacement information (replacement parts, replacement specification, replacement value, replacement cost, etc)	☐	☐	☐	☐	☐

Comments:

5. Key Factors that Influence the Adoption of Open BIM Standards

Awareness of BIM

	5 - Strongly Agree	4	3 - Neutral/ Don't know	2	1 - Strongly Disagree
I'm familiar with the term COBie	☐	☐	☐	☐	☐
I'm familiar with how COBie works for facilities management	☐	☐	☐	☐	☐
I'm familiar with the term IFC	☐	☐	☐	☐	☐
I'm familiar with how IFC works for facilities management practice	☐	☐	☐	☐	☐
I'm familiar with the standard guidelines PAS1192-3:2014	☐	☐	☐	☐	☐
I'm familiar with how PAS1192-3:2014 helps in adopting BIM in facilities management	☐	☐	☐	☐	☐
I'm familiar with the standard guidelines BS1192-4:2014	☐	☐	☐	☐	☐
I'm familiar with how BS1192-4:2014 helps in adopting COBie in facilities management	☐	☐	☐	☐	☐
Compatibility					
	5 - Strongly Agree	4	3- Neutral/ Don't know	2	1 - Strongly Disagree
The use of COBie improves the way I work	☐	☐	☐	☐	☐
The use of COBie facilitates effective working	☐	☐	☐	☐	☐
The use of COBie improves the handover data from construction to operational phase	☐	☐	☐	☐	☐
The use of IFC improves the way I work	☐	☐	☐	☐	☐
The use of IFC facilitates effective working	☐	☐	☐	☐	☐
The use of IFC improves the handover data from construction to operational phase	☐	☐	☐	☐	☐
Trialability					
	5 - Strongly Agree	4	3 - Neutral/ Don't know	2	1 - Strongly Disagree
Being able to try out COBie is important in my decision to adopts it	☐	☐	☐	☐	☐
Being able to try out IFC is important in my decision to adopts it	☐	☐	☐	☐	☐
I have used COBie on live projects	☐	☐	☐	☐	☐
I have used IFC data exchange on live projects	☐	☐	☐	☐	☐
Observability					

	5 - Strongly Agree	4	3- Neutral/ Don't know	2	1 - Strongly Disagree
I have seen case studies where COBie has been used in facilities management	☐	☐	☐	☐	☐
I have seen demonstrations of COBie in facilities management	☐	☐	☐	☐	☐
I have seen case studies where IFC has been used in facilities management	☐	☐	☐	☐	☐
I have seen demonstrations of IFC in facilities management	☐	☐	☐	☐	☐
Perceived Usefulness					
	5 - Strongly Agree	4	3- Neutral/ Don't know	2	1 - Strongly Disagree
COBie is a useful mechanism for handing over data to operational and maintenance stage	☐	☐	☐	☐	☐
COBie will benefit facilities management practice	☐	☐	☐	☐	☐
IFC has a structured information for handing over data to operation and maintenance stage	☐	☐	☐	☐	☐
IFC is a useful data exchange format	☐	☐	☐	☐	☐
PAS 1192-3:2014 provides clear guidelines for adopting BIM in FM	☐	☐	☐	☐	☐
BS1192-4:2014 provides clear guidelines for populating COBie	☐	☐	☐	☐	☐
Perceived ease of use					
	5 - Strongly Agree	4	3- Neutral/ Don't know	2	1 - Strongly Disagree
COBie spreadsheet is easy to use	☐	☐	☐	☐	☐
COBie spreadsheet has a user-friendly interface	☐	☐	☐	☐	☐
IFC is an easy format for facilities manager to use	☐	☐	☐	☐	☐
IFC is a user-friendly data exchange format	☐	☐	☐	☐	☐
PAS1192-3:2014 standard helps facilities managers to understand how to managed information easily	☐	☐	☐	☐	☐
BS1192-4:2014 standard helps facilities managers to implement COBie	☐	☐	☐	☐	☐
Cost					
	5 -		3- Neutral/		1 -

	Strongly Agree	4	Don't know	2	Strong Disagree
Capturing of information in COBie may involve expensive cost in hiring specialist (e.g. computing firm, technical specialist)	☐	☐	☐	☐	☐
The benefits of information populated in COBie are greater than its cost.	☐	☐	☐	☐	☐
Capturing of information in IFC may involve expensive cost in hiring specialist (e.g. computing firm, technical specialist)	☐	☐	☐	☐	☐
The benefits of using IFC are greater than its cost.	☐	☐	☐	☐	☐
Classification of BIM data					
	5 - Strongly Agree	4	3 - Neutral/ Don't know	2	1 - Strongly Disagree
The use of classification systems is useful in structuring FM data	☐	☐	☐	☐	☐
The Uniclass/Omniclass/SFG20 standard is important for defining information in COBie	☐	☐	☐	☐	☐
The Uniclass/Omniclass/SFG20 standard enhances the use of COBie in FM system	☐	☐	☐	☐	☐
Information that carries Uniclass/Omniclass/SFG20 standard is readable in FM system	☐	☐	☐	☐	☐
Comments:					
Data Exchange					
	5 - Strongly Agree	4	3 - Neutral/ Don't know	2	1 - Strongly Disagree
COBie can easily be used to import data into FM system	☐	☐	☐	☐	☐
IFC format allows integration with my FM system	☐	☐	☐	☐	☐
As-Built Model					
	5 -	4	3 - Neutral/	2	1 -

	Strongly Agree		Don't know		Strongly Disagree
As-Built model helps facilities managers to identify the relevant information in COBie	☐	☐	☐	☐	☐
As-Built model helps facilities managers to reduce redundant information in COBie	☐	☐	☐	☐	☐
As-Built model helps facilities managers to identify errors in COBie	☐	☐	☐	☐	☐
As-Built model helps facilities managers to identify missing information in COBie	☐	☐	☐	☐	☐
Upskilling					
	5 - Strongly Agree	4	3 - Neutral/Don't know	2	1 - Strong Disagree
Training workshops help me to enhance my skill set in updating COBie information in facilities management system	☐	☐	☐	☐	☐
Training workshops help me to enhance my skill set in using IFC data exchange format to update graphical information in facilities management system	☐	☐	☐	☐	☐
Behaviour Intention					
	5 - Strongly Agree	4	3 - Neutral/Don't know	2	1 - Strongly Disagree
I have the intention to adopt open BIM standards and standard guidelines in near future.	☐	☐	☐	☐	☐
I anticipate that I will adopt open BIM standards and standard guidelines in my work	☐	☐	☐	☐	☐
I intent to apply open BIM standards and standard guidelines in my work	☐	☐	☐	☐	☐
6. The extent to which BIM guidelines can support the adoption of open BIM standards					
In your opinion, please rate the extent to which BIM guidelines (PAS1192-3:2014 and BS1192-4:2014) can facilitates the adoption of open BIM standards.					
	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
					Unknown

PAS 1192-3:2014 has clarified the process and procedure of information communication with facilities management system	☐	☐	☐	☐	☐	☐																																																															
PAS 1192-3:2014 sufficiently covers the key information requirement for facilities management tasks	☐	☐	☐	☐	☐	☐																																																															
PAS1192-3:2013 has clarified the role and responsibility of managing and maintaining BIM model in operation and maintenance stage	☐	☐	☐	☐	☐	☐																																																															
PAS1192-3:2014 can support the adoption of BIM in FM on a live project	☐	☐	☐	☐	☐	☐																																																															
BS 1192-4:2014 provides a comprehensive guidance to use COBie for facilities management	☐	☐	☐	☐	☐	☐																																																															
BS1192-4:2014 provides the key information requirement for COBie	☐	☐	☐	☐	☐	☐																																																															
BS 1192-4:2014 has clarified the role and responsibility of populating COBie in facilities management	☐	☐	☐	☐	☐	☐																																																															
BS1192-4:2014 can support the adoption of COBie on a live project	☐	☐	☐	☐	☐	☐																																																															
Others (Please specify):																																																																					
In your opinion, please rate the following concepts/tasks as part of a framework to guide the adoption of open BIM standards and standards guidelines in facilities management. * <table border="1"> <thead> <tr> <th></th> <th>Strongly Agree</th> <th>Agree</th> <th>Neither agree nor disagree</th> <th>Disagree</th> <th>Strongly disagree</th> <th>Unknown</th> </tr> </thead> <tbody> <tr> <td>Reduce the content of COBie to more relevant material</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> </tr> <tr> <td>A process map for BIM use in facilities management</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> </tr> <tr> <td>Early involvement of facilities manager in the EIR document</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> </tr> <tr> <td>Suppliers and Manufacturers has an important factor to play in providing details for COBie data input</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> </tr> <tr> <td>Reduce the cost of training in promoting the use COBie and IFC for facilities management</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> </tr> <tr> <td>Regulatory enforcement in using COBie and IFC for facilities management</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> </tr> <tr> <td>Communication with design and construction team to get information needed for facilities management in COBie and IFC</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> </tr> <tr> <td>Assigning BIM manager to update information in COBie</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> <td>☐</td> </tr> </tbody> </table>								Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Unknown	Reduce the content of COBie to more relevant material	☐	☐	☐	☐	☐	☐	A process map for BIM use in facilities management	☐	☐	☐	☐	☐	☐	Early involvement of facilities manager in the EIR document	☐	☐	☐	☐	☐	☐	Suppliers and Manufacturers has an important factor to play in providing details for COBie data input	☐	☐	☐	☐	☐	☐	Reduce the cost of training in promoting the use COBie and IFC for facilities management	☐	☐	☐	☐	☐	☐	Regulatory enforcement in using COBie and IFC for facilities management	☐	☐	☐	☐	☐	☐	Communication with design and construction team to get information needed for facilities management in COBie and IFC	☐	☐	☐	☐	☐	☐	Assigning BIM manager to update information in COBie	☐	☐	☐	☐	☐	☐
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and IFC in the FM system

Others (please specify):

Would you like to take part in the in-depth interview with regards to this study? (If yes, please leave your details/ if no, please proceed to the next page)

Name:

Email Address:

Telephone (optional):

Appendix D- COBie Spreadsheet

COBie. Contact

<i>Email</i>	A well-formed email address used to identify this specific Contact
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Category</i>	The category of business in which the specific Contact is engaged.If allowable values are not specified by contract, the default list in OmniClass Table 34 – Organizational Roles
<i>Company</i>	The name of the company for the Contact
<i>Phone</i>	The telephone number for the Contact
<i>ExternalSystem</i>	The telephone number for the Contact
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie date
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Department</i>	The name of the department for the Contact
<i>OrganizationCode</i>	The organizational code for the Contact
<i>GivenName</i>	If the Contact is a person, the given name of the Contact/ (n/a)
<i>Familyname</i>	If the Contact is a person, the family name of the Contact /(n/a)
<i>Street</i>	The street address for the Contact / (n/a)
<i>PostalBox</i>	The postal box address for the Contact / (n/a)
<i>Town</i>	The city or town address for the Contact / (n/a)
<i>StateRegion</i>	The street address for the Contact
<i>PostalCode</i>	The postal box address for the Contact
<i>StateRegion</i>	The street address for the Contact
<i>Country</i>	The postal box address for the Contact

COBie.Facility

<i>Name</i>	The name of the Facility as it appears on design drawings, or as otherwise specified by contract
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Category</i>	The category of facility described by the COBie data set. If allowable values are not specified by contract, the default value for this information is the current OmniClass Table 11- Construction Entities by Function (can be customize
<i>Project Name</i>	The name of the project as it appears on design drawings, or as otherwise specified by contract
<i>Site Name</i>	The name of the Site as it appears on design drawings, or as otherwise specified by contract
<i>Linear Units</i>	The associated unit of measurement applied to all COBie information other than that found in the Attribute and Impact worksheets
<i>Area Units</i>	same as above
<i>Volume Units</i>	The associated unit of measurement applied to all COBie information other than that found in the Attribute and Impact worksheets
<i>Currency Unit</i>	The associated unit of measurement applied to all COBie information other than that found in the Attribute and Impact worksheets
<i>Area Measurement</i>	The associated measurement method used to calculate spatial are measurement applied to all COBie information other than that found in the Attribute worksheet
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie date
<i>External Identifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem

<i>External Site Object</i>	For information originating in IFC models this information is an additional object identifier, allowing information about this Facility to be referenced back to the computer software that initially generated that information
<i>External Site Identifier</i>	same as above (n/a)
<i>External Facility Object</i>	For information originating in IFC models this information is an additional object identifier, allowing information about this Facility to be referenced back to the computer software that initially generated that information
<i>External Facility Identifier</i>	same as above (if not provided – n/a)
<i>Description</i>	A general text description of the facility (or n/a)
<i>Project Description</i>	A general text description of the project (or n/a)
<i>Site Description</i>	A general text description of the site (or n/a)
<i>Phase</i>	The designation of the phase of the project reflected in a given COBie data set (each COBie file is delivered step wise as the project progresses- can check if planning stage compare to design stage to see if room data is not been violated.)

COBie. Floor

<i>Name</i>	The name of the floor as it appears in other contract documents, such as design drawings
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Category</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are: “Floor”, “Roof”, and “Site”
<i>External System</i>	The name of the computer system generating the row of COBie data
<i>External Object</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie date

<i>External Identifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Description</i>	A general text description of the floor
<i>Elevation</i>	Elevation at the top of the floor structure. If allowable values are not specified by contract, the default value is measured as a relative value compared to the facilities datum
<i>Height</i>	Distance between top of floor structure to bottom of structure above. Typically applicable to rows having the Floor. Category of “Floor”

COBie.Space

<i>Name</i>	The Space.Name must match the value found on design drawings at the equivalent project stage of the current deliverable (space names must be unique and match contract documents)
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Floor Name</i>	The Space.Name must match the value found on design drawings at the equivalent project stage of the current deliverable
<i>Description</i>	The description of the space found design drawings at the equivalent project stage of the current deliverable
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie date
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from which it was developed in the name ExternalSystem
<i>Room Tag</i>	Signage provided for each space. Signange applied to doors, if different, is identified as Attribute records related to each applicable door. The information here is equivalent to that found in construction signage submittals.

<i>Usable Height</i>	Distance from the top of finished floor to bottom of ceiling. If there is no ceiling then this value must match Floor.Height
<i>Gross Area</i>	Total space area as specified in the design contract and calculated by the identified Facility.AreaMeasurement
<i>Net Area</i>	Usable space areas as specified in the design contract and calculated by the identified Facility.AreaMeasurement

COBie.Zone

<i>Name</i>	The name of the specific function performed by a group of spaces within a given Zone.Category
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Category</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are: “Circulation Zone”, “LightingZone”, “Fire Alarm Zone”, “ Historical Preservation Zone”, “Occupancy Zone”, and “Ventilation Zone” Note: (Must make sure that owner properties has been properly reflected in design and construction deliverables. Owner must be asked if the zones they want are to be modeled. Zones must be defined at the early stage of planning)
<i>Space Names</i>	A foreign key identifying the COBie.Space.Name. The plural designation of “SpaceNames” indicating use of a delimited list of Space.Name values is depreciated in COBie version 2.4
<i>External System</i>	The name of the computer system generating the row of COBie data
<i>External Object</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie date
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Description</i>	A general text description of the zone (n/a)

COBie.Type

<i>Name</i>	The Type.Name must match the value found on design drawing schedules at the equivalent project stage of the current deliverable
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Category</i>	The category of the type described by the COBie data set. If allowable values are not specified by contract, the default value for this information is the current OmniClass Table 23 – Products
<i>Description</i>	A general text description of the type. If description is present on design drawings schedules, this value must match
<i>Asset Type</i>	A classification of the asset within one row. If allowable values are not specified by contract, the default values are: “Fixed” and “Movable”
<i>Manufacturer</i>	During construction and handover phase: the Contact.Email of the installed product. However, during planning and design phase is not applicable.
<i>Model Number</i>	During construction and handover phase: the manufacture’s model number of the installed product. However, during planning and design is not applicable.
<i>Warranty Guarantor Parts</i>	During construction and handover phase: the Contact.Email of the party, or parties, responsible for replacement parts during the warranty period. This field does not apply in planning and design phase.
<i>Warranty Duration Parts</i>	During construction and handover phase: the length of the warranty period for replacement parts provided by the product manufacturer. However, during planning and design phase this is not necessary.
<i>Warranty Guarantor Labor</i>	During construction and handover phase: the Contact. Email of the party, or parties, responsible for labor costs during the warranty period. This field does not apply in planning and design field.

<i>Warranty Duration Labor</i>	During construction and handover phase: the length of the warranty period for labor repairs provided by the product manufacturer. However, during planning and design phase the entry of this information isn't relevant.
<i>Warranty Guarantor Unit</i>	The identification of the unit of measure associated with values found in Type. WarrantyDurationParts and Type.WarrantyDurationLabor. If allowable values are not specified by contract, the default values are: "month" and "year"
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie data
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that allows COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Replacement Cost</i>	During construction and handover phase: The manufacture's suggested retail price for this type. This information is not needed during planning and design phase.
<i>Expected Life</i>	During handover phase: the expected service life of the product type given the level of service within the facility. Meanwhile, during planning and design and construction phase, this field should left blank unless if conducting total cost of ownership studies.
<i>Duration Unit</i>	The identification of the unit of measure associated with value found in Type.ExpectedLife. If allowable values are not specified by contract, the default values are: "month" and "year"
<i>Warranty Description</i>	A general text description of the warranty
<i>Nominal Length</i>	An approximate measure of the bounding box surrounding the product type (if not required then n/a)
<i>Nominal Width</i>	same as above
<i>Nominal Height</i>	same as above
<i>Model Reference</i>	During construction and handover phase: the manufacturer's catalog or reference resource, such as website, where information about the installed product type may be found. During planning and design phase: not applicable

<i>Shape</i>	This information provides common properties that are associated to the building asset. If this value appeared in design schedule or product name plate, information should be required, otherwise should fill in as not applicable (n/a)
<i>Size</i>	
<i>Color</i>	
<i>Finish</i>	
<i>Grade</i>	
<i>Material</i>	
<i>Constituents</i>	
<i>Features</i>	
<i>Accessibility Performance</i>	
<i>Code Performance</i>	
<i>Sustainability Performance</i>	

COBie. Component

<i>Name</i>	The Component.Name must match the value found on design drawing schedules at the equivalent project stage of the current deliverable. For equipment scheduled by Type (and not Component) naming requirements to ensure unique names for every component shall be specified by contract (must be unique – by designer)
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Type Name</i>	A foreign key identifying the COBie.Type.Name
<i>Space</i>	A foreign key identifying the COBie.Space.Name. For components not contained in a single space, the value shall refer to the space from which the equipment is most likely to be maintained
<i>Description</i>	A general text description of the component
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data

<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie data
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Serial Number</i>	The serial number of the installed equipment. Component.SerialNumber must match the value found on installed equipment nameplates. This information does not apply during planning and design phase. (the rule of thumb is if there a name plate, there is also a serial number).
<i>Installation Date</i>	The date on which the product or equipment was placed in its final location. It is not applicable in planning and design phase.
<i>Warranty Start Date</i>	The date on which the product or equipment was first powered.
<i>Tag Number</i>	If a tag is required to be affixed to the product or equipment during construction, this value is the designation for this product or equipment found on the associated tag. However, during planning and design phase is not applicable
<i>Bar Code</i>	The bar code found on the installed product name plate. This information is not applicable in planning and design phase.
<i>Asset Identifier</i>	As alternative identifier for the specific component to be used as defined by associated contract

COBie.System

<i>Name</i>	The name of the specific function performed by a group of components within a given System.Category
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field

<i>Category</i>	The category of the system described by the COBie data set. If allowable values are not specified by contract, the default value for this information is the current OmniClass Table 21- Elements (Owner provides)
<i>Component Names</i>	A foreign key identifying the COBie.Component.Name. The plural designation of “ComponentNames” indicating use of a delimited list of Component.Name values is depreciated in COBie version 2.4 in favor of the use of a single row for each System.Component
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie date
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Description</i>	A general text description of the system

COBie.Assembly

<i>Name</i>	The name of the assembly identifies a type or component that owns or encloses other types or components
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Sheet Name</i>	The name of the computer system generating the row of COBie data
<i>Parent Name</i>	The name of the data object within the computer system that holds the data provided in a given row of COBie date (Outer box /shell of the assembly)
<i>Child Name</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from which it was developed in the named ExternalSystem (Inside the outer shell of assembly)

<i>Assembly Type</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are: “Fixed”, “Optional”, “Included”, “Excluded”, “Layer”, “Patch”, and “Mix”
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie data
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Description</i>	A general text description of the Assembly

COBie.Connection

<i>Name</i>	The name of the connection between the two parts identified a COBie data row
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>ConnectionType</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are: “Control”, “Flow”, “Return”, “Supply”, and “Structural”
<i>SheetName</i>	Specific references in this row as pertaining to COBie data in either the “Type” or “Component” worksheet
<i>Row Name 1</i>	A foreign key identifying the upstream COBie.Type,Name or COBie.Component.Name
<i>Row Name 2</i>	A foreign key identifying the downstream COBie.Type,Name or COBie.Component.Name
<i>Realizing Element</i>	The object, if appropriate, that creates the connection
<i>Port Name 1</i>	The name of the output connection port on Connection.RowName 1
<i>Port Name 2</i>	The name of the input connection port on Connection.RowName 2

<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie data
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Description</i>	A general text description of the Connection

COBie.Spare

<i>Name</i>	Name of item
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Category</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are: "Part", "PartSet", "Lubricant", "Other", "Spare", and "SpareSet"
<i>Type Name</i>	A foreign key identifying the COBie.Type.Name.
<i>Supplier</i>	A foreign key identifying the COBie.Contact.Name of the companies supplying spare parts
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie data
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Description</i>	A general text description of the Spare (on space which on-site spare are stored, logistic information about order Spare account and order quantity should be provided, ref to website catalogue (easily obsolete) where items can be found. Owner should include specification of properties to be added in the Attribute in specific classes of spares and consumable part
<i>Set Number</i>	A general text description, if applicable, identifying the manufacturer's spare part set number (note: it is the manufacture's number and not the supplier be given, so that FM could purchase these items from multiple sources)
<i>Part Number</i>	A general text description, if applicable, identifying the manufacturer's spare part numbers(not supplier's)

COBie.Resource

<i>Name</i>	The name of the resource that is required to be used on the project. This resource may be shared across multiple Jobs
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Category</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are: "Labor", "Material", "Tools", and "Training"
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie data
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Description</i>	A general text description of the Resource

COBie. Job

<i>Name</i>	The name of the job
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Description</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract the default values are: "Adjustment", "Calibration", "Emergency", "Inspection", "Operation", "PM", "Safety", "ShutDown", "StartUp", "Testing", and "Trouble"
<i>Status</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are: "Not Yet Started", "Started", and "Completed"

<i>Type Name</i>	A foreign key identifying the COBie.Type.Name
<i>Description</i>	A general text description of the job. There are typically three uses of this field. Firstly, the Job.Description may contain a general description of the job, with all steps outlined in an associated document. Secondly, the Job.Description may contain the complete set of numbered steps. To assist CMMS/CAFM vendors these steps should be delimited with a semi-colon. Finally, the Job.Description may contain one of several linked steps using the Job.TaskNumber and Job.Priors
<i>Duration</i>	Length of time required to perform the job
<i>Duration Unit</i>	Unit of time associated with Job.Duration
<i>Start</i>	The length of time, from the delivery of the COBie data set when the next occurrence of the Job should take place (days, weeks, month or years)
<i>Task Start Unit</i>	The unit of time associated with Job.Start
<i>Frequency</i>	The length of time between each service period. [Example: 6]
<i>Frequency Unit</i>	The unit of time associated with Job.Frequency (days, weeks, months or years) [Example: months]
<i>ExternalSystem</i>	The name of the computer system generating the row of COBie data
<i>ExternalObject</i>	The name of the data object within the computer system that holds the data provided in the given row of COBie data
<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Task Number</i>	If Job.Description contains a series of individual operations, this identification non-zero integers used to reference each step. Job.Task.Number becomes the third part of the compound key, if Job.Description contains a series of individual operations; otherwise it is ignored. The first Job.Desription in the series shall have a value of “0” and provide the general information about the job whose tasks follow

COBie.Document

<i>Name</i>	The name of the document
<i>CreatedBy</i>	The Contact.Email of the person or company creating or updating a row of COBie data
<i>CreatedOn</i>	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
<i>Category</i>	A classification of the type of the information contained within one row. If allowable values are not specified by contract, the default values are “Preconstruction Submittals”, “Shop Drawings”, “Product Data”, “Samples”, “Design Data” , “Test Reports”, “Certificates”, “Manufacturer Instructions”, “Manufacture Field Reports”, “Operation and Maintenance”, “Closeout Submittals”, “Contract Drawings”, “ Design Review Comment”, “Specifications”, “Request for Information”, “Client Requirement”, “Contract Specification”, “Contract Drawings”, “Contract Modifications”, and “Punch List Items”
<i>Approval By</i>	A classification of the type of information contained within row. If allowable values are not specified by contract, the default values are: “Owner Approval”, “Contractor Certified”, and “Information Only”
<i>Stage</i>	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are : “As Built”, “Submitted”, “Approved”, “Exact Requirement”, “Maximum Requirement”, “Minimum Requirement”, and “Requirement”
<i>Sheet Name</i>	Specifies references in this row as pertaining to COBie data in any other COBie worksheet
<i>Row Name</i>	A foreign key identifying the row in the associated Document.SheetName
<i>Directory</i>	The path name to file. If COBie is delivered on a portable media the directory should be there relative path name from the COBie file to the referenced document. If the COBie file references documents that are available on the World Wide Web, the complete path name to the document including the Internet protocol used shall be

	included. In all cases the document directory should include the trailing "/" of all path names
File	The name of the file, with file extension, that contains the associated information
ExternalSystem	The name of the computer system generating the row of COBie data
ExternalObject	The name of the data object within the computer system that holds the data provided in the given row of COBie data
ExternalIdentifier	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
Description	A general text description of the description
Reference	If different from the Document.Directory/ Document.File this is a reference to documents provided from manufacturer's catalogs or websites

COBie.Attribute

Name	The name of the attribute
CreatedBy	The Contact.Email of the person or company creating or updating a row of COBie data
CreatedOn	The date on which the information provided in a row of COBie data was created or updated by the person or company identified in the CreatedBy field
Category	A classification of the type of information contained within one row. If allowable values are not specified by contract, the default values are: "As Built", "Submitted", "Approved", "Exact Requirement", "Maximum Requirement", "Minimum Requirement", and "Requirement"
Sheet Name	Specifies references in this row as pertaining to COBie data in any other COBie worksheet
Row Name	A foreign key identifying the row in the associated Attribute.SheetName
Value	The value of the attribute
Unit	The unit defining the value of the attribute
ExternalSystem	The name of the computer system generating the row of COBie data
ExternalObject	The name of the data object within the computer system that holds the data provided in the given row of COBie data

<i>ExternalIdentifier</i>	The unique identifier of the identified ExternalObject that would allow COBie data to be matched back to the data from the which it was developed in the name ExternalSystem
<i>Description</i>	A general text description of the attribute
<i>Allowed Values</i>	A comma delimited list of one or more allowed values