CHALMERS

Utilization of BIM from Early Design Stage to facilitate efficient FM Operations

Master of Science Thesis in the Master's Programme Design and Construction Project Management

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Department of Civil and Environmental Engineering
Division of Construction Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2013
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TO MY MOTHER

MASTER'S THESIS 2013

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ABSTRACT

Utilization of BIM beyond design and construction is extremely important in the pursuit to provide value at owner's organization through efficient FM operations. Currently, BIM utilization at FM stage is not fully realized. This study has explored how to bridge the existing gap by bringing the facility operations in design stage.

In order to comprehend fully BIM utilization from early design stage and the existing gap between design and operations, a case study has been conducted at Liljewall Arkitekter which is one of the competent architectural companies in Sweden.

Semi structured interviews were deplored in order to explore the type of inquiries addressed by this study. Four interviews with prominent BIM managers from different architectural companies in Sweden and Denmark were conducted. Three big FM companies and one prominent researcher were interviewed. The architects and owner's experience and opinions about BIM utilization from early design stage for efficient FM operations provided the base of the findings and the conclusion.

The main findings of this study are discussed. To provide a BIM model for efficient FM, it is extremely important to understand BIM support areas for FM and information needed to be applied in a BIM model for those particular areas. Holistic collaborative design processes, and sustainability performance analysis are necessary. Moreover, simplicity of information management and financial returns are motivational triggers for owners to adopt BIM in their processes. BIM FM integration is viewed in the light of potential benefits provided by BIM, and challenges throughout the entire project lifecycle.

This study concludes by calling upon a holistic integration of people, processes, and business systems through BIM in order to reach the optimum performance of BIM FM integration.

Key words: BIM, Facility Management (FM), Architecture, Sustainability, AEC/FM industry, Motivation, Design

Contents

Preface

This thesis is about BIM a new digital technology in construction which provides standardized, efficient and consistent information throughout a project life cycle.

The adoption of BIM at design and construction is outstanding, but application of BIM at later stage of the project lifecycle is yet to be realized. This thesis focused more on BIM application at facilities management by bringing the operation in early design stage.

The work outlined in this study was carried out in the department of Civil and Environmental Engineering at Chalmers University of Technology Göteborg, Sweden. This research has been conducted and was supervised by Dr. Petra Bosch-Sijtsema from January, 2013 to May, 2013.

This study has been carried out in collaboration with Liljewall Arkitekter an architectural consultancy company operating in Sweden and Latin America. The company goal was to extend the provision of BIM services in facility management phase.

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Göteborg May 2013

Clifford F Hungu

Notations

BIM	**Building Information Modelling**
FM	**Facilities Management**
AEC/FM	**Architecture – Engineering –Construction / Facilities Management**
CAD	**Computer Aided Design**
ICT	**Information Communication Technology**
FMS	**Facilities Management**
CAFM	**Computer Aided Facilities Management**
CMMS	**Computerized Maintenance management Systems**
BMS	**Building Management System**
EMS	**Energy Management System**
IFC	**Industry Foundation Class**
COBie	**Construction Operation Building Information Exchange**
LEED	**Leadership in Energy and Environmental Design**
BREEA:	**Building Research Establishment Environmental Assessment Method**

1 INTRODUCTION

The impact of BIM on architectural practice is significant to the extent that it raises new ways and processes of delivering designs, construction and facilities management services. Clients are not only demanding buildings to be designed and delivered on time, cost efficient and with high quality but also services beyond design and construction should be provided (Clayton, et al 1999).

The adoption of technologies, especially BIM and building management systems, provides a consistent set of solutions beyond design and construction by supporting the collaborative creation, management, dissemination, and use of information through the entire product and project lifecycle. Furthermore, this provides a new approach to processes through more effective integration of people, processes, business systems, and information (Shen et al, 2009).

Extension of BIM beyond the initial stages of a construction project's life cycle for maintenance and operations stage by creating a single repository of information is extremely important in order to provide a competitive advantage for facility management organization. Bringing the operations into the design stages as a key strategy to collect reliable and accurate information can bridge the gap prevailing in current architectural practices.

In the current practice operation and maintenance phase, are viewed as separate entities and less effort is exerted towards achieving proper information in the pursuit of developing BIM models for the facility management (FM) stage. This process however is at the infant stage.

The benefits offered by BIM at the FM stage are yet to be realized at a mature level. The development and implementation of BIM has been fruitful in architectural practice not only for 3D modelling but also 4D, 5D and hazard and risk analysis (Meadati, 2009). The main reason that hampers utilization of BIM during operations and maintenance phase includes unavailability of proper information to develop 3D as-built models and lack of integration in the development process especially from the initial project's life cycle.

De Silva (2011) argued that, facilities managers can contribute significantly in the delivery of effective decisions based on their practical experience on maintainability problems that they face during the operation phase. It is therefore paramount to involve FM in the early design phase to bring attention to future maintainability issues in design. The current 2D as-built drawings for example, are proved to be inefficient during operations phase.

This research has explored necessary information to be put in a BIM model during early design stage to facilitate efficient FM operations. Furthermore, the research has explored the motivational factors among FM for the development of 3D as-built models. Owners are interested in utilizing 3D as-built BIM models as a single repository that provides proper and accurate information for the operation.

It is evident as well that, owners are aware of the benefits of utilization of BIM at the later stage of project's life cycle. Many companies are striving to formulate strategies to utilize BIM in their operations.

FM companies in Sweden currently focus on achieving sustainability goals by using a-well coordinated design and BIM 3D simulation aimed at assessing performance of facilities during design stage. Some have managed to reduce energy consumption, reduced waste and increased productivity.

More benefits, however, could be achieved by companies through use of performance assessment at commissioning stage and throughout the operation and maintenance lifecycle. Moreover, the proliferation of building management systems nowadays, if linked with BIM models, will provide untapped resources that improve the designs and operation of facilities. O'Sullivan et al (2004) stresses that currently building performance assessment is done at the design stage of a building through the use of simulation tools, some assessment is carried out at the construction and commissioning stage by means of commissioning tests, but afterwards there is little or no assessment carried out in the operation and maintenance phase of a building's life cycle.

Bringing the operation in design stage can definitely bridge the existing gap of BIM application beyond design and construction. The study has attempted to bridge the gap by interviewing architects and facility managers. The findings show that, effective multidisciplinary collaboration during design stage, information addressing the BIM support areas for FM, simplicity to put access and update information in a BIM compliant FM system is necessary.

1.1 Statement of the problem

From an architectural point of view, there is a prevailing knowledge gap about areas where BIM models can be fully utilized to enhance the efficiency of FM processes. It has been difficult for architects to provide design solutions and data that facilitate the efficiency for FM functions. Recently, researchers have explored potential benefits of BIM for FM functions which provide information that ultimately bring value to the facility owners. The optimum data for FM operations can be fully comprehended from early design stage right across the whole spectrum of a project's life cycle. This research will investigate how integrated BIM based design solutions have to be delivered for efficient FM functions.

1.2 Purpose

The purpose of this research is to analyse how BIM can be applied from an early design stage and throughout the entire project's life cycle to support Facility Management operations.

1.3 Main Objective

To investigate and understand the main basics of integrated BIM based designed techniques from an architectural point of view and facility managers on how it can be used to facilitate efficient FM operations.

To understand managerial aspects and proper framework for efficient utilization of BIM based Facility Management (FM) that support sustainable building performance.

1.4 Specific objectives

- To explore how BIM models should be delivered from early design to FM stage to facilitate FM operations.
- To explore information needed during Planning, Designing, and Operations (PDO) processes.
- To explore potential areas that are beneficial for FM where BIM can provide value in terms of sustainability, etc.
- To explore motivational triggers for FM companies to change their processes.

1.5 The main research question

How can BIM be applied effectively from an early design stage to support the efficiency of FM operations?

Sub research question based on specific objectives are;

- How can BIM models be applied from early design to facilitate FM operations?
- What information is needed during planning and design processes important for BIM models?
- What are the potential areas that are beneficial for FM where BIM can provide value
- What are motivational triggers towards process change for FM firms?

1.6 Delimitation

Due to the limited time and resources this research will not examine technically the practical case study. The research understands that the BIM FM integration in Sweden is still at infant stage and there is a need for practical design case study for both architects and owners. This research will pave way on how to approach the design solutions and application of BIM for facility management.

2 THEORETICAL FRAMEWORK OF REFERENCES

Under this chapter theories about BIM, architectural application of BIM, and FM are discussed. This theoretical framework provides previous researches in the area of application of BIM from early design stage to the operation of facilities. Terms and up to date knowledge about BIM are reviewed in the light of research questions. Furthermore, the theoretical framework stands as a background for analysis and discussion to draw conclusion of this research.

2.1 General about BIM, Benefits and Risks

2.1.1 Background

Building Information Modelling (BIM) has gained popularity in AEC/FM recently but was first coined over a decade ago to distinguish the information rich 3D modelling from traditional 2D drawings. It is widely adopted in the building industry due to its ability to correct error in early design stage as well as aid in accurately scheduled construction, construction sequencing, clash detection and an advocate design alternatives and facilitates easy solutions for complex projects (Kubba, 2012, Azhar, et al, 2011),

BIM has evolved from the CAD development to generate integrated management of multi-disciplinary information that is produced in the process during the project's life cycle. Yoon et al (2009), argues that, adopting BIM could make the better use of variety of information in the field of architecture and several attempts have been made globally.

Despite rather rapid acceptance of benefits of BIM, the implementations of BIM across the globe to cover the whole project's life cycle have not been adopted to its full potential (Becerik-Gerber, et al., 2010).

2.1.2 What is BIM?

Eastman et al (2011) define BIM as a modeling technology and the associated set of processes to produce, communicate, and analyze building models. Building models are characterized by:

- Building components that are displayed as digital representations (Objects) that carry computable graphic and data attributes that identify them to software applications, as well as parametric rules that allow to be manipulated in an intelligent fashion.
- Components that include data that describe how they behave as needed for analysis and work processes, for example, quantity take off, specifications, and energy analysis.
- Consistent and non-redundant data that changes to component data are represented in all views of the component and the assemblies of which it is part.

- Coordinate data such that, all views of the model are represented in a coordinated way.

BIM is a fundamentally different way of creating, using, and sharing building life cycle's data. This involves the whole cycle of BIM stakeholders including owners, architects, engineers, and designers.

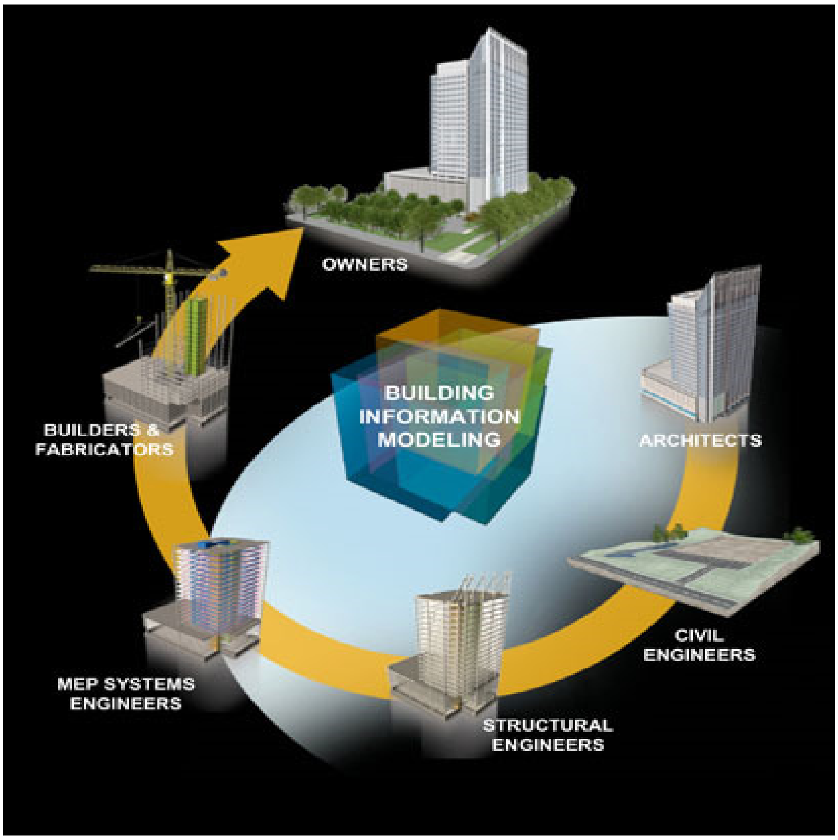

Figure 1: Complete cycle of BIM stakeholders; (source: Smartrevit.com)

Jerry Laiserin, a well-known future technologist and industry analyst define BIM as;

> *"BIM is a process of representation which creates and maintains multidimensional data-rich views throughout a project a project life cycle to support communication (sharing of data); collaboration (acting on shared data); simulations (using data for predictions); and optimization, (using feedback to improve design, documentation, and delivery)"* (Mihindu and Arayici, 2008).

The National Building Information Model Standard (NBIMS) define BIM as;

> *"BIM is the virtual representation of the physical and functional characteristics of a facility from inception onwards. As such, it serves as a shared information repository for collaboration throughout a facility life cycle."*

National Institute of Building Science (NIBS) defines BIM as;

"a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle, defined as existing from earliest conception to demolition'.

Generally, BIM technology allows an accurate virtual model of the facility to be constructed digitally. Completed computer generated models contains accurate and a well-defined geometry and pertinent digital data required to facilitate the construction processes such as, construction sequencing, fabrication, procurement activities, etc, which are necessary to realize the final building.

BIM programs today are designed applications in which the documentation flows from and is a derivative of the process, from schematic design, construction and facilities management (Kuba, 2012).

2.1.3 Common BIM Platforms

There are several BIM platforms available on market nowadays. Most of the BIM platforms available today are targeted towards service providers, such as architects, engineers, contractors, and fabricators; they are not specifically targeted for owners (Eastman et al, 2008). The available platforms have variety of tool functionality marketed to different or multiple users.

2.1.3.1 Revit

Revit is considered to be the best-known and current market leader for BIM in architectural design (Eastman et al, 2011). This platform was introduced to the market by Autodesk in 2002. This platform is a family of integrated products that currently includes Revit architecture, Revit structure, and Revit MEP.

As a tool: Revit as a tool provides an easy to use interface with drag-over hints for each operation and smart cursor.

As a platform: it has the largest set of associated applications including; Facility Management: AutoDesk FM Desktop, Archibus (IFC) (Eastman et al, 2011).

2.1.3.2 Bentley System

Bentley system offers a wide range of related products for architecture, engineering, infrastructure, and construction.

As a tool: As a building modeling and drawing production tool, Bentley has a standard set of predefined parametric objects

As a platform: Bentley platform applications are file-based systems, meaning that all actions are immediately written to a file and results in lower load memory

Bentley offers a wide range of building modeling tools, dealing with almost all aspects of the AEC industry. It supports modeling with complex curved surfaces (Eastman, et al, 2011).

2.1.3.3 ArchiCAD

ArchiCAD is the oldest and continuously marketed BIM platform for architectural design.

As a tool: ArchiCAD user interface is well crafted with smart cursors, drag over operator hints and context sensitive operator menus. Its model generation and its ease of use is loved by its loyal user base. View generation of drawings is automatically managed by the system; every edit of the model is automatically placed in document layouts, details, sections, and 3D images can be easily inserted into layouts.

As platform ArchiCAD has links to multiple tools in different domains including;

Facility management; OneTools and ArchFM

Furthermore, ArchiCAD has strengthened its interaction with IFC and provides good bidirectional exchange of data. (Eastman et al 2011).

2.1.4 Adoption of BIM in AEC/FM Industry

According to Kubba (2012), BIM is now used widely all over the world. Some countries such as the United States, the United Kingdom, France, Germany, Finland, Denmark, Australia, Malaysia, and Singapore have achieved remarkable advancement in BIM deployment. Moreover, BIM has gained increasing attention internationally in the building industry and organizations involved in architecture, engineering, construction and facilities management/owners (AEC/FM). Several efforts have been made in the global arena to ensure standards of this digital information are shareable, are interoperable among different stakeholder's information systems, are based on accepted open standards, and are definable in contract language.

Unlike, traditional 2D CAD, in architectural drawings that consists of lines, 3D CAD (object based) use building components such as walls, pillars, floors, doors, windows and many other building components to make architectural drawings. Moreover, various properties are embedded, supporting extensive types of information such as geography, materials, space, typology, and user information (Yoon, et al, 2009).

Adopting IT and related technologies in the field of architecture has increased efficiency and productivity. BIM in particular, as modelling technology in the process to produce, communicate, and analyse design solutions, is seen as an enabler of improving productivity.

Application of BIM which is based on building component information throughout the project's life cycle is expected to enhance the current productivity level of project management. Furthermore, there is general consensus on the application of BIM from early design stage to operation and maintenance phase (Yoon, et al, 2009).

BIM is fundamentally bringing a paradigm shift in the way AEC project teams work together to communicate, resolve problems, and build efficient design, production and cost effective operations. In today's highly competitive construction market, it is no longer sufficient to execute a project in the fragmented nature. BIM has provides an opportunity for collaborative design and an effective interoperable object database covering the whole project's life cycle (Plume et al, 2007, Kubba, 2012).

The use of BIM has flattened the traditional the traditional hierarchical management structure and reduced the fragmented nature of AEC/FM industry through collaborative processes (Mihindu and Arayici, 2008)

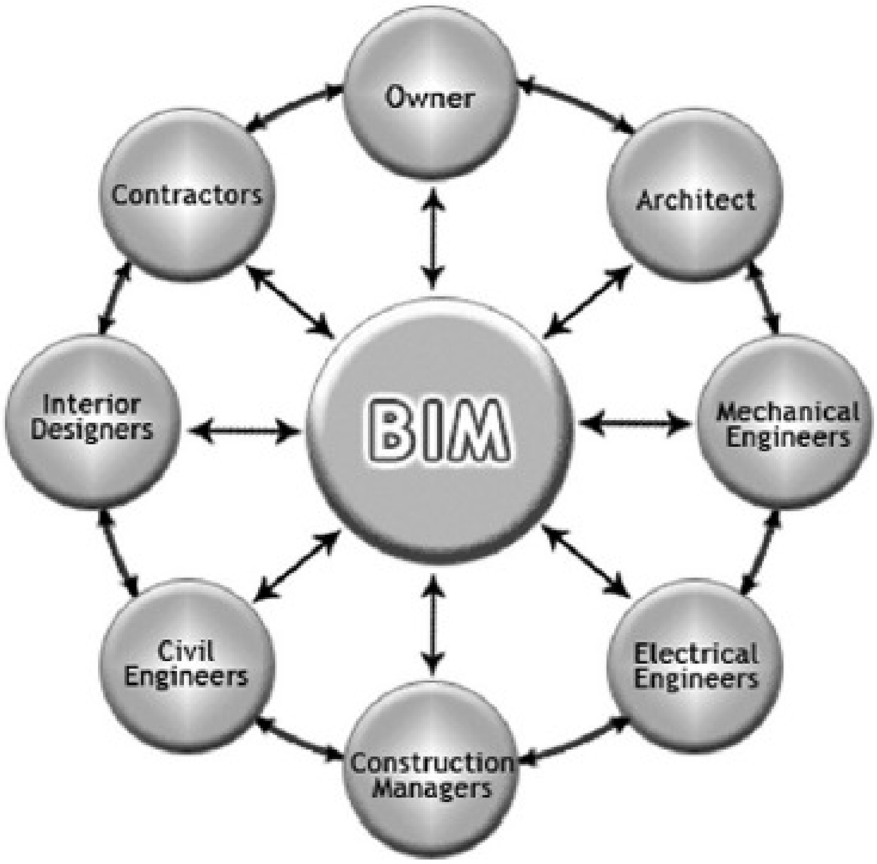

Figure 2: Interlinking relationship of BIM with various stakeholders (Source, Kubba, 2012)

2.1.5 BIM Benefits

The advent and increased awareness of using BIM in the building industry has triggered so many researches on relevance of information related to its use and implementation. There are numerous case studies (Eastman et al. 2011, Khemlani 2004, Kymmell 2008, Becerik-Gerber 2010, Kam et al. 2003) that provide unabridged evidence to support the idea that the use of BIM makes the building process more efficient and effective.

The following benefits have been identified so far: accurate and consistent drawing sets, early collaboration, synchronized design and construction planning, clash detection, model driven fabrication and greater use of prefabricated components, support of lean construction techniques, and streamlined supply chain management (Becerik-Gerber, 2010, Campbell, 2007).

Kubba,(2012), Becerik-Gerber & Rice, (2010), identified the following most significant benefits of BIM:

- Lower net costs and risks for owners, designers, and engineers.
- Development of a schematic model prior to the generation of a detailed building model, allowing the designer to make a more accurate assessment of the proposed scheme and evaluate whether it meets the functional and sustainable requirements set out by the owner; this helps increase project performance and overall quality.
- Improved productivity due to easy retrieval of information.
- Improved coordination of construction documents.
- Coordination of construction, which reduces construction time and eliminates Change Orders.
- Reduced contractor and subcontractors' costs and risks.
- Accurate and consistent 2D drawings generated at any stage of the design, which reduces the amount of time needed to produce construction drawings for the different design disciplines while minimizing the number of potential errors in the construction drawings process.
- Increased speed of project delivery.

2.1.6 Challenges and Risks

Kubba (2012) identified several most anticipated challenges and risk that confront a BIM project which are;

- Utilization of BIM to provide projections of value, cost saving, and efficiencies may vary from the actual outcome, so BIM liability is not addressed.
- Ownership of the BIM model is not adequately addressed
- BIM collaboration does not address the responsibility of each part which may result to unexpected inefficiencies.
- It is not clear on what are mandatory deliverables and information reliance from each part in the process of applying BIM model.
- Legal issues addressing for example wrong information related to BIM leading to faulty in the operation are not clear.

From the challenges and risks mentioned above, Kubba (2012) suggests that it is extremely important to identify who or what holds key project details. Whether it is the architect, general contractor or the facility owner, with that ownership can contribute to the reward or risk.

Kubba (2012) pointed out further that identifying these legal risks should assist the parties in addressing the challenges available in relation to utilization of BIM, particularly since there are few standard form contracts or BIM guidelines currently on the market that adequately address them.

It is also emphasized that contracts play an important role in defining deliverables, interactions with project stakeholders, and risk obligations for in building projects (Kubba, 2012).

2.1.7 Complete Project Lifecycle and BIM Application

Building project lifecycle stages include planning, design, construction, and operation and maintenance phases. Each stage encompasses a lot of information to be exchanged among various project participants. This information includes graphical and non-graphical data. The graphical data are mainly 2D and 3D drawings and non-graphical data includes other project documents. BIM is practically developed to integrate all information at each stage into a single repository that can easily be deposited, retrieved, edited and shared (Meadati, 2009, Bullinger et al., 2010).

Currently BIM is adopted in architectural services from early design stage, to cover the following services aimed to clients; programming, conceptual design, detail design, simulations and analysis, documentation, fabrications, construction 4D and 5D, and construction logistics. An application of BIM at operation and maintenance phase is not yet realized to the fullest potential. BIM 4D deals with time allocation and construction sequence scheduling presentations, while 5D deals with cost and simulation of construction, focusing on building sequence, cost, and resources. There are BIM platforms on the market that help designers create a 3D digital model of a building while also providing 4D and 5D. Incremental data input by all team members creates a feedback loop that streamlines project delivery.

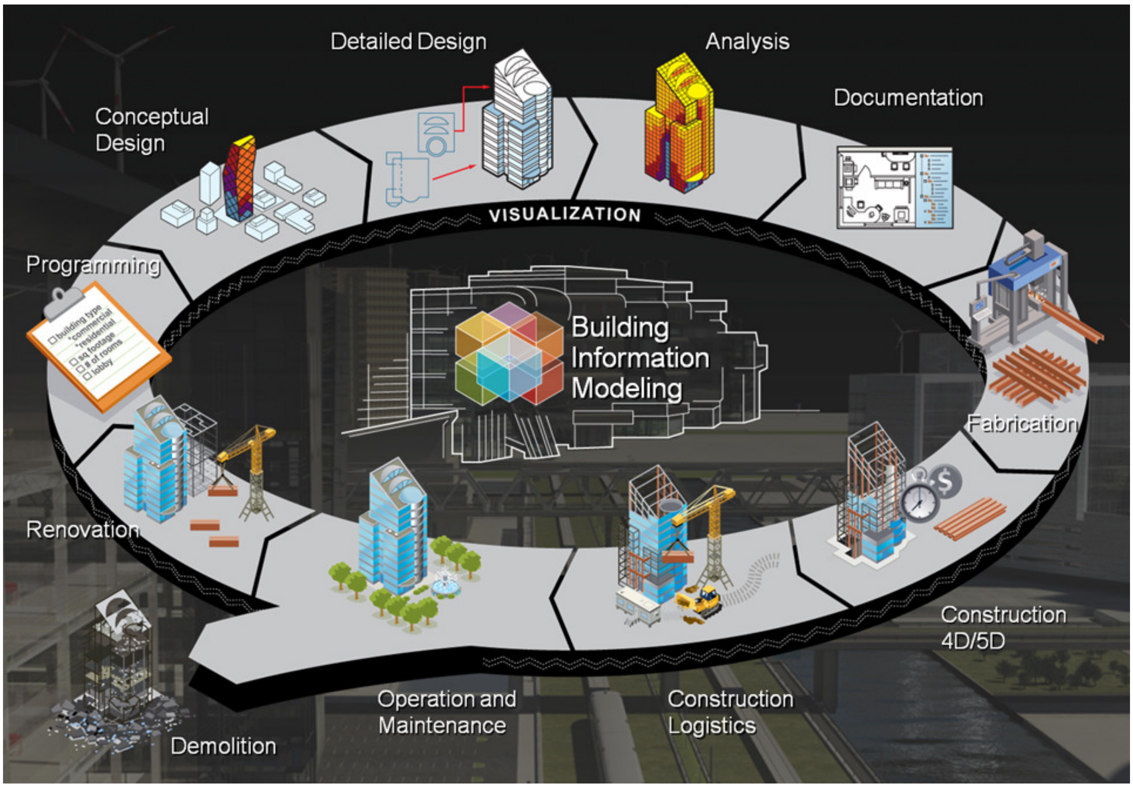

Figure 3: BIM project's life cycle application (Source: smartrevit.com)

2.2 BIM IN ARCHITECTURAL PRACTICE

Building Information Modeling (BIM) has brought a paradigm shift in architectural practices. The adoption and growing awareness of BIM utilization has led to a methodological shift in Architecture-Engineering-Construction (AEC) and FM industry, towards new ways of delivering services. It is currently vivid that companies are moving towards new ways of delivering designs, construction and facility management services, through proper sharing and management of information systems covering the entire project's life cycle (Jung, et al, 2010; Johnston, et al, 1998). Penttilä (2007), emphasized more that despite BIM being used as a tool and technology, there is a widening of spectrum of requirements posed by society due to accelerated changes in the professional environment which is reforming a new profile of architectural profession"

Architectural professions with their counterparts' designer's professional organization see the need and are striving towards adapting to new changes brought by Information Communication Technology (ICT). Moreover, new professional roles have emerged, particularly, BIM managers or ICT leaders, and coordinators to, cope with rapid changes of professional services (Penttilä, 2007).

The design processes to cope with new trends in society and increased focus on sustainability, life-cycle costs, global environmental, and value for money issues for instance, has become the highest agenda in construction business systems. This depicts very high uncertainties to achieve project goals from an early design stage, which ultimately calls upon new ways of design and delivery of projects (Moum, 2010).

The trend now is increasingly towards not only provision of quality buildings at reasonable price and within time, but also services beyond design and construction being provided. That means clients require the full range of services covering the whole spectrum of a project's life cycle. Clayton, et al. (1999), refers to this as a shift from focus on project delivery to a focus on service delivery.

BIM facilitates a multidisciplinary approach of analysis on complex problems that require fullest exploitation of multidisciplinary solutions from early design stage and throughout the project's life cycle. The utilization of Building Information Modeling is proved to be a success in the improvement of fruitful design processes through multi-disciplinary collaborations to achieve good architectural design solutions (Moum, 2010).

It is paramount to really comprehend the operation of the facility during early stages of facility development, with consideration to knowledge and previous problems experienced in the past. This will help to lower the cost of operation. Maintenance and Operation of facilities contribute up to 5 times the initial capital expenditure of an investment (Ishizuka et al, 1992).

Under traditional architectural practice, architects have difficult knowing which choices to make when clients ask for a design data that suits into theirs IT system.

Current studies about usability of BIM for the operations phase and commercially available technologies focus on transferring information from the design and construction phase to the operations phase by enabling creation and capturing of digital facility information throughout the facility lifecycle (Akcameter, et al, 2010).

2.2.1 The role of the Architect in the BIM based Design Processes

The main objective of architectural practice is to provide design services of buildings to meet the requirements of the client, end user, and the community (Coates et al 2010).

Architects play the leading role in the administration of the BIM based design processes from an early design stage. They have to manage extensive information from clients to determine the design intent and provide design solutions of a particular building project.

According to Pantitila (2007), the nature and essence of the information normally availed to architects is heterogeneous and possesses a rich and complex information structure to be managed closely.

Therefore, architects manage not only information about the design and building process but also about user organization. BIM technology can facilitate managing the complexity of early design stage to enhance development of design dialogue (Coates et al 2010).

The most important architectural design ideas, design parameters and principles are created from an early design stage. This makes architects leader and integrators in the process.

Furthermore, architects alone cannot provide a whole range of design solutions. Moum (2010) insist on the design as a social creation where building are collectively conceived and delivered, a reason which make architect play a leading role in the BIM based design process. Moreover, architects have to deal with all predictable and unpredictable issues which have impact on the project success or failure in a collective manner.

2.2.2 BIM in Early Design Phase

Numerous researchers from the past few decades have explored the potential offered by integrated 3D as opposed to traditional 2D based design. BIM is now employed to strengthen the interaction of design teams and to facilitate management through a common standard of sharing information and data management from an early design stage. Holzer (2007), poses a question on how far down the track in the design process should we start using BIM? Can a single BIM model assist in the design process from early design stage to operations?

Holzer (2007), argues that BIM by itself is not enough to provide a good design but is rather a tool that can be employed from early design stage whereby the degree of project's uncertainties is high to support, to define, weigh, and prioritize aspects of design, in a collaborative process.

Decisions are made from early design stage, which ultimately have significant impact on the project outcome and facilities management.

Despite growing awareness of BIM benefits and management requirements in the AEC/FM industry, BIM based design methods have not been adopted so much in the early design phase (Pentitila, 2007). It is predominantly the architects who play the leading role during the process of design to determine the design intent, methodology and how BIM can be employed efficiently.

However, there is a gap and lack of integration in a common architectural practice between building designers, experts and available tools in early design stage regarding performance analysis during operation stage, which leads to extensive inefficiency afterwards in facility management (Schlueter, et al 2008).

Most of the research findings on the current development of computer IT applications in architecture reveal impressive results especially in the area of advanced geometry, and computer-aided performance analysis and production methods. In all aspects, applications in the early design stage address the domain of the architect in the process. Schlueter, et al. (2008), however argue that in the traditional architectural work flow, performance assessment is mostly done subsequent to the architects design. It is done by the expert, in most cases the engineers.

A lot of expert software exists for every type of simulation of specific and over all performance of buildings and building components. Available simulation tools are primarily aimed at the expert and make explicit expert knowledge necessary to input the data needed, run the simulations and interpret the results. The main challenge is that, in the early design stages, where architects play a major role, most of the data is often not available. Architects are mostly non-experts considering performance simulation. This information, if defined during the design, can be used as input to evaluate building performance. The amount of information and the complexity of its dependencies makes involvement of all professionals in the process necessary.

One of the key goals of BIM is to ensure that the collaboration between stakeholders in the building process becomes more efficient. The strength of the BIM model to store relevant design information at every step in the design process makes the design process more efficient. The model serves as an interdependent, multi-disciplinary data repository making new approaches on integrating performance analysis into design possible. Parameters defined during the design process can be accessed and edited during the design process and utilized for the performance analysis of the facility (Schlueter, et al 2009).

Recently, studies in BIM used for the operation phase and available technologies focus on the transferring information from design and construction stage to the operation phase by enabling creation and capturing of digital facility information throughout the facility lifecycle. Akcameter, et al. (2010), stresses the possibility of using Information Communication Technologies (ICT) systems (in this case BIM) to retrieve past project information quickly. The increased interest in both building and facility management information and the increased interest in both building and service maintenance value throughout the project life cycle have brought a greater awareness of the value of accurate, accessible information. In this reason, utilization of BIM in early design processes has greater influence on economic efficiency of projects especially during operation and maintenance phase by providing accurate and easily accessible information (Eastman et al, 2011).

2.2.3 Early Building Performance Analysis using BIM

It is paramount to consider building performance from early design stage by using BIM simulation possibilities available. Yoon et al (2009), emphasized that the prediction of building performance from early design stage, for example designing low energy building provide improvement in the economics of buildings due to reduction of unnecessary consumption during operations.

The underlying assumption is basically proven in practice to be of utmost importance, since building performance can fully be analyzed during early design stage in order to meet and exceed the design intent. Improving the building performance consequently improves the life cycle cost of building economics, and high quality designed indoor workspace where people interact in different ways. This is crucial since have an impact on the effectiveness of the organization and the well-being of the employees (Lindahl, 2004).

The advent of BIM along with the emergence of global challenging issues like sustainability, and life cycle cost of buildings, necessitates architects to incorporate the basic performance analysis from an early design phase. That is special quality analysis, energy performance, social impact and environmental performance into its framework by further developing the concept of virtual space and virtual building, Kam and Fischer (2004).

A well-managed integrated BIM system can facilitate collaboration and communication processes between project participants in an early design phase to effectively provide a well performing building during operations.

2.3 COLLABORATIVE DESIGN AND DELIVERY PROCESS

Collaboration is the best approach in the pursuit of successful application of BIM in a project (Eastman et al, 2011).

The fragmented nature of the building industry, its complexity and multiple phases of the construction life cycle make the collaboration of multidisciplinary teams to be very important. The involvement of multidisciplinary teams, (Owners, architects, consultants, engineers, contractors, subcontractors, suppliers, etc) and the use of heterogeneous ICT tools provide an opportunity to achieve efficient and effective collaboration (Shen, et al, 2009). Checking for maintainability of the facility for instance should be fully addressed by the design team from early design stage.

Architects and owners should be at the center of the process to manage all information (See figure 4 below)

Kim et al. (2004) emphasized that through collaboration, project teams quickly generate design options with relevant building systems alternatives and other works that add value to the client. Moreover it is emphasized that user's ability to understand the design is enhanced to make necessary early and more efficient decisions. For instance, early environmental impact analysis, early building performance such as, energy and thermal building performance helps to foster effective communication among end users, owners, and project teams.

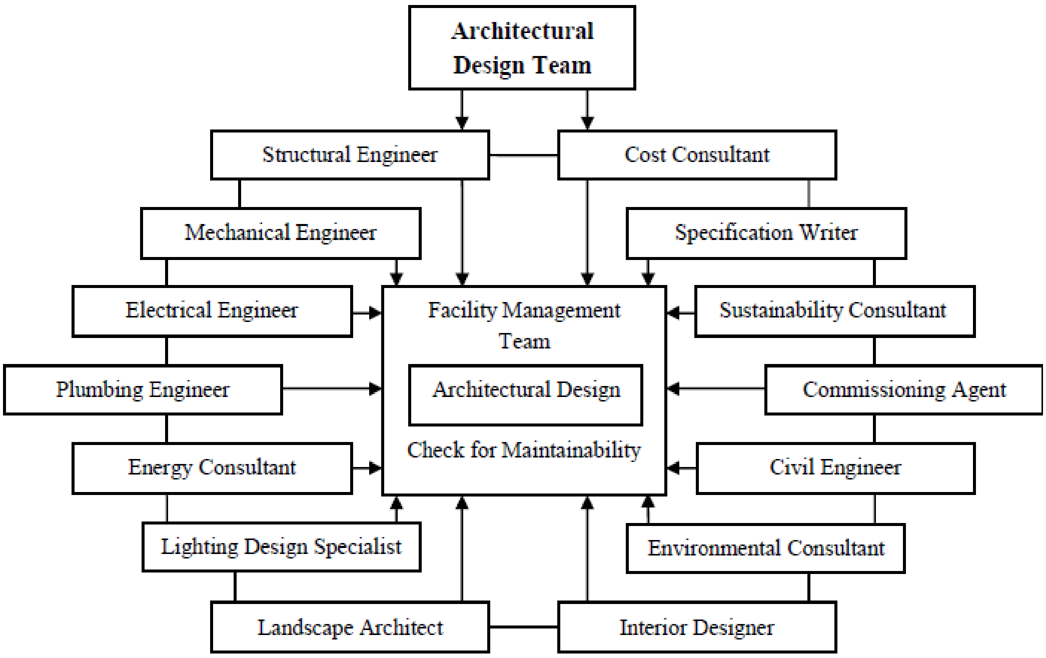

Figure 4: Desired BIM FM design integration, (source: Mohammed and Hassanain, 2010)

Furthermore, effective collaborative design process is said to be more dependent on the richness of the shared model, and the quality of the design analysis being undertaken to support the early decision making, to resolve issues through negotiation and evaluation (Plume et al 2007).

2.4 FACILITY MANAGEMENT INTERGRATION IN DEVELOPMENT PROCESS

This chapter will integrate the theories about facilities management processes, technologies applied to manage information, and the way BIM can be adopted in the operation phase of a building.

2.4.1 General about FM

Numerous researchers have attempted to define FM differently; Becker (1990) defined FM as;

"*the discipline responsible for coordinating all efforts related to planning, designing, and managing buildings and their systems, equipment and furniture to enhance the organization's ability to compete successfully in a rapidly changing world*".

Alexander (2009), defined FM as;

"the integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities"

Moreover, Moore and Finch (2004) defined FM as a professional discipline that involves;

"the development, coordination, and management of all of the non-core specialist services of an organization, together with the buildings and their systems, plant, IT equipment, fittings and furnishings, with the overall aim of assisting any given organization in achieving its strategic objectives"

In a traditional way, facilities management tasks begin as soon as handing over of the building after construction and operations take place, and continue throughout the life cycle of the building. The main role of the facility manager is to assist the organization to meet its strategic business goals and objectives. They have a close focus on the physical facility as a process for coordinating the physical workplace, technology, and people in daily pursuit to meet primary and strategic fit of the organization (Mohammad and Hassanain, 2010); Jensen, 2010).

In order to meet and exceed the facility management goals, Venlande et al (2008) emphasized that the successful facility manager needs a range of skills to be able to develop innovative strategies for the organizations they work in. They need powerful tools to organize knowledge on the various types of information generated throughout the entire project life cycle.

2.4.2 Facility managers as agents of change

There is increasing awareness among designers on the need to take operational aspects into consideration in the early design process; however this is not fully executed in architectural practise except in partnering projects (Jensen, 2008). Moreover, he analyses why and when facilities managers should be involved and contribute to the design process and why facilities managers are often excluded from the design process. Facilities managers have the daily contact with users and obtain an in depth knowledge about special needs for facilities that support the process and culture of that particular organization. The involvement of FM can be a valuable source of proper planning designing, execution and operation phase, if is put in appropriate way (Jensen, 2008).

Facility managers who play a role in developing and owning properties are the agents of change towards a-well designed and operating building. Facility managers here are referred to as entities that initiate and finance building projects. They make strategic decisions in the facility delivery process which ultimately have influence on the final product and operations. Therefore facility managers possess huge influence on effectiveness of BIM development (Eastman et al, 2011). This calls upon integration of facility management expertise in the developing process, which will provide operation consideration in the developing process from early design stage. Researchers have recently concluded that the integration of FM in the full development of a building will have a huge impact to the longevity of the building lifecycle, and have a positive influence on its sustainable development (Tucker, et al, 2003,; Jensen, 2010, Bröchner, 2003).

Mohammed and Hassanain (2010), argue that direct involvement of facilities manager in the design stage has the potential to reduce maintainability problems during the operation phase of the facility. Moreover, the involvement of facility managers in the integrated design process will contribute to reduction of design errors leading to major repairs, and alterations of facility during operations. Furthermore, most owners who have taken initiatives to participate in the process of BIM development are receiving benefits and advantages in the market place, through the delivery of higher value facilities and reduced operational costs (Eastman et all, 2011).

On the other hand, integration of facility management (FM) in the development process is always a challenge due to lack of awareness, competency and self-esteem on their contribution during the design stage. Several studies have been carried out to explore benefits, triggers and barriers to effective collaboration of various experts in the early stage of development process (Jensen, 2008; Macomber, 2003). Under current practice, the involvement of facility managers in the process of BIM development is limited, the importance of the integration of FM, and the role of FM in the full development process is not yet realized. Several barriers for the involvement of facility managers were identified, including the perception of the facility managers within their own organization and the design team. The main problem seemed to be that facility managers in general are not sufficiently qualified to be capable of and accepted as an equal dialogue partner in the design process. The report also outlines the development plan for the facility managers including recommendation for how to become empowered and a presentation of a self-assessment tool. Generally, the problem of facility manager’s limited contribution to the design process is related to a lack of the necessary competences and prestige (Jensen, 2008).

From a holistic view, the facility management involvement in the design process’ focus is made to ensure that, the facility and the built environment perform the intended function under which was designed and constructed. Sapp (2009), emphasized that operations and maintenance typically include the day-to-day operations necessary for the building and its systems and equipment to perform their intended functions.

Researchers have realized immense increase in cost of maintenance due to faults in the operation of systems and components and to a large extent are due to deficiency in design (Al-Hammad et. al., 1997). The involvement of FM from early design stage will reduce unnecessary costs during operation stage.

According to The building research established in England, 58% of the building failures in the UK originated from faulty or poor design. The result was based on the survey of building failure patterns and their implications (Seeley, 1986). Faults in building design place a heavy burden on the owners for the rest of its operational life of the facility. It is paramount for the facility managers and building designers to take advantages brought by BIM in the process through efficient corporation to strengthen the integrity of the design output (Eastman et. al., 2011).

2.4.3 Facility Management Systems

A facility management system (FMS) is an overarching system of a smart building that brings together some of the operational management functions of the facility and the building technology systems. The FMS is typically a server-based configuration coupled with operator workstations, which may be supplemented with wireless devices (Sinopoli, 2009) (see figure 5).

In his book, Sinopili (2009) has analysed the FMS to consist of a series of software modules that allow an owner or facility manager to select modules based on operational and facility management needs. Among these software includes, Energy Management Systems (EMS), Computerized Maintenance Management Systems (CMMS), and Computer Aided Facilities Management (CAFM) etc.

Building Management Systems BMS, on the other hand, according to Sinopoli, are focused on the operational functions of the smart building systems, primarily life safety and building automation systems. The BMS is typically vended by the manufacturer of the building automation and life safety systems. These systems may integrate systems and controls, provide data on specific devices or equipment provide system alarms and allow the operators to establish set points and system schedules, among other functions (Sinopoli, 2009).

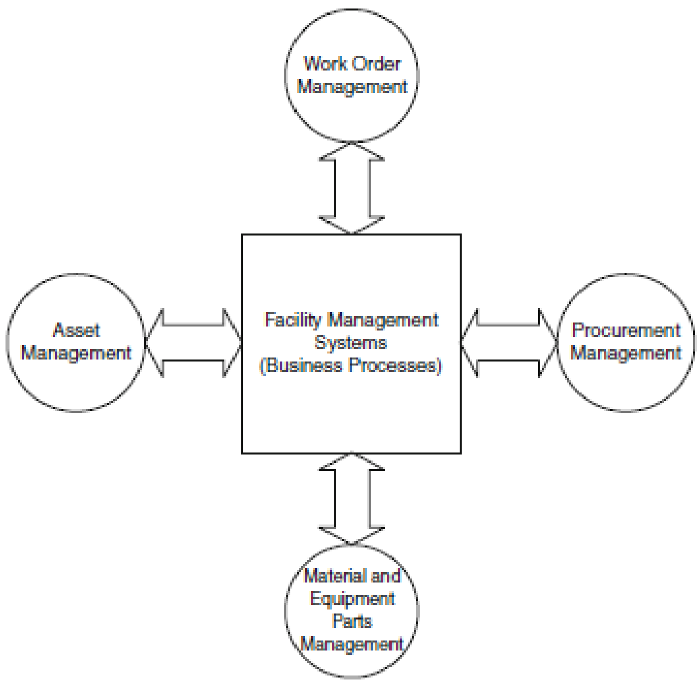

Figure 5, Facilities Management Systems, (Source: Sinopoli, 2009)

2.4.4 System and Data interoperability

Lack of data interoperability of software or ICT systems is one of the major challenge facing the AEC/FM industry to manage information flow, storage, retrieval editing and reuse in order to progress in their business (Grilo and Jardim-Goncalves, 2009; Froese, 2003). Furthermore, Froese (2003), emphasized that manual data entry and reinterpretation is a non- value adding activity, and most often introduces inherent errors in the process and inhibits the use of available ICT tools. In order to gain competitive advantage companies should strive to increase the level of interoperability of their ICT systems.

Interoperability has been defined as

> *"the ability of two or more systems or components to exchange information and to use the information that has been exchanged*".

This is the enabler of information to flow from one ICT system to the next throughout the project's life cycle by developing information structure throughout the AEC/FM industry (Grilo and Jardim-Goncalves, 2009; Froese, 2003).

BIM is a process, essentially, that can help to manage project information through the interaction of project's participants. These interactions can only be supported by interoperability. The interaction is enabled by the 3D, 4D and n-D modelling capability of BIM from early design stage and throughout the project's life cycle. Therefore a common link with BIM to enable interoperability is essential during the operation phase. The interoperability of various models that may have been created by different software tools from different software vendors is required (Grilo and Jardim-Goncalves, 2009).

2.4.5 BIM Data Standard for FM

2.4.5.1 IFC Format

In order to address the interoperability issue, efforts have been made to have a standard information format in AEC/FM technology. The Industry Foundation class (IFCs) have now been established as an acceptable international standard for system interoperability with different IT technologies available in the market.

According to Froese (2003), The Industry Foundation Classes (IFCs) are a high-level, object-oriented data model for the AEC/FM industry. The IFCs model all types of AEC/FM project information such as parts of a building, the geometry and material properties of building products, project costs, schedules, and organizations, etc. All information regarding geometrical and non-geometrical data can be mapped into an IFC data file. The file is the neutral format that can be efficiently shared and exchange information in AEC/FM computer systems applications (Froese, 2003).

2.4.5.2 COBie

COBie is the accepted international standard that delivers structured managed facility information. The term COBie stands for Construction Operation Building information exchange. COBie information can be exchanged by using different open standard format like IFC, ifcXML, and SpreadsheetML. The spreadsheet version of COBie is now widely accepted and can be exchanged with different commercially available software worldwide. COBie was developed to enable easy data exchange to those with no computer programming skills. COBie together with other open international standard data exchange format allow the facility manager to secure, own, access, and update his/her information over the entire life of the project (Teicholz, 2013).

Currently, the only format that can sufficiently capture COBie requirement is the Industry Foundation Class (IFC) model.

The common underlying format for all buildingSMART alliance projects is an ISO standard for building Information called the Industry Foundation Class (IFC) model (ISO 26739).

The IFC model information is typically an exchange format called STEP (ISO 10303) and the specification of COBie is called the Facility Management Handover Model view, (Teicholz, 2013, Plume and Mitchell, 2007).

2.4.6 Necessary information that add value on BIM at FM Stage

Jensen (2008) identified the most important FM-specific tasks in building planning to facilitate operations. Among the most important aspects according to his broad experience working as deputy project director in a client organization in Copenhagen, Denmark are:

- Flexibility and ability to adapt to changing needs over time during operation
- Logistics issues, internal communication, and distributions.
- Ease of maintaining the facility and the surrounding area.
- Healthy, Safety and security of the facility, people and assets
- Optimization of energy and resource consumption (electricity, heating, cooling, water etc.)
- Assessment of environmental impact on the surroundings
- Indoor climate and working conditions analysis
- Facility management systems and installations (Jensen, 2008)

The above mentioned aspects can be sustained to the highest degree with BIM from early design stage.

The capability of BIM to carries quantities and shared properties of building materials that can be easily extracted has potential to be used at FM stage. Scope of work can be defined, building systems, assemblies, and sequences are displayed in a relative scale with the entire facility (Sabol, 2008). Furthermore, Sabol (2008), emphasized BIM as a single repository of digital information of building components that is capable to display necessary information for FM. A BIM space tool for example can provide all information regarding, room number, area calculation, and occupant census. Equipment objects can record manufacturer, room location, references, and many other attributes.

Moreover, Becerik-Geber et al, (2012) identified 9 areas that BIM can add value at the FM stage, such as locating components, facilitating real-time data access, visualization and marketing, checking maintainability, creating and updating digital assets, space management, Feasibility Studies of Noncapital Construction Management, Controlling and Monitoring Energy, and Personal training and development.

2.4.7 Sustainability and Lifecycle Cost approach to FM

The concept of sustainability and lifecycle cost is extremely important for companies to attain competitive advantage. Many FM companies involved in property development are striving to achieve sustainability and lowering of lifecycle cost in their processes. Utilization of BIM from an early design stage can facilitate performance assessment of facilities and allow for reasonable decisions necessary to lower energy consumption, reduce cost, lower environmental impact and maintain positive economic effect (Hodges, 2005).

Facility managers are in this case, in a unique e position to view the entire process. FM can provide influence over the entire life cycle of a facility. This is due to financial and leadership ability within their power to properly address their requirements. Facility managers are therefore expected to create long lasting value in the organization by developing, implementing and maintaining facility practices (Duffy, 2000),

Addressing the same concern, Azhar, et al. (2010), argue that the demand for sustainable building facilities with minimal environmental impact is increasing. Rising energy costs and growing environmental concerns are the main reason for such high demand.

It is also said that "a slight increase in upfront costs of about 2% to support sustainable design, on average, results in life cycle savings of approximately 20% of total construction costs; which is more than ten times the initial investment. Hence sustainable buildings are economically viable too" (Azhar, et al, 2010: 217).

2.4.8 SUMMARY

This Chapter has reviewed the general understanding of BIM, the definitions, benefits, challenges and its applicability in the whole project spectrum of project's life cycle.

The current BIM platforms used in architectural practices are discussed in connection to their application for facilities management.

The literature indicates that, the adoption of BIM in the AEC/FM industry is fundamentally bringing the paradigm shift in the industry in such a way that, new ways of design and services beyond design have to be provided.

Theories indicate that BIM in architectural practice is paramount. The application of BIM from early design stage is fundamentally necessary to provide value at FM stage.

Furthermore, theories indicate that the involvement and integration of multidisciplinary in the design stage is extremely important because that can bridge the existing gap by bringing the operation in design. That is how value can be passed on at operation stage from early design phase.

Common FM technologies are discussed together with BIM data standard for FM.

Lastly, theories regarding BIM for sustainability and lifecycle approach to facilities management are reviewed.

3 Research Methodology

This chapter describes how this study was conducted and discusses the method adopted to collect the reliable empirical data. This section also explains precisely the tools that were deployed in the process of conducting this study.

3.1 Qualitative research approach

In order to accurately address the type of inquiries regarding this research, a qualitative research approach has been adopted. Morgan and Smircich (1980) suggest that, the choice of the method should be based upon the nature of the research problem. According to Dawson (2007) qualitative studies attempt to explore an in-depth opinion from the respondent about their attitude, behaviour, experience and perspectives in a particular set of issues. Qualitative method is built on the facts which are socially constructed based on people's experience (Noor, 2008).

The main focus for qualitative method lies in the analysis of specific processes, through which reality is formed, and the reality here is confined in the process through which it is created, and possible knowledge which lies with the understanding of that process (Smircich, 1980). Moreover, qualitative research is an inductive approach where theories are generated out of collected data (Bryman and Bell, 2003).

Therefore, this method has been adopted primarily to explore a multidimensional understanding and experiences within Architectural and FM industry towards potential areas, and information needed where BIM can provides an efficient Facility Management.

Semi-structured interviews are chosen to comprehend interviewee's experience and opinions which will facilitate further analysis.

3.1.1 Data Collection Method

Several methods have been adopted to draw relevant information related to the researched area. Primarily, the literature review is conducted in order to establish a theoretical framework by which the results are to be interpreted. The literature review is adopted to stem better source of secondary data, and to understand the research problem. Harre (1972) stated "we cannot describe the world in the absence of prior understanding of it, in the absence of any theory". Kvale (1996) proposes the thematic questions of "what" and "why" have to be answered before the "how". This provides an existing knowledge about the topic of investigation in order to ascertain the knowledge obtained on the interviews and what the scientific contribution of the study would be. Based on qualitative research approach, several data collection methods have been adopted including semi-structured interviews, and observations at architectural offices.

3.1.2 Observation

According to Noor (2008), observation generates insight and better understanding on the phenomenon being studied. This draws information that is not collected from other methods.

In order to fully comprehend the prevailing knowledge gap, this research is conducted within an architectural company to observe current practices on how BIM models are developed from early design stages.

This observation provides an opportunity to grasp and relate the knowledge drawn from literature review, and practical situation prevailing in the company. This will provide a base of the research recommendations and conclusions.

3.1.3 Semi-Structured Interview

Exploratory **s**emi-structured interviews are chosen in order to obtain the kind of empirical information that is necessary to interpret interviewee's opinions and experience, and to facilitate further analysis (Kvale, 1996). DiCicco-Bloom and Crabtree (2006) also stated that the purpose of the qualitative research interview is to contribute to a body of knowledge that is conceptual and theoretical and is based on the meaning that life experiences hold for the interviews.

Moreover, semi-structured interviews are one of the most sole data sources for a qualitative research (DiCicco -Bloom, and Crabtree 2006). Predetermined open-end questions, with other questions during the interview are focused to explore key information from the research problem.

In this research the main themes that guided the interview were the same to both architects and facility managers. The main reason to make the themes similar was to explore and compare the architects and facility managers' views, opinions, and experience regarding processes, and application of developing BIM for FM.

The main themes were divided into four main categories of research objectives.

Firstly, was to explore the understanding of processes and application of BIM for FM.

Secondly; was to explore information needed and areas where BIM can be applied for FM from both architects and facility managers.

Third, was to explore areas where BIM can provide value in terms of sustainability.

Lastly, was to explore the motivational triggers for FM companies to change their processes.

To thoroughly address the above mentioned themes, semi-structured interview method was selected.

3.1.4 Interviewee Selection

In order to collect the most relevant evidence from respondents, Remenyi et al (1998) suggested a well-considered approach. In this study, judgment sampling as described by Remenyi et al. (1998) is adopted. The same technique is described by Bryman (2008) and is called purposive sampling.

Under purposive sampling a researcher does not choose respondents for the study on a random basis rather, respondents are chosen within a purpose. Normally, the respondents are practitioners with experience and knowledge in a particular area and are capable to bring knowledge on research questions (Bryman, 2008; Remenyi et al., 1998).

This research will interview practitioners within architecture and facility management (A/FM) on how they make use of BIM from an early design phase for efficient FM functions.

Eight interviews with architects and facility managers have been conducted. Four interviews with architects who possess extensive knowledge and experience working as BIM managers in their respective organization was conducted. Three interviews with facility managers/owners and property developers in big corporations were conducted. Moreover, this study interviewed one prominent researcher in the field of services management from Chalmers University of Technology.

3.1.5 Interview transcription

According to Kvale (1997), interview transcription is not only converting an audio to text, but also interpretative process for a researcher.

All 8 interviews were recorded and transcribed and notes were taken during the interview and provided a more understanding of the data, ideas, and opinions from respondents.

Proper analysis of how respondents provided answers was closely considered with respect to the objective and research questions addressed in this study.

The analysis was done by comparing answers from the architects and facility managers with respect to the BIM and FM previous empirical studies identified beforehand.

4 FINDINGS

The primary objective of this research was to investigate and understand the main basics of BIM based designed processes, information needed from early design stage, and how that can be used to facilitate efficient FM operations.

Moreover, it was to understand benefits and motivational triggers that BIM can provide at Facility Management (FM) to support sustainable building performance.

The findings are hereby presented in four main aspects; Processes and BIM delivery for FM, Information needed to be applied in BIM for FM stage, Potential benefits and BIM values for FM stage and motivational triggers to adopt BIM at FM stage.

Different respondents from architectural offices, facility management and property developers were interviewed to explore the above objectives. All respondents have the capacity working as BIM managers or facility managers and property development managers. Unabridged opinions from respondents are discussed

4.1 Processes and BIM delivery for FM stage

Unlike traditional processes of design processes, BIM provides involvement of different stakeholders in the process. All architects and owners interviewed indicated the need to involve not only facility managers but also suppliers or manufacturers in the processes.

Concerning involvement of suppliers and facility managers, one respondent said;

> *"I think it very important for FM and suppliers to take part in early design stage; because that is the right time to make decisions to avoid any problem that may arise to the final result. It is very important*".

He also added that;

> *"If the building is not performing becomes very expensive too. If you get the heating wrong, ventilation wrong and in the long term when is not working well becomes very expensive. For example, to lower energy consumption, to make the building as efficient as possible saves a lot of money"*

The information developed in the process need to be applied in a BIM model. The final as-built BIM model should be delivered in a neutral format that is FM system readable and simplicity to use.

4.2 Information needed to be applied in BIM for FM stage

Respondents from the architectural offices had similar view on the need of proper knowledge of types of information to be put in a BIM model from early design stage to facilitate FM operations.

4.2.1 Architects respondents

All architects who are working as BIM managers from different offices in Sweden and Denmark responded that, it is paramount to bring the operation phase in design stage.

One architect in Sweden emphasized that,

> *"It is a common mistake to think that the parameters during the design and construction stage are the parameters for the FM stage"*

Some of the non-core support services in FM need to be pre considered during early design stage to enhance facility management operations. The main challenged encountered is lack of knowledge on what kind of information is needed from facility managers or developers point of view for FM stage.

The architects pointed out that information normally demanded at FM, are related to space planning and management, these are said to be very crucial and have to be applied in BIM model. The respondent mentioned the most specific demand by clients is the areas information. Among many benefits of BIM is that BIM can provide all areas correct for different purposes.

The architect mentioned the potential for getting different alternatives in a BIM model during early design to suit clients need. Accuracy of geometrical information provided during design processes is reported to be paramount for FM stage.

It was also emphasized that the clients demand information that that are compatible to their systems. It was also demanded that clients demand information that can fit into their systems like COBie or CoFM parameters for FM, etc.

Information related to maintainability of building was emphasized; it is easy to have all smart information related to building components like windows, doors etc. in a 3D BIM model. Nonetheless, the manager pointed out information related to functionality such as room information. The 3D view of the building and 3D view of rooms specifying all components for example wall types, and functions are very important during the operation of facilities.

Moreover information regarding control of building performance from early design stages is important for the FM stage. The respondent mentioned the potentials for analysis provided by BIM model especially on energy efficiency analysis, light analysis etc. provide better results during FM operations.

4.2.1.1 Sustainability

Regarding information for sustainability the respondent pointed out information regarding material specification, environmental information based on BIM simulations such as light analysis; wind analysis is mainly applied during early design stage.

These analyses are mostly done when the clients need to the building certification at a certain level BREEAM or LEED, etc. One responded indicated that, these environmental analysis need to be done early during design stage because is expansive to do such analysis after the design stage.

Moreover the respondent emphasized on planning information based on social perspective during early design stage.

All this information mentioned according to the respondent, need to be in their system to be retrieved, and modify instead of manual handling of data all the time.

4.2.2 FM Respondents

In order to collect unabridged information that can be applied in a BIM model during early design stage for FM stage, different FM companied and property developers (owners) were interviewed.

The aim was to explore from owner's perspective the kind of information that are necessary and are useful to their processes. Prior to interviewing owners, the information provided from architects revealed a huge gap between designers and facility managers regarding awareness of necessary information to be put in BIM model from early design stage.

Architects are not fully aware of all necessary information for FM and Owners as well are not fully aware of all information that need to be put in a BIM model from early design stage. Most of the FM companies in Sweden are now striving to understand what type of information is necessary to be n BIM model for the FM stage.

Most of the companies are now trying to adopt BIM in their process. One respondent (a BIM manager) in one FM/ Property owners Company in Sweden argued;

> "*I think that the problem is that, we don't have the knowledge here to know what type of information at FM stage, we can demand all the type of information, and if we demand it we have to use it in anyway, otherwise will just cost money, and we normally demand areas information; you know in Sweden we have different type of areas demand depending on what type of use for different type of people living in that type of building. The areas information has to be in our IT systems*".

An interesting finding was that both Architects and facility managers/owners are aware of potential benefits of BIM to facilitate FM operations. The major motivational triggers at FM stage are simplicity to put, retrieve, use and modify information in their FM systems.

Through in-depth discussions with facility managers/owners the following information were discussed and possess high potentials to facilitate FM operations if are applied in a BIM 3D model.

The spatial data have been discussed by all respondents to be necessary information used so much at FM stage and should be developed from early design stage. Spatial Areas information is commonly used at FM stage for different purposes during operations. Next to spatial information one respondent said they normally demand physical asset information such as walls, doors, windows and ceiling etc. the respondent said that;

> *"We normally demand areas information; you know use in Sweden we have different type of areas depending on what type of use for different type of people living in that type of building, and have to be in our systems. I worked in the southern part of Sweden in an architectural firm, and there one client demanded different information like doors, fire safety doors, what kind of windows, the handles, what kind of keys, and how to use them, they demanded all that"*

Therefore, area information is basic and needs to be correct according to the respondents. Physical asset information for planned maintenance information is paramount to be considered during design stage. Based on the data it is important that spatial data is necessary in the design stage and will be used operationally moving into FM but other than physical asset (maintainable assets i.e. planned maintenance) information, it might be that other operational data should not be included in the early stages of a design. In many cases the owner/user have to set their requirements and have to elaborate on what is necessary at FM stage because in the end they are the one to maintain the building.

One respondent emphasized that naming the rooms properly and according to how they will be named by the owner/user and creating a 3D furnished floor object can works better with BIM model for FM stage.

Application of BIM model for spatial management provide an opportunity to analyse the existing use of space, propose changes, flexibility or effective plans for future needs.

Having accurate and detailed spatial information is paramount for planned maintenance and renovations In connection to planned maintenance all respondents see the importance to include not only facility managers information but also suppliers information regarding materials and product information in a BIM model from early design stage. One respondent said;

> *"One simple example is that, there is a time when you want to decide on which component need to be built in the building, and at that time you should know how often you should change component B, like technical service of the building object, may need to change it in every 3years, or every 1 year, and I think that is not part of the architect to provide that information, is most probably the supplier or manufacturers who has that information. Today you have to read the manual somewhere in CD records, but this can be done in a BIM model*".

More specifically, information related to energy consumption, installation information, elevators, cooling systems, ventilations, fire protection, etc. Other respondents emphasized that building components put in the BIM model are necessary when you make serious refurbishment.

Furthermore, it was emphasized that with BIM several information are developed from early design stages to help management and decision making. This information includes, Life cycle cost estimation, scheduling and inventories information, and repair information including what should be changed and when.

All respondents emphasized on information of environmental aspects when the design intent is to achieve a certain environmental goal through building certification such as LEED or BREEM. Nevertheless, several companies have their internal policies regarding environmental goals regardless certification goals. The building regulations in Sweden on the other hand demand architectural companies and owners to meet environmental goals.

4.2.2.1 Sustainability information

During the interviews, many FM companies revealed strong focus on sustainability in their processes. Projects are undertaken with special consideration on social, economic and environmental perspective. The main drive revealed by respondents was to ensure projects are run with target towards zero social harm, less economic disruption and less environmental harm.

All projects from new building projects, renovations, repair and maintenance that encompassed sustainability goal on the operations have provided positive impact in their organization and the built environment. Issue of energy conservation, and waste reduction were discussed.

Regarding information that needs to be applied in a BIM model to enhance sustainability, respondents from FM and facility developers had almost similar opinions. Information regarding material specifications and standards was highly emphasized to be considered from early design stage. Environmental-friendly materials were preferred in this case. Building components information such as floor, window treatment to minimize glare or heat gain, door, and facades types were considered necessary to be applied in a BIM model.

Respondents emphasized on proper building performance analysis from early design stage. It was highly emphasized that proper energy analysis during early design stage was paramount. Moreover, environmental data like natural daylight, artificial light, wind analysis, are necessary information discussed by all respondents from the early design stage.

One FM Company emphasized more on information regarding indoor climate that is connected to better productivity at work place. He stressed more on routine information about air conditioning, heating, ventilation systems to provide environmentally controlled condition for occupant comfort and health. This kind information has to be integrated in FM systems for easy retrieval, and track changes when the change happens in the model.

As discussed earlier, many building owners see the importance to bring the operation phase into the design phase. One of the major driving forces is to reduce the operating cost permanently and to optimize the use of the building. Moreover reducing the operating cost was one of the major goals towards sustainability of built facility.

Some of the respondents believe that BIM can provide the economic feasibility analysis through proper life cycle cost analysis. Information of all costs including initial investment costs, building maintenance, energy and operating cost are necessary. Estimations of these costs from early design stage provide a basis for different options as well as clear basis for decision making. The respondents see it very important to integrate this information in their systems.

Information about life cycle cost analysis was required as part of green building certification (e.g. LEED or BREEAM). Owners prepare the evidence that building has met the criteria based on performance analysis done from the early design stage in accordance with the requirements.

In this, it is essential that FM issues on sustainability to be considered as early as possible in the design phase. Through considering FM issues early in the design phase, the space use can be optimised and efficient operation established.

4.2.3 BIM support areas in FM and information needed (Summary).

S/No	BIM support area in FM	Necessary Information needed at FM stage from architects perspective	Necessary Information needed at FM stage from owners perspective
1	Technical systems i.e. (MEP),Ventilations, Fire, cooling, elevators, etc.	• Planned maintenance information (building maintainability)	• Repair information (what need to be changed and when • Supplier information • Planned maintenance information • Material Specifications.
2.	Documentation	• Accurate Geometrical and non-geometrical information • Building components i.e walls types, doors, windows, surface finishes, facades, roof, floor, etc. •	• Geometrical and No geometrical, building components information • Material specifications • Contractual information • Suppliers information
3	LCC and Long term budgeting	• Cost analysis information	• Estimated life cycle cost, including operational costs information
4.	Dialogue with users	• Space planning i.e. 3D view of	• Space planning/use information

		furnished rooms with well-defined room use • Accessibility • Disaster planning, escape routes • HSE information • Spatial usability information	• Indoor quality information • Cleaning and access • Supply and disposal information • Safety and access control information including disaster planning information. • Contractual information
5.	Efficient area use	• Spatial planning • Cost analysis information • Standards and building regulation compliance	• Space planning, different options information • Budgeting information • Spatial standard from government regulations
6	Sustainability goals	• Environmental information, i.e. natural light, wind simulations, • Energy consumption analysis • Planning information based on social perspective • Life cycle cost.	• Energy consumption information • Materials specification including building components information • Environmental information i.e. Daylight and wind data • Certification needs, LEED or BREEAM

Table 1: Summary of FM support areas and information need from early design stage, (South: Author)

4.2.4 Potential benefits, values and challenges of BIM for FM

All respondents from architectural firms and owner's organizations have indicated potential benefits, values and challenges of applying BIM at FM stage.

The major benefits and values that BIM provide from architects perspective are as follows;

- Quality control and standardization of work process

One architect responded that, BIM provide an opportunity for better quality control. Moreover, the responded indicated that it is easy to work on agreed standards on one platform. The respondents added that, it is possible to work in virtual collaborations and provide the same quality end product. The model can be controlled for quality check from early design stage until operational phase of the built facility.

- High quality geometric information and non-geometrical information embedded in a BIM model

All respondents indicated that BIM provides high quality and accurate geometric information. Useful non- geometric information can be tagged in a BIM model to be used later in the operational phase. All this information has to be embedded in owners' FM systems and should be easy to use, reposition, and revise to support the FM activities.

4.2.5 Benefits and Values at FM stage

Respondents from FM organizations described precisely areas where BIM models provide Benefits and value to support their processes. Areas repeatedly indicated by many respondents are as follows.

- Save time to retrieve information,

Personnel responsible for FM activities spend a lot of time to find necessary information to support their operational activities. Most of the time spent is non-value adding in their processes and as a consequence have negative financial implications in the organization. One respondent said;

> *"I think BIM is useful at FM because it saves a lot of time, you don't have to go to all places to find the information. I spend a lot of to just time going around seeing what is going on and I have to call to see what you have in that place and that. There is a lot of cooperation in the process too and we spend a lot of time to find information".*

- Easy to track and trace building materials used in the building process.

The potential for BIM to carry all geometrical data and non-geometrical data provides potentials of tracking every type, quantity and properties of building materials used. That provides potentials to even trace where those materials were used.

> *Everything we use in the building should be tracked in the future, how much we used and where was it applied. If at all was harmful to people or environment can be easily traced*,

- Quality control and standardization of work processes

The respondents describe the potential of getting best quality products when using BIM models from early design stage. They pointed out that, it is possible to have different design options for different customers. It is also possible to sell one options to different customers instead of redesigning every time.

- BIM models minimizes risks

All respondents at FM companies indicated potentials provided by BIM models to explain building usability through graphical interface. The graphical interface linked to users helps to minimize risks during operational phase. Proper signage, accessibility, and disaster graphical planning in 3D were among few issues discussed by the respondents.

4.2.6 Challenges

Respondents at FM organizations also indicated some challenges pertaining application of BIM to support their activities during operation stage. Some of these challenges are as follows;

- Keeping the information so that the right information may not get lost

Most of the respondents at FM stage are striving to ensure that the building information is kept to be used as long as the facility exists. Most of the companies are striving to keep digital format of building facility into their databases. Nevertheless, it has been difficult to keep the right information into the database. It was indicated that once the information is lost becomes expensive to the owner to get the same information. The respondent said;

> *"There is only in the interest of the owners to secure that the building information is not lost. A lot of other stakeholders in this game, are not concerned if the information get lost, so they can be paid to develop again and again"*

The respondent indicated that, there is a huge possibility for the building owner to even loose the right information even in their databases once the people working in those systems step out of the office.

- Difficulty to track changes made by customers during operations

It was also indicated that, it is sometimes difficult to track changes made by customers during the operation stage. Customers tend to change the building to fit their activities in a particular building. Those changes are normally not reported to the owners. That becomes difficult to keep the model up to date.

> *"The key issue is to keep the model up to date. The problem might not be the design stage; the problem might be at the FM stage. When no one really cares the original version and becomes like a frozen object. That is the risk".*

This calls on the accuracy of the BIM model and to track changes whereby errors my not propagate in the process resulting into working in a wrong assumptions.

- Lack of BIM expertise in the company

  Another big challenges reported by respondents was lack of BIM professionals in their organizations. They all indicated the need for BIM experts in their companies to be able to use BIM efficiently in their processes. One respondent said;

> *"This is the kind of new competency in the industry, who in the industry should obtain and develop all these knowledge, is it real estate owner or is it a new*

knowledge that should be supplied from the architects? Who should supply you with this expertize. In a normal case, real estate owners have to develop new competency to develop and manage BIM models. Because, the architects are only in contact when the project is running, when the project is done and handed over to the owner, they head to another project. There is no continuous involvement of architects in the operation phase"

BIM is viewed as a new competency supplying new knowledge at FM stage, which requires creating new employment positions in the companies.

- Legal ownership of BIM model

Some respondents indicated the challenge regarding lack of precise legal framework safeguarding what need to be delivered and how should be the model be delivered and ownership of the BIM model. The owners need to work with BIM without worries of legal consequences in the process.

One respondent indicated that, the issue of ownership of provision of BIM services should be solved in some ways in a standard contract between the architects and the owner. Architects should be protected by law to provide BIM models for owners. He said that;

> *"Ownership is the legal issue, to some extent can be fixed in standard contracts; architects are BIM consultants and are protected to so many countries by legislation"*

That is to avoid nonprofessional or software vendors to pursue professional jobs.

4.2.7 Motivational triggers for FM factors to adopt BIM in their processes.

The most motivational trigger reported by all respondents was simplicity to access, use, and modify information that support FM activities

One respondent said;

> *"Simplicity and adaptation to the set of activities needed by everyday FM, It should be pre extraction and ability to update the information. Anything which is difficulty to update must be dropped"*

Furthermore, all FM respondents need information that needs to be compatible and user friendly in their FM systems.

5 DISCUSSION AND ANALYSIS

This chapter will point out the answers of the research questions based on findings obtained from the study. The outcome will be examined in the light of previously portrayed theoretical background. .

The research questions were formulated to explore four main areas; application of BIM from early design stage to facilitate FM operations; exploration of information needed in the process of applying BIM for FM from early design stage; potential areas in which BIM can be beneficial and provide value at FM stage; and lastly Motivational triggers for FM to change their processes.

The integration of BIM, people, business processes and processes will be discussed with respect to findings obtained from both architects and facility managers.

Furthermore the study will critically analyse the findings as to why and what need to be done different based on theories and previous studies.

5.1 Application of BIM from early design stage to facilitate efficient FM operations

Application of BIM for FM is at the infant stage. Most of BIM application and services provided by consultants stop during the construction stage when as-built drawings have been provided to the client. Currently companies are striving to bring in the operation during the design stage, in order to support FM operations efficiently. Application of BIM from early design stage for FM has been discussed by all respondents that are essential towards provision of efficiency and value in their processes. The main reason being simplicity to access, modify and put necessary information needed at FM stage. For this reason saving a lot of money encountered due to non-value adding processes.

To reach the desired output provided by a BIM model to support FM processes, a collaborative approach through involvement of not only owners but also suppliers or manufacturers, is paramount. This inquiry is supported by aforementioned researchers, Brochner (1990; 2003) and Holzer (2007). Brochner (2003), argued that many facility managers contribute to the design process for new buildings and their roles in the design process is not fully utilized. He added that, the experience and knowledge possessed by facility managers, suppliers and manufacturers play a vital role for better decision-making during the design stage especially when developing BIM model for the operation stage.

Regarding the application of BIM and multidisciplinary approach from early design stage in the pursuit of bringing operations into design, Brochner (2003) pointed out potentials of BIM to provide fruitful output even before the maturity of BIM in the industry was experienced, he argued that

> *"Integrated development of design and services for facilities may still be a distant reality"*

He also added;

> *"While we are still waiting for information systems platforms that deliver integration, it is obvious that human integrators are needed and also good teamwork from a range of disciplines" (Brochner, 2003, Pg. 23)*

It is now evident that BIM has reached the maturity level in recent years to the extent of pushing towards inevitable paradigm shift in AEC/FM industry, which focuses on not only product development but also services provided in the facility. This call for the involvement of multidisciplinary expertize to develop and apply BIM models in FM practice

Holzer (2007) on the other hand, emphasized the importance of applying BIM from early design stage where the degree of project uncertainty is very high, in order to support defining, weigh, and prioritize aspects of design in a collaborative process. He pointed out that early decisions have significant impact on project outcomes especially during operations. With this regard all respondents from FM said they have not attempted to participate in the design process to develop BIM models that support their processes. It is in recent years, most FM companies are striving to find ways on how they can ask and apply 3D BIM model in their processes.

There is a growing awareness in Sweden to bring the operation stage in the design mainly to add value and quality of facilities and services thereafter.

The involvement of suppliers or manufacturers in the design stage is still a challenge. This might be due to weak legal relationship between designers and suppliers. Suppliers and manufacturers are procured as subcontractors with a different contract by the owners. There is a weak legal framework that hinders efficient collaboration between designers, engineers, owners and suppliers. One respondents from architectural practice mentioned partnering contracts to be effective in this respect.

5.2 Information needed in the process of applying BIM for FM stage.

Results from all respondents architects and facilities managers show that all are aware of necessary information that can be applied in a BIM model for efficient FM operations. Nonetheless, it was indicated that it was difficult for architects to comprehend accurately and link all information needed within BIM support areas for FM. The five support areas provided by Brochner (1990), and one additional support area added by the author provided a gateway to understand how the information can be applied efficiently for FM operations.

Architects and facility managers can compare these support areas and information provided by both parties to develop further a proper BIM model for the operations stage. Those six identified support areas for FM; Technical systems, LCC and long term budgeting, dialogue with users, efficient areas use, documentation, and sustainability can be used in relation to all information identified to support that area.

Therefore, it is necessary to ensure all information provided by all parties is collected, before are assimilated in FM systems.

5.2.1 Benefits, Values and Challenges of applying BIM at FM stage

Different benefit, values, and challenges have been identified from both, architects and facility managers. From architects point of view the following are seen as primary benefits of applying BIM at FM stage;

- **Performance analysis of facilities**

Findings from this study show that, there is a growing awareness in Sweden of benefits provided by applying BIM from early on for operations stage. Among many benefits, owners are striving to evaluate whether the projects meets the functional goals intended. These kinds of analysis to assess are being done in early design stage, and have been reported to have positive influence on project quality and performance. This is supported by Kubba, (2012), Eastman et al, (2011) and Yoon et, al, (2009). Kubba (2012) identified the benefits provided by accurate assessment from early design stage to evaluate whether the project meets the functional and sustainable requirements set by owners and overall project quality and performance during operation stage.

In contrast to this strong benefit as viewed by all architects, the performance analyses of buildings are done subsequently to the design stage. The main reason pointed out is a lack of in-house competency for the case of architectural practice and greater reliance to engineers who are considered to be experts in this area especially on early energy analysis. This is not a holistic way since it can result in rework of design works if the design could not meet the desired parameters. Schlueter, et al. (2008), suggested that the involvement of all professionals from an early design stage for this case is necessary. Results from architectural companies' show that it would be more important to develop in-house capabilities to be able to avoid that, and consider performance analysis of facilities from early on during the design stage. Moreover, the provision of IFC model has enabled closer collaborations between experts during the design stage.

There is now a greater evolvement of IT software that enables early performance analysis, such as early energy analysis, light analysis, wind, and indoor quality. The trend is now towards systems that provide quick information at the fingertips. These triggers another important aspect in architectural practices to manage change over time, and develop corresponding IT expertize that facilitates performance analysis from early design stage. This provides a tremendous benefit due to shorted design time and quick returns of Investment provided by a well performing facility.

Findings on the other hand reveal that many clients, who have demanded building certifications such as LEED or BREEAM, are yielding returns of investments.

- **Quality control and standardization of work process**

BIM provides potentials for quality control and standardization of work process in all phases of a products' and project's life cycle. Both architects and owners have reported to be aware of this benefit in practice. Previously researchers put more emphasis on potentials benefits provided by BIM on quality control only from design stage and construction stage until recently where the focus is now towards benefits at operations stage. Major benefits for early design mostly reported by researchers was the ability of BIM to correct errors from early design stage, accurate scheduled construction, construction sequencing, clash detection, design alternative and easy solutions for complex projects (Kubba, 2012, Azhar, et al, 2011). Nevertheless the model can be used in the design process to record all best practices through different alternative solutions that can be provided to reach the desired design output.

- **Accurate geometrical and non-geometrical information**

The accurate geometrical and non-geometrical information provided by BIM from early design stage have been found to be one of the major benefits in the processes. Facility managers face difficulties to manage their operation processes when the information provided does not comply with the reality. All architects and owners revealed application of BIM for this case to be paramount. This is supported by Yoon, et, al (2009), who emphasized on the potential to apply the BIM model to provide accurate geometrical and non-geometrical data from early design stage. Eastman et, al (2011), and Yoon, et al, (2009), went further, and explored application of BIM from early design stage for maintenance and operations especially on provision of efficient work process and quality control.

It is therefore necessary to make sure that the as-built BIM models are accurate and should comply and be delivered to the owner's working IT systems, in such a way that it can be easily usable to place, retrieve and modify when needed.

5.2.2 Benefits at FM stage

Results from facilities managers have pointed out several benefits of applying BIM models for their processes. The most important benefits requested;

- **Quick accessibility of facility information provided by the model.**

It was pointed out that, 3D BIM model to provide all necessary information when integrated in owner's FM systems. This is especially to avoid non-value adding processes which carry negative financial consequences in organizations.

On the other hand, this calls for a paradigm shift for FM practices to accurately involve BIM in their processes from the early design stage. Moreover, this will trigger new roles in the FM to develop in-house BIM competencies to manage the extensive information provided by BIM. Again there is a need for FM systems that can easily accommodate a BIM model for quick retrieval, placement, and modification when needed. The results indicated huge inefficiencies for the case of owners in their processes when the need for particular information arises and when one has to walk around the facility, taking physical measurements or measuring from as –built 2D drawings which in most cases they find a lot of errors in practice.

- **Easy track and trace of building materials applied in the facility**

The findings indicated potential benefits that BIM can provide to track and trace type, quantity, and properties of building materials used in the building process. This is necessary at FM when they need to make alterations, refurbishments, maintenances or removal of materials that are no longer required in the facility. It was also pointed out that, ability to trace the materials from the model in relation to where they have been applied in the building is important if at all that material will be found hazardous.

- **Quality control, Performance analysis and increased facility life span.**

The current practices at FM, as-built 2D drawings are delivered to owners by the format that is capable of structuring, transporting, and storing information to be placed unto the owner's IT systems for future use. The current open formats mostly used at FM stage are xml format or pdf format for drawings. The drawings are printed out from their databases when the need to use them arises. There is a growing demand now enforced by law to deliver all drawings and 3D models in an open IFC format, and many FM companies are striving to change their policies to adopting BIM models in an open IFC format in their processes. Application of BIM from early design stage is necessitated by its rich data repository capability and ability to use the information contained in the whole project life cycle. This is supported by Sabol (2008), emphasized the use of BIM as a single repository of information for from design stage to operations stage.

Results from all respondents' reveals that adoption of BIM at FM stage is slow but the awareness of BIM benefits stages is high. There is a need to develop new legal frameworks that guide the BIM development processes, application and sharing of information covering the whole project life cycle. Many FM companies, however, do not have responsible personnel responsible for BIM management because they have not adopted BIM in their processes.

Moreover, the result indicates the importance of the performance analysis of the facility from early design stage is the integral strategic resource for FM business. The performance led design for FM has proved to be beneficial unto the owner's perspective especially on provision of a well performing indoor quality in dialogue with users. Moreover, includes spatial quality, and provides better monitoring of risks associated with health and safety.

5.2.3 Application of BIM for sustainability goals

Regarding sustainability, results show that owners are demanding more sustainable buildings. Sustainability is the central agenda at FM companies especially in the processes of addressing social, environmental and economic efficiency.

They are striving to attain sustainability goals in terms of life cycle cost, energy consumption, and light and ventilation analysis. Owners see this as paramount to use BIM to mitigate negative consequences as a result of poor design, which ultimately lead to financial disruptions.

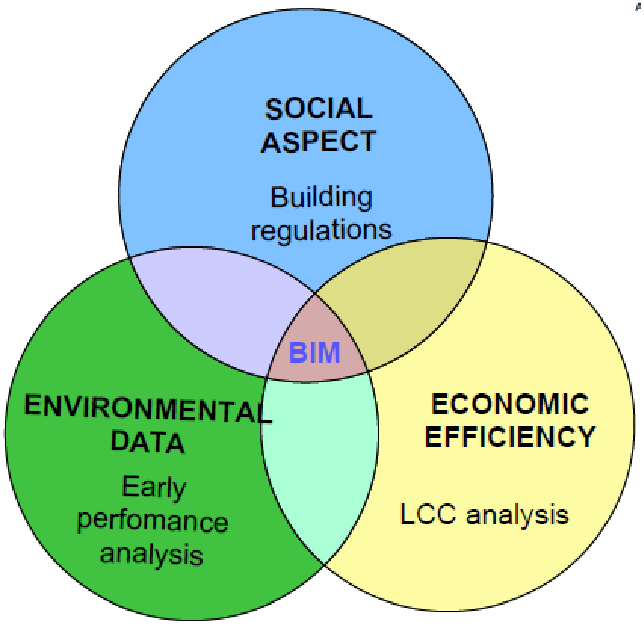

Figure 6: Three BIM support areas for sustainability (Source, Author)

Moreover, some companies have attempted to certify building at a certain level under "miljöbyggnad", (Swedish green building certification) and have responded to gain financial returns on their investments. One responded indicated that, these environmental analysis need to be done early during design stage because it is expansive to do such analysis after the design stage. Incorporating the sustainable goals from early design stage is supported by early awareness of sustainable products and materials used in the particular facility. This has been supported in theories by Yoon et al, (2009), who emphasized the performance analysis of building to meet sustainable goals from early design stage.

5.2.4 Challenges

- Lack of BIM expertise and best practices

Results indicated that, despite the growing awareness of potential benefits provided by applying BIM at FM stage, it is still not crystal clear on how BIM can be applied practically at FM. Facility managers have no knowledge on how BIM can be assimilated in their systems and how to practically use BIM in the process in a simplistic way. This calls for inevitable knowledge need on practical projects associating architects and facility managers

There is a need to develop BIM competency and good example practices in Sweden so that companies can benchmark their processes based on real life best practices.

- Legal ownership of BIM model

Legal ownership of the BIM model is still an inquiry that needs to be addressed in the industry. Kubba (2012) suggested regarding this challenge, that it is extremely important to identify who or what holds key project details. Whether is the architect, general contractor or the facility owner have that ownership can contribute to the reward or risk.

It was not clear so far if the owners have legal power to owner and make changes on a model without the consent from the architect. The contracts should therefore specify legal obligations and deliverables from both sides.

- Control difficulties; Difficulty to track changes made by stakeholders or customers during operations

A control difficulty is one of the main concerns that have been raised by all FM respondents. It requires a strong coordination from design stage to keep the right information at the right place. It was also revealed that owners make several changes during operation and sometimes there is no feedback of what has been changed. This has to be clearly stated on contractual bases on duties and obligations of each stakeholder in order to maintain value during operations.

5.3 Motivational triggers for FM at change their current processes.

Research findings indicate that current facility management operations experience inefficiencies especially on utilizations of proper asset information to assist day-to-day activities. The objective of the study was also to explore what are the motivational triggers for the owners to change their processes. All respondents have indicated that the main motivational trigger is simplicity to access, place and modify information in their FM systems. This is supported in theory; Eastman et al, (2011) emphasized that, BIM can be efficiently applied to provide an efficient and agile FM processes through quick information access from user-friendly systems.

The owners are striving to achieve value-adding processes with the main target to foster economic efficiency. It is evident that the potentials of BIM on this regard is high and require a holistic approach from the projects participants to provide the right information from early stages of project life cycle. Moreover, all necessary information from design and construction should be collected and should be stored in an efficient FM databases for easy retrievals, and modifications when needed.

On the other hand, it was revealed that, owners are willing to invest in new technologies that are user friendly and can add value in their processes by providing quick information flow. Similarly it is the duty of the facility managers to develop technical know-how on new technologies to be able to utilize the fullest potential of their investment.

Similarly to be able to acquire simplicity of information flow, integration of FM systems and IT tools is desirable. It was also pointed out by Eastman et al, (2011), that, this kind of integration of IT tools and systems in the construction industry is not yet common in practice. This calls for inevitable clear understanding of available tools that support agile and efficient FM operations.

For example, there is a growing demand of applying COBie (Construction operations, building information exchange) in some countries outside Sweden. This primary standard of BIM FM integration was developed for the purpose of providing accurate, efficient and agile information flow throughout the project life cycle (Eastman et al, 2011).

All FM respondents in Sweden have not demanded or applied COBie in their practice, may be because application of BIM at FM stage is still at infant stage in Sweden.

Other FM respondents had different opinions regarding motivational triggers. They argued that many facility managers will be motivated to adopt BIM in their processes if they can comprehend the financial returns out of IT. There is the need for further research on quantitative monetary returns that owners can achieve by applying BIM in their processes.

5.3.1 BIM, Processes, People and Business systems

This study has identified four main interlinking areas that need to be addressed accurately in a holistic way in order to achieve a-well thought functioning facility. The interlinking areas are BIM, processes, people, and Business systems. Consider the figure below;

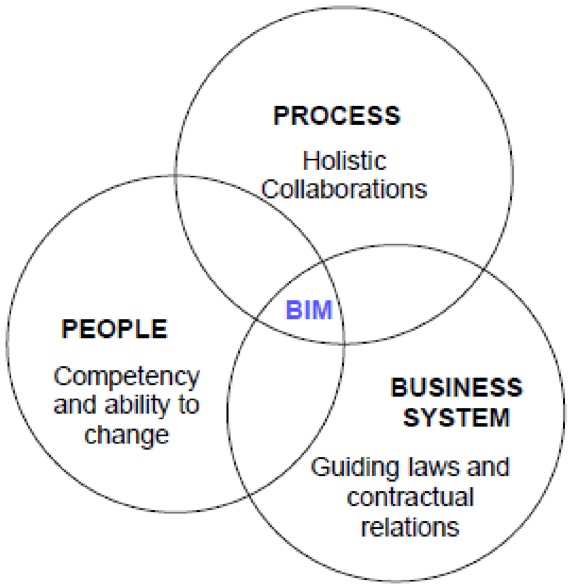

Figure 7; BIM FM integration, People, Processes and Business systems (Source: Author)

The application of BIM for facilities management may be successful if all four interlinking factors are considered seriously.

People; this aspect takes into considerations the need for both architects and facility managers to develop competency on proper application of BIM from early on design stage for operations in the future. The results indicated slow adoption of BIM and lack of BIM competency at the owner's organization.

- **Resistance to change**

There is a large gap between the practitioners in the building industry on how to adjust their routines of work processes and potential benefits offered by the IT information systems. This is mainly due to failure of IT technology to address and enhance the routines and work processes, and tacit knowledge among AEC/FM professionals. BIM for example has failed to provide simplicity that pencil and paper offers to the human brain analysis of multiple design options among architects (Coates, et al 2010; Hartmann et al, 2008; and 2009).

Therefore, resistance to change is said to be natural and important at user's side to comprehend all benefits and incentives provided by adopting BIM in their processes (Hartmann, et al, 2009).

Furthermore, BIM is considered to enhance collaboration, but in reality, most of the architectural firms are not multidisciplinary in nature, and BIM utilization and decision are made internally within firms with respect to their processes, and perceived benefits within the firm (Coates, et al, 2010).

With this respect, organizations and people in organizations are obliged to comprehend on how value can be passed on to the operations and services to the customers through BIM. All parties involved should develop a sense of commitment towards achieving the intended value from early design stage. This commitment includes willingness to change old processes that do not add value, accept new technologies. This may depict a change of organization's culture from carrying non-value adding processes. Eastman et al, (2011), emphasized that application of BIM for FM may be fruitful if stakeholders are open to ideas and willingness to participate in innovative processes and adopt new technologies.

Processes; Results indicates that, due to fragmented nature of the construction industry, it has been difficult to have a holistic processes that carries holistic views from all parties regarding efficient FM operations.

To achieve this closer collaboration of all stakeholders to bring in accurate information to be put in a BIM model is necessary. This is very important later on during operation to that the asset information is accurate.

Technology/ IT tools/ BIM; It was also revealed that BIM is not utilized at its fullest potential to provide efficient FM operations.

It is profoundly important to explore the fullest potential provided by the tools and technology from design stage to operations. This is due to the potential that BIM provides to carry on all information needed from design stage, construction and also during the facility service life.

Business Systems; Results from architects and owners indicates guiding laws and regulations in the application of BIM. The development of processes is also guided by policies developed in companies. It is comprehended that, the business systems normally operate under the atmosphere of National legal systems. The sustainability goals for example are enforced in Sweden and other countries through regulations pushing forward mandatory minimum sustainability goals and deliverables to meet.

Nevertheless, it is still not very emphasized on the proper legal framework guiding how BIM should be provided at FM stage in Sweden.

6 CONCLUSION AND RECOMMENDATION

Bringing the operation phase of facilities in early design stage through involvement of multidisciplinary stakeholders can bridge the existing knowledge gap on how BIM can be applied from early design stage for facilities management. The prevailing knowledge gap on how architects and owners can apply BIM from early design stage to facilitate efficient FM operations is mainly due to existing fragmentation with AEC/FM industry, lack of proper information regarding BIM support areas within FM, and low motivation to adopt in new technologies and processes.

Involvement of owners, suppliers and manufacturers is the key component of integration to articulate necessary information and ideas that facilitate to provide value and efficiency during operation stage.

The study however, concludes that to reach the fruitful application of BIM for FM integration design alone is not enough, rather a holistic approach that integrates competent people, right technology, processes, and business systems in a particular context would be suitable.

There is a great demand of competent people with the right skills who can apply BIM at its fullest potential for efficient FM. It is very necessary to consider the right technology of FM systems that can provide compliance with a BIM model especially on simplicity to access information, place information and modify information.

Holistic design processes and commitment of project participants into ethical code of conducts to ensure project success is necessary.

Moreover, Business systems have great influence on how and what a BIM model should deliver at the FM stage. It is much more necessary to have a national legal framework within building industry in Sweden which specifies how and what should be delivered in every phase of a project’s life cycle. The contractual relations provide some limitations on the level of procurement and involvement of project participants from early design stage. There is no legal framework for instance that stipulates how suppliers and manufacturers can be procured and be involved from early design stage to develop BIM for FM. This might be against the current competitive tendering procedures.

Necessary information to support FM operations has been explored in the light of FM support areas because, every type of information to be put in a BIM model should lay a foundation, which reflects and supports areas within FM, that information which will add value to facilitate efficiency. The explored information to be applied in a BIM model stems a better source of a data rich model that supports FM at operations later.

On the other hand the information obtained from both architects and facility managers can be too much to apply all in the model. It is important to consider what kinds of information are requested depending on the type of facility and processes of that organization.

Provision of this information from both architects and facility owners reduces high uncertainties from initial design stage on what kind of a BIM model is needed for FM operations, and what kind of information should be carried. The information reliability was viewed in the light in-depth discussion with competent facility managers, property developers, architects practicing in Sweden and one big architectural company practicing in Sweden.

Moreover, information that supports sustainability has been explored. Sustainability in terms of social, economic and environmental values, are placed at the centre of FM companies processes.

These kinds of information are necessary to be considered in order to reach the desired sustainable goals. However, the study concludes that to reach the optimum sustainable goals of facilities a proper performance analysis of building facilities is necessary. The performance analysis can yield more optimum value if will be performed concurrently from early design stage than being done subsequently after the design stage. It is however another challenge that this study has experienced on the architects side, because architects are not experts on performance analysis during the early design stage. There are so many software programmes on the market for performance analysis and they are mainly meant for engineers or other experts. This necessitates architects to develop in-house competence to meet this demand. Performing facility performance analysis may create inefficiency and non-value adding rework

Lastly the study has explored motivational triggers for FM to apply BIM in their processes. The main trigger most of FM companies are striving for is simplicity to place, use and modify necessary information from a BIM model embedded in their FM systems. This goes hand in hand with developing BIM expertise within FM companies to acquire efficient operations. Moreover, other owners have added economic efficiency to be another motivational factor to adopt BIM in their processes.

Future research should focus on BIM technology knowledge and change management in A/FM industry.

Secondly, a quantitative research study about financial gain as a result of adopting BIM at FM stage is viewed as necessary since the processes are at infant stage in Sweden.

6.1 Recommendations

Closer corporations of various stakeholders can be a gateway towards process, product innovations and technological efficiency in the building industry. It is important to reduce the fragmentation nature of the AEC/FM industry to involve not only professionals but also owners in the processes.

Architects need to focus more to bring operations information in early design stages is necessary. BIM can be efficiently applied in this case.

There is high demand to invest more to develop competency of utilizing BIM for facility performance from early design stage. Similarly, facility managers need to develop competency on how to apply BIM in their processes

Moreover, there is a need for BIM building regulation to include National BIM guidelines on how BIM models should be provided to the owners, and what are mandatory deliverables at each stage of the project's life cycle in Sweden.

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8 Appendices

8.1 Appendix 1A: Interview questions for architects

The main research question

How can BIM be applied effectively from an early design stage to support the efficiency of FM operations?

Specific questions

1. What is BIM according to the architectural practice? How do architects make use of BIM in their daily practice?

2. How long have you been using BIM based design models for clients? What are your reasons for using BIM?

3. Are there formalized ways to create a BIM model? How does it work in practice?

4. Do you have a BIM manager? What are her/his major responsibilities regarding BIM management.

5. What IT tools do you use to develop BIM models? What benefits are provided by that tool compared to other tools on the market?

6. At what stage do architects begin to develop a BIM model? Why is it necessary at that stage?

7. Have you ever attempted to provide a BIM model for facility management (FM)?

Main question

What is the necessary information to be put in a BIM model during PDCO (Planning, Design, and Construction & Operation) suitable for FM?

8. What are the mandatory deliverables from architects for clients/owners at planning, design and construction stage? How do you gather information necessary for facility management?

9. What is the primary purpose of as-built 2D drawings? And how can an as-built BIM model supplement 2D as-built drawings?

10. How do you transfer data to the owner and facility manager?

11. Since lack of systems and data interoperability is so costly at FM, how do you think data interoperability can be achieved for FM stage from existing design IT tools you are using in the company?

Specific questions

12. What kind of information needs to be added in a BIM model that facilitates sustainability (Social, Economic and Environmental values) of the building?

13. How do you develop the concept of sustainability from early design stage, or does that depends on client's requirements?

14. What is your experience of utilization of BIM for sustainability of buildings especially during operations stage?

Specific questions

15. What do you think can motivate FM companies to adopt BIM models into their systems?

16. In what ways do you think BIM will add value if it is integrated in FM?

8.2 Appendix 1B: Interview questions for facilities manager/owners

The main research question

How can BIM be applied effectively from an early design stage to support the efficiency of FM operations?

Specific questions

1. How do you understand BIM? How can BIM be useful to FM?

2. What are the major responsibilities of a facility manager?

3. What IT tools (CAFM tools) do you use to facilitate FM operations? How do you assimilate information from the design team into these IT tools?

4. What information needs to be available to the design team to develop a BIM model suitable for FM operations? How do you manage this information during operations?

5. Are there formalized ways to create a BIM model compatible to other IT tools in the company? How does it work in practice?

6. At what stage of the building lifecycle do facility managers need to develop a BIM model? Why is it necessary at that stage?

7. What are major challenges for facility managers to collaborate with design team during design stage to the entire project's life cycle?

8. What do you think are benefits of BIM for FM?

Specific questions

9. What are the mandatory deliverables expected for facility management from architects, engineers, and contractors at planning, design and construction stage? How do you gather information?

10. What is the primary purpose of as-built 2D drawings? And how can an as-built BIM model supplement 2D as-built drawings?

11. How do you extract and use data from as-built 2D drawings in FM operations?

12. Do you think that a lack of data interoperability between IT systems is costly?

13. If it is so costly, how do you think data interoperability can be better achieved for the FM stage and between existing designs IT tools in companies, especially AEC?

Specific questions

14. What kind of information needs to be added in a BIM model that facilitates sustainability (Social, economic and environmental values) of the building?

15. How do you develop the concept of sustainability from early design stage, or does that depends on your requirements as the client?

16. What is your experience of utilization of BIM for sustainability of buildings especially during operations stage?

Specific questions

17. What do you think can motivate FM companies to adopt BIM models into their systems?

18. In what ways do you think BIM will add value if it is integrated in FM?

8.3 Appendix 1C: Interview question for researchers

The main research question

How can BIM be applied effectively from an early design stage to support the efficiency of FM operations?

Specific questions

1. How do you understand BIM? How can BIM be useful to FM?

2. What are the major responsibilities of a facility manager, regarding creation, capturing and transferring of facility data? What are the data mostly dealt by Facility Managers during facility operation stage?

3. What are IT tools (CAFM tools) normally used to facilitate FM operations? How is the information assimilated from the design team into these IT tools?

4. What kind of information are necessary be available to the design team to develop a BIM model suitable for FM operations? How can this information be managed during operations?

5. At what stage of the building lifecycle do facility managers need to develop a BIM model? Why is it necessary at that stage?

6. What are major challenges for facility managers to collaborate with design team from design stage to the entire project's life cycle?

7. What do you think are benefits of BIM for FM?

Specific questions

8. What are the mandatory deliverables expected for facility management from architects, engineers, and contractors at planning, design and construction stage? How can the information be gathered?

9. What is the primary purpose of as-built 2D drawings? And how can an as-built BIM model supplement 2D as-built drawings?

10. How can the data from as-built 2D drawings be used in FM operations?

11. Do you think that a lack of data interoperability between IT systems is costly?

12. If it is so costly, how do you think data interoperability can be better achieved for the FM stage and between existing designs IT tools in companies, especially AEC?

Specific questions

13. What kind of information needs to be added in a BIM model that facilitates sustainability (Social, economic and environmental values) of the building?

14. How can facility Managers/ owners develop the concept of sustainability from early design stage, or does that depends on your requirements as the client?

Specific questions

15. What do you think can motivate FM companies to adopt BIM models into their systems?

16. In what ways do you think BIM will add value if it is integrated in FM?