Building Information Modeling for facilities management: skills, implementation and teaching map

Building Information Modeling for facilities management: skills, implementation and teaching map

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Abstract

Digitalisation and Building Information Modelling (BIM) provide efficiency for facilities management teams to help manage information during the operations and maintenance (O&M) phase of building usage. BIM as a promising solution empowers facilities management teams to take the control of tomorrow and improve the long-term efficiency and performance of their facilities. This chapter provides an overview of Building Information Modeling (BIM) and how it can be applied to facilities management. The objective of the Chapter is to enable facility managers, owners, and students to read and navigate the BIM tool, and to impart knowledge of best building information modeling practices and techniques to improve facilities management practices. It details the applications of BIM in facilities management practices and their benefits and associated challenges. Finally, this chapter spot on the main challenge of information exchange and interoperability between BIM and facilities management systems.

1. Introduction

Facilities management (FM) involves a wide range of multidisciplinary services with an overall purpose of maintaining and enhancing building assets to ensure occupants wellbeing (Becerik-Gerber et al. 2012). The key challenge for FM teams is to have real-time, accurate and comprehensive information to perform their day-to-day activities and to provide their senior management with accurate information for decision-making (Atkin and Brooks, 2009).

Currently, various technology platforms, data repositories or database management systems, including Computer-Aided Facility Management (CAFM) Systems are used for information management in different facilities. In most FM practices today, the data required for CAFM/CMMS systems come from various sources. These data are collected and entered manually into these systems, manipulated several times during the project lifecycle, and entered manually into each FM system several times, as these systems lack interoperability between each other, resulting in error-prone processes (Becerik-Gerber et al., 2012; Teicholz, 2013; Patacas et al., 2015).

Using Building Information Management (BIM) in FM practice facilitates information management of building components and systems during its lifecycle (Teicholz, 2013). The more accurate and up-to-date information is available to the FM team, the higher is the opportunity for the enhancement of processes throughout the operation and maintenance (O&M) phase. One of the key success factors for BIM implementation in FM is to identify the required data for day-to-day activities (Liu and Issa, 2016). Accordingly, the FM industry is beginning to acknowledge the importance of having a standardisation for data format specification. Standards such as UK PAS1192-3:2014 have been issued, which support data management and provide a specification for information management for the operational phase of facilities using BIM. Suggestions have been proposed to use the Construction Operation Building Information Exchange (COBie) as a data exchange method (BSI, 2014a). COBie is a neutral spreadsheet format that organises a facility's non-geometric data in a structured simple format for use by the owner / FM teams (Thabet, & Lucas, 2017). However, even though different ways processes and tools have been developed to exchange information during a facility's lifecycle, there is still a lack of understanding of what sort of information is needed for this to be used by the FM team during the O&M phase and how to transfer this information seamlessly into existing FM systems. This chapter aims to examine how internal and external contexts shape exploration and exploitation of learning when implementing BIM in facilities management. This is done by presenting a general insight of facilities information systems and highlights the applications and challenges of using Building Information Modelling (BIM) in FM practice.

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2. Facilities Information Management

Today's facilities are ever more sophisticated and the need for available and reliable information for O&M activities is vital (Jordani, 2010). The key challenge for facility managers is to have real-time accurate and complete information to perform their day-to-day activities and to provide their senior management with accurate information for the decision-making process (Atkin and Brooks, 2009). Currently, there are various technology platforms, data repositories, or databases such as Computer-Aided Facility Management (CAFM) and Computerized Maintenance Management System (CMMS) that are used for these purposes in different facilities. In most current practices, data is extracted from paper construction documents and is re-entered manually in one of these computerised information systems (Teicholz, 2013).

Most of the facility information needed to support FM practice is often created and accumulated throughout the design and construction phases and is often handed over to the owner/ FM teams when the construction is completed, in the form of papers and/or electronic copy. However, this late delivery of unstructured information causes a serious challenge for owners/FM teams to check and verify whether the delivered information includes the required information to perform FM activities during the O&M phase (Teicholz, 2013; Patacas et al. 2015). Moreover, the fragmentation in the construction industry and the consequent lack of communication between project stakeholders at different phases of the facility lifecycle result in in handing over unstructured and incomplete information to the owner/FM teams. In the case of the delivered information being solely in the form of a paper copy, it remains in the owner/ FM team's storage system until it becomes outdated or damaged. In the best-case scenario, FM teams start to scan the delivered hardcopy documents to transfer them to a digital format. However, scanning documents does not actually mean a digital format, since the FM teams cannot update them or conduct any query on this scanned database (East, 2007).

East and Brodt (2007) point out that the owner will have to pay at least three times for the handover of the construction information: the first time is when the cost of providing this information was embedded in the design and construction costs; the second time is when the FM firms are paid to survey the existing facility conditions to obtain as-built drawings, while the third time is when the delivered/collected information has to be re-entered manually into FM systems (East and Brodt, 2007).

The project information handed over to the owner/FM teams is bulky and includes many documents such as as-built drawings, specifications, operation and maintenance manuals, warranties and guarantees of the installed systems and equipment. Processing a large amount of fragmented information to organise and re-enter them into FM systems is a costly and time-consuming process, resulting in a lengthy period and error-prone process which can be extended for up to six months to finalise this task (Gallaher et al. 2004; Patacas et al., 2015). As an example, according to a study conducted by Penn State University, DoD & DoD Sandusky Laboratories, University of California, each maintenance work order required 75-120 minutes to collect related information to complete that work order. If the required information could be made available within 15 minutes to execute this work order, the cost savings for the total 6356 work orders per year were estimated to be about 583,316.00 USD per year, considering the average cost of executing a work order is 50.00 USD per hour (Alevras and

Arabia, 2014).The National Institute of Standards and Technology (NIST) pointed out in their study that two-thirds of the estimated $15.8 billion lost in the U.S. capital facilities industry were associated with inadequate interoperability during the O&M phase to cover for expenses related to manual information re-entry, information verification, redundancy and idle labour time spent in looking for unavailable information (Gallaher et al., 2004; Rundell, 2006; Jordani, 2010).

BIM has been developed to enable the project stakeholders during different phases to collect, manage, exchange and share the facility's information during its lifecycle (Isikdag et al. 2008). A BIM database includes information about the facility's geometry and its components. Thus, owners/FM teams can minimise their share of the cost related to inadequate interoperability by adopting BIM. BIM allows for managing the vast complexity and large amount of information generated during the facility's lifecycle to make the information available during the O&M phase for the FM team's use (Rundell, 2006; Azhar, 2011; Becerik-Gerber et al. 2012; Kassem et al. 2015).

Although BIM is developing as the main database for a building's lifecycle, the use of BIM in the O&M phase is limited. Becerik-Gerber et al. (2012) conducted interviews with FM practitioners to outline the role of BIM in FM. Their study indicates that the existing FM information management is being done manually and that integrating BIM in FM could leverage FM practice.

Although BIM is currently recognised by academics and FM practitioners, it is still unclear how to efficiently integrate it into FM practice. Moreover, it is still unclear what information is needed for the FM teams' use and how to transfer this information from BIM models to FM systems. Issues of information exchange and interoperability need to be addressed to facilitate transferring the relevant information to FM systems and to facilitate BIM implementation in FM (Becerik-Gerber et al., 2012; Kassem, et al., 2015).

Among many ambiguous issues that need to be cleared up to extend BIM implementation in FM, interoperability remains the main issue. Interoperability is the capability to exchange information among various applications to enable automation of information exchange and access and to avoid manual data re-entry. Due to the wide variety of BIM and FM platforms, interoperability between these platforms remains one of the key challenges in using BIM in FM practice (Arayici, 2015; Ham & Golparvar-Fard, 2015; Kassem et al., 2015; Ibrahim et al. 2016).

Recently, there have been various attempts to solve the interoperability issue by introducing different universal data standards, such as the Industry Foundation Classes (IFC) and XML schemas, and structured specifications such as the Construction Operations Building Information Exchange (COBie) (Azhar et al. 2012). However, these attempts still have their inherent limitations. Pragmatic strategies for purposeful information exchange among BIM models and different FM information systems such as CMMS are required to overcome the interoperability challenge.

Moreover, most of the existing studies related to integrating BIM in FM practice are focusing only on the human and organizational issues, and business and legal barriers and avoiding the technical barrier (interoperability barrier). However, most of the proposed theoretical framework of BIM information exchange for FM use is based on the assumption that information can be transferred seamlessly between the various BIM and FM systems (Kensek, 2015). Successful integration of BIM in FM demands a proper approach to address the lack of standardised information exchange process and the lack of interoperability between BIM and FM systems. **Signposting sentence/para required here which makes the transition from this section to the next DONE**

So What: It is hard to follow how the above paras are leading to an argument. Please keep on informing that A is important as it leads to B, and so on DONE Findings show exploration of BIM is seen as essential for future viability and facility managers, owners, and students explore BIM through facility scenarios on how BIM could provide a viable solution to resolve information gaps. Exploitation is based on previous experiences where apparent similar changes happened and inferences are imposed onto a new BIM context. Emphasis is on BIM leveraging information processes rather than changing facilities management practices. The Chapter therefore shows a balance between exploration and exploitation learning is essential in order for BIM to leverage facilities management practice.

3. The following sections will discuss the existing facilities management systems and highlight the current challenges and obstacles hindering the integration of the various facilities management systems to achieve efficient information management.

Facilities Information Systems

Over the last few decades, the scope of FM has both evolved and become more complex. FM's role, that at one time entailed mainly operating and maintaining individual facilities, has now evolved to include other responsibilities such as health and safety, code compliance and energy and sustainability management. As the scope and responsibilities of FM have increased, the supporting information technologies have too. Currently, there is a wide range of FM information systems available to support the day-to-day activities of FM (Whittaker, 2017).

Since the late 1980s, FM information systems have been established to automate FM information collection and to provide the FM teams with the tools to track, plan, manage, and report on facilities information. These systems enable decision-makers to automate many of the data-intensive FM functions and accordingly results in continuous cost savings and improved utilisation of facilities throughout their entire life cycle (NRC, 2008).

There is no ideal FM information system suitable for all conditions to meet the specific demands of the FM team. However, FM information systems continue to evolve at a rapid pace. Even the basic Computerized Maintenance Management Systems (CMMS) continue to add functional modules to enhance capabilities. Furthermore, the use of handheld technologies that seamlessly interface with FM information systems continues to expand (Whittaker, 2017).

FM systems consist of a variety of software applications and information sources that may include object-oriented database systems, Computerized Maintenance Management Systems (CMMS), Integrated Workplace Management Systems (IWMS), and also Project Delivery Systems, CAD systems, Revit, Building Information Models (BIM), as well as interfaces to other systems such as Building Automation Systems (BAS) and Enterprise Resource Planning (ERP) applications (Whittaker, 2017). Today most systems are web-based and provide a host of features, including facilities-related scheduling and analysis capabilities. Data may be collected from a variety of sources through technology interfaces or human transfer processes and may be stored, retrieved, and analysed from a single data-store (Whittaker, 2017).

The generally accepted terminology commonly used to describe the various types of FM information technologies is presented as follows:

Computerised Maintenance Management Systems (CMMS): CMMS is a conventional software that is used to support FM teams in scheduling and recording operations and preventive/planned maintenance activities associated with the facility's equipment. CMMS also supports the FM team in prioritising work orders and in planning for periodic/preventive maintenance. Moreover, all historically recorded information related to work order execution is loaded into the CMMS database for future planning and control (Vanier, 2001). Although CMMS has the potential to increase the efficiency of the FM team and serve as a maintenance history database, more than 50% of CMMS implementation fails to achieve its purpose (Berger, 2009).

Computer-Aided Facility Management (CAFM) Systems: CAFM systems were traditionally software applications that included core CMMS functionality and incorporated CAD- or Geographical Information Systems (GIS)-based spatial management capabilities. They were generally used to manage building space allocation, and space planning, in addition to the basic work order (WO) processes. Today, this class of software has expanded to include more FM functionality and is now generally referred to as integrated workplace management systems (IWMS) (Lee et al., 2013).

Integrated Workplace Management Systems (IWMS): The term IWMS refers to FM information systems with the broadest functionality to support real estate and FM requirements. Effectively, IWMS have evolved from CAFM systems and can encompass the entire life cycle of the facility, from design to construction and operations. IWMS are enterprise-class software platforms that integrate five key functional domains within a single hosted database. The functional domains typically include: maintenance management, space management and planning, real estate and lease management, project portfolio management, and environmental sustainability (Clarke and D'arjuzon, 2019).

Building Automation System (BAS): This is a software package used to automatically monitor and control mechanical equipment, including Heating, Ventilating and Air-Conditioning (HVAC), lighting, and other systems through a Building Management System or building automation system (BAS) (Elmualim & Pelumi-Johnson, 2009). It is a computerdriven system programmed to control mechanical equipment. It is also called the building control system and Energy Management System (EMS) (Marinakis et al. 2013).

Enterprise Resource Planning (ERP): ERP is a software package used as a financial management system to manage organisations' business processes and automate other functions related to facility services, technology, financial management and human resource management (Lee et al., 2013).

Currently, data is handed over to facility managers through handover process which is integrated into one of the Facility Management Systems mentioned above. Information from construction projects is established and then formatted to fit facilities management systems. When considering BIM, there is an implicit change with obvious obstacles such as interoperability issues, learning curves, user resistance and disruption to business activities (Love et al., 2014). To facilities management, information is a key commodity and BIM may offer "added value" to leverage the existing facilities information management. The key is to understand the existing facilities management systems requirements.

This section introduced the existing facilities management systems. In the following section, the challenges facing the facilities management organisations to reap the full benefits of these existing systems will be discussed.

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4. Challenges related to Facilities Management systems

FM information systems are developed to streamline facility workflow processes, provide data for facilities decision-making, and to help measure FM performance. Although FM information systems can deliver significant benefits to businesses, the FM team faces several challenges in successfully utilising these systems. Aziz et al. (2016) emphasise that the quality of information entered into FM information systems is a key factor in utilising these systems successfully. According to Whittaker (2014), the implementations of most of the FM information systems either fail or lead to underutilised solutions. The most common reasons for the failure of these systems to meet the FM team's needs include the following:

- Lack of understanding of what the FM team wants to get out of the system prior to feeding theses systems with facility information
- Lack of clear expected outcomes of performance measures
- Poor definition and application of data standards
- Lack of clear system configuration standards to enable the reporting of the desired KPIs
- Poorly defined information exchanges or application interface requirements
- Lack of understanding of the resources required to implement and maintain the technology and data
- Lack of training of FM teams on workflow processes aligned with the software standard operating procedures
- Lack of training of FM teams on managing critical data and consistency in workflow processes.

The challenge for FM teams is to overcome these failure points by focusing on these aims: identifying the system application goals and objectives, developing realistic outcomes for performance measures, establishment of consistent and holistic data standards, appropriate software configuration to allow analytics and reporting, and development and training on data capture and maintenance and consistent workflow processes (Whittaker, 2014).

In addition to the challenge of overcoming the above failure points, the main challenge that needs to be overcome is related to the lack of interoperability among the different FM information systems.

The integration of the component systems is an on-going requirement for facilities management information system development. Software products with modules that can provide all or most of these capabilities or that have created interfaces to other industry leading products are being developed in response to this need. Whenever possible, data is shared and is not duplicated. The best example of this is the location data (site, building, floor, room) that is managed in the CAFM system and is shared by the CMMS. This reduces data entry and allows all location-based information to be validated upon entry.

To date, little attention has been given to the ongoing issue of the interoperability between BIM technologies, and current and legacy FM technologies (e.g. Computer Aided Facility Management

Systems (CAFM)) during the handover of information and data to operation stage. The existing systems need to be linked to BIM technologies to enhance, support and leverage the existing information and process. It is essential that BIM data is transferred or linked to existing FM legacy systems and used to improve current methods of operation, in order to support the business case for adopting BIM on existing assets.

During the life of the building, a facility should exist for information to be updated which is also responsive to change. There is a need for standardised data libraries and open systems that can be utilised by any CAFM or facilities management system. Without such non-proprietary formats, facility owners and managers must dictate which proprietary information systems to use, or re-input information into a CAFM system. Re-inputting information into relevant FM systems is inefficient, timely and costly to the owners and facility managers.

This section addressed the challenges of the existing facilities management systems and highlighted the necessity of resolving the interoperability between the existing legacy of facilities management systems. The following sections will discuss in more depth the integration of BIM into facilities management practice.

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5. BIM integration in facilities management practice

Facilities management encompasses a group of multi-disciplinary practitioners from independent disciplines who are working together to optimise the performance of the building's functions while ensuring it meets end-user's needs (Atkin & Brooks, 2009; Becerik-Gerber et al., 2012). FM functions rely on an extensive range of data and information which are usually fragmented between various disciplines. Alvarez-Romero (2014) summarizes the traditional handover process in which the FM team have often been provided with hardcopy and electronic forms of O&M manuals. Usually, these documents are provided several months after completion of the facility's construction and may also need substantial effort and time to integrate such information into FM information systems.

Traditionally, FM information is managed by dispersed information systems (e.g. CMMS, CAFM, BAS), in which data have to be re-entered many times for each FM information system, individually, and are not synchronised between systems, resulting in error-prone, inconsistent data, and consuming time and effort in the process (Becerik-Gerber et al., 2012). BIM technologies and processes facilitate FM information management throughout the facility's lifecycle phases. BIM can be used as a single source of accurate and up-to-date FM information, which is an opportunity for the FM team to reduce the cumbersome and error-prone data-entry process, and accordingly minimise facility information loss during its lifecycle (Eastman et al., 2011; Al-Shalabi & Turkan, 2015).

In a few words, BIM, with its capabilities, can act as a data pool during the facility lifecycle, including the O&M phase. However, some research has contradicted this position and concluded that the value of integrating BIM in FM is considered to be marginal, due to a lack of alignment between BIM embedded data and FM required data (Bosch et al. 2015). This view resonates with the conclusions of Kassem et al., (2015), who concede that BIM-FM integration represents a major challenge.

There are some actual case studies showing the tangible benefits of integrating BIM in FM. One of the earliest efforts to use BIM for FM was in the IFC-model-based Operations and Maintenance of Building project (Nisbet, 2008). In this project, a college building was designed using BIM and an IFC schema to capture the required FM information. The FM information was then transferred to the Maximo data structure (FM information system). The outcome of this project provided the base for the development of COBie.

Another early exemplar was the Sydney Opera House case study, where integrating BIM in FM showed the different applications of BIM in FM and underlined the need for changing the business processes and workflows. The project identified the key barrier to integrating BIM in FM, which was the lack of IFC standard support by FM tools (CRC, 2007; Eastman et al., 2011). A recent implementation of BIM for FM is in the Manchester Town Hall Complex project (Codinhoto et al., 2013). The project identified the lack of awareness of BIM potential in FM and the lack of guidelines for BIM implementation in FM as key challenges. Another case study of using BIM for FM is the existing Northumbria University campus buildings, where many challenges facing BIM in FM applications were identified.

Other examples by Dempsey (2009), revealed that there was a 98% reduction in time and effort when creating the FM database using BIM. A study by Ding et al., (2009) supports these findings and reveals that the integration of BIM in FM brought about a 98% reduction in time required for updating FM databases. Moreover, the School of Cinematic Arts at the University of Southern California (USC) may well be the first project that implemented BIM throughout the project's lifecycle in the U.S. (Smith & Tardif, 2009). This project used BIM to monitor the HVAC and electrical systems in the building (Becerik-Gerber & Kensek, 2010). Finally, the General Services Administration (GSA) and NASA are joining to integrate BIM for FM at the NASA Langley Research Center. The overall objective of that project was to test if the integration between BIM and CMMS is possible and valuable (Kasprzak and Dubler, 2012).

The overall aim of integrating BIM for FM was not to add an additional information system but to support the standardisation of data delivery, define data ownership, and facilitate data accessibility (Sabol, 2013). However, developing technologies and processes to fully integrate BIM with FM applications and data repositories will be an ongoing challenge.

Organizations will continue to implement facilities information systems and building automation systems on a parallel basis. In the future, they will be seeking opportunities for further enhancements through shared data repository to link between these different technologies and to overcome interoperability issue. BIM in envisioned to be bridge this gap and to link different facilities information and automation systems. Before exploring how BIM can do this, the next section will introduce where BIM can be implemented in facilities management.

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6. BIM application areas in facilities management

BIM offers significant potential for supporting FM practice. Following is a summary of main BIM applications in FM:

- **Locating building components:** Locating building components and equipment is a repetitive, time and labour consuming task for FM teams. Usually, the FM team depends on hard copies of documents or on their experience to analyse the problem situation (East et al., 2013). A BIM model can be utilised to visualise the location of equipment and link the items to their related data. In addition, integrating BIM with the FM database helps in providing the equipment’s maintenance history to better diagnose the problem. Moreover, safety, security and productivity could be enhanced by the real-time components being located through the utilisation of a BIM model and Radio Frequency Identification (RFID) technology (Costin et al., 2012). Lin et al. (2014) proposed the use of a barcode-based system to locate different building components.
- **Facilitating real-time data access:** To perform accurate maintenance activities, FM teams need the availability of an accessible database. BIM with its capabilities can act as a unified digital database, in which the collected data, along the facility lifecycle, could be used to establish a knowledge management database. Motawa & Almarshad (2013) incorporated the Case-Based Reasoning (CBR) technique with BIM and proposed a knowledge-based system to support O&M activities. For effective maintenance schedules, Motamedi et al. (2014) applied failure-cause detection patterns based on knowledge-assisted and BIM-enabled visual analytics.
- **Visualization and marketing**: BIM provides a more reliable method of visualising for the FM team, which enables them to conduct a what-if analysis and accordingly improve decision making. In addition, the benefits of rendering tools and walk-through options have the potential to support marketing by creating images for the interior spaces and furniture which can significantly influence the customers.
- **Checking maintainability**: BIM can support maintainability studies by addressing accessibility issues, such as examining the availability of enough access spaces for the removal/ replacement of equipment. As suggested by Becerik-Gerber et al. (2012), BIM-based maintainability studies are related to the following areas: preventive maintenance, accessibility, and sustainability of materials.

- **Creating and updating digital assets:** Usually, when the project is constructed and handed over to the client, digital assets are manually prepared and transferred to the FM systems, in which they tend to be error-prone. BIM offers the opportunity to capture, digitise and automatically transfer the required assets' data efficiently. The digital assets include equipment and systems such as manufacturer/vendor information, HVAC information, and documents include warranties and specifications.
- **Space management**: Space management includes assigning spaces, forecasting requirements, and streamlining the moving process. The types of required information for these activities are related to space descriptions, numbers, boundaries, areas, etc. Traditional CAD files were used to present this information, in which deficiencies occur. A BIM model can visualise space and host spatial attributes, which helps in recognising underutilized spaces, estimating space requirements, and conducting space analysis.
- **Planning and feasibility studies for non-capital construction:** a building continuously changes based on the end-user's requirements and deteriorates due to many factors, including the weather; this ends with the need to renovate. A BIM model can be used to help with the renovation of a facility. In addition, the extracted historical data of the facility, such as material specifications and cost could be used as a reference for the planned work.
- **Emergency management**: In the case of an emergency, the most important priority is the availability and accessibility of information. BIM can support emergency responders in identifying and finding possible emergency problems and locating hazards through its graphical interface. A BIM model can also help in simulating emergencies to develop a response plan.
- **Controlling and monitoring energy:** Usually, energy management systems are used to control and monitor a facility's energy consumption. These systems are working individually and are not compatible with other FM systems. The BIM model's graphical interface and its linkage to building sensors, metering and sub-metering information could allow automated control and real-time monitoring of data. Using BIM with an understanding of occupant behaviour can help apply 'what-if' scenarios to analyse and simulate energy systems' performance.
- **Personnel training and development**: Traditionally, training is conducted through several methods, including: presentations, site visits, hand-by-hand demonstration, and self-study, which is considered a time-consuming process. The BIM model can allow trainees to

virtually walk through the model and, therefore, help them gain a better understanding of assigned zones.

There are several applications for BIM in facilities management. Among these several applications, the main drivers for using BIM in FM is improving the handover processes. Data and information collected through a BIM process during the building lifecycle will reduce the cost and the time required to collect and build FM systems (even with current interoperability challenges). BIM will also eliminate the need to duplicate information in downstream FM systems.

To better capture the value of implementing BIM-enabled FM, the following two sections are highlighting the benefits and challenges of BIM implementation in facilities management.

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7. Benefits of BIM for facilities management

AEC/FM practitioners are constantly seeking new technologies and approaches to gain a competitive advantage in the current challenging economies and competitive markets. According to Baladhandayutham & Venkatesh, (2012), AEC/FM should improve its performance efficiency and productivity and needs to be more client-centred. The use of BIM technologies is seen to be a promising tool for the AEC/FM industries to enhance their performance and competitiveness. The benefits of utilising BIM in the facility lifecycle are well acknowledged. According to Azhar et al. (2012), the essential benefit of utilising BIM in FM is that it delivers accurate information about the facility’s spaces, components and systems in which these types of information can enhance the efficiency of the FM practices.

Eastman et al. (2011) identified many benefits of utilising BIM during the O&M phase, which are as follows: (1) improving the commissioning and handover process of FM data; (2) enhancing FM practices by providing an accessible bank of information that can be analysed, exchanged and updated, and (3) integration with FM systems through different software packages, such as ‘FM: Interacts’ and ‘FM: Systems’.

Langdon (2012) details a number of benefits of BIM in the FM field, which include; (1) creating an FM database automatically using the BIM as-built model; (2) enabling FM costing and procurement, and (3) enabling real-time updated facility information to be available by updating the BIM as-built model through the facility lifecycle.

Kasprzak & Dubler (2012) believe that BIM has become a successful tool for handing over accurate information which supports FM teams in the decision-making process. However, Changyoon et al. (2013) recommend that for successful FM practices, an effective information management of the facility’s information needs to be implemented throughout each stage of the facility’s lifecycle process. It can be challenging to collect and store facility data and make them available to FM systems. This is where BIM has an opportunity to improve FM practices, as it enables maintenance information to be accessed and linked to its related component, as well as enabling speedy identification of any problem area by using BIM’s visualisation capabilities. Codinhoto et al. (2013) point out that BIM enables the FM team to perform a what-if analysis technique, which saves effort and time spent looking for accurate relevant information. Moreover, Kelly et al. (2013) outline the main benefits of integrating BIM in FM, which include: (1) improving the information hand-over by providing augmented manual processes; (2) improving the FM data accuracy, and (3) enhancing the efficiency of work order performance by providing an accessible bank of data which enables quick problem location and interventions.

Other valuable benefits of using BIM in FM are identified by Volk et al. (2014). These include: data documentation through the as-built model, quality control, energy and space management, assessment and monitoring, emergency management, maintenance of warranty and service information, and the ability to continuously update facility information to reduce errors in the renovation process. Similarly, Kassem et al. (2015) summarise the benefits of BIM for FM as: improvements to current information handover processes; increasing the accuracy of FM data; facilitating the accessibility of FM data; and increasing the efficiency of work order performance.

Brinda & Parsanna (2014) list several BIM benefits related to various stakeholders, who include:

1. Maintenance workers: the BIM model can reduce redundant field trips to locate problems by providing accurate field conditions and relevant maintenance information, which can reduce the cost by providing accessible information and accordingly prompt responses to work orders;
2. Building operators: the BIM model can identify and track facility equipment and accordingly provide accurate equipment inventories. It can also identify hidden facility components, maintain the facility maintenance history, and therefore enhance the facility's performance by enabling analysis and comparison between actual and predicted energy performance, and
3. Building occupants: the use of the BIM model can increase building occupants' satisfaction by decreasing the time needed for a work order response.

Arayici et al. (2012) articulate similar benefits of using BIM in FM: space planning, accurate quantification of assets such as equipment and furniture and avoiding interoperability inconsistencies among FM software. In addition, efficient space management, the existence of an accurate FM database, and accessible data for maintenance are three common reasons for BIM to have better integration with FM (Kensek, 2015).

The overall purpose of using BIM for FM is to leverage the facility's information system through its lifecycle to provide effective and efficient, safe, and healthy work environments (Jordani, 2010).

This section presented the benefits of BIM utilisation in FM. However, in the most current practice, stakeholders are not entirely implementing BIM in facilities management practices. The most current facilities management operations that use BIM, most functions still done manually even facility manager knowing by adopting BIM during operational building can decrease chance of errors and increase efficiency (Becerik-Gerber, Jazizadeh, Li, & Calis, 2012; Motamedi, Hammad, & Asen, 2014, Matarneh et al. 2019). There are several challenges yet to overcome to facilitate BIM implementation in facilities management practices. The following section shed the light on the main challenges hindering BIM implementation in facilities management.

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8. Challenges of BIM for facilities management

The productivity, cost and time reductions, and efficient information exchange benefits of BIM are generally accepted in the AEC/FM industry. Yet BIM adoption in FM has been much slower than expected (Azhar et al. 2008). A survey conducted by Becerik-Gerber & Kensek (2010) found "BIM for FM" as the least interesting topic for both practitioners and academics. Participants listed several challenges to account for this, which are: organisation-wide resistance to major change, a lack of interoperability among BIM and FM software packages, and the lack of real-case studies that support the value of BIM for FM.

The outcome of the survey agrees with the conclusions of Wong and Jay (2010) who found that even with the growing research interest in BIM, the adoption of BIM has been narrowed to specific phases of a facility's lifecycle. These authors concluded after reviewing over 50 BIM-related case studies that there was a lack of interest in adopting BIM in post-construction phases. They considered that the limited available maintenance budgets and condition of assets are the main challenges.

According to Azhar (2011), there are two types of challenges facing BIM adoption, which can be divided into two broad categories: legal and technical. The first challenge is related to the lack of BIM data ownership, responsibility and liability for updating the BIM model data to ensure its accuracy, while the second challenge is related to interoperability. This claim was backed up by Gu & London (2010) who concluded that the lack of processes for updating BIM models with as-built information is the main challenge facing BIM adoption in FM.

Becerik-Gerber et al. (2012) list a number of technology and process-related challenges:

- Unclear roles and responsibilities for loading data into the model or databases and maintaining the model.
- Diversity in BIM and FM software tools, and interoperability issues.
- Lack of effective collaboration between project stakeholders for modelling and model utilisation.
- Necessity yet difficulty in software vendor's involvement, including "fragmentation among different vendors, competition, and lack of common interests".

In addition to technology and process-related challenges, there are organizational challenges which include:

- Cultural barriers toward adopting new technology.
- Organisation-wide resistance need for investment in infrastructure, training, and new software tools.
- Undefined fee structures for additional scope;
- Lack of sufficient legal framework for integrating owners' view in design and construction;
- Lack of real-world cases and positive proof of return of investment.

Arayici et al. (2012) also highlight the lack of evidence on how BIM can support the FM decision-making process. Aguilar & Ashcraft (2013) mentioned that BIM adoption in FM depends on the understanding of the information management system between different stakeholders and suggested that this should be clarified and legally controlled. Sabol (2013) points out that the overwhelming amount of information in BIM models is difficult to be managed, updated and maintained by the FM team.

Kelly et al. (2013) also listed several challenges facing BIM adoption in FM as follows:

- The lack of tangible benefits of BIM in FM despite agreement about the potential of BIM in FM;
- The interoperability between BIM and FM technologies;
- The lack of clear requirements for the implementation of BIM in FM;
- The lack of clear roles, responsibilities, contracts and liability framework, and
- A lack of real-world case studies of BIM applications in FM.

Liu & Issa (2012) identified another challenge which was related to the lack of understanding of the end user's requirements to improve the business processes. According to Volk, et al. (2014) adopting BIM in FM has many challenges and particularly in existing facilities which include: difficulties in capturing existing data, modelling uncertain data under changing environmental conditions, and objects' relations in existing buildings. Kiviniemi & Codinhoto, (2014) found that, unlike its acknowledged benefits in the design and construction phases, there is a little hard evidence of BIM's benefits in the operation and maintenance phase.

Love et al. (2015) discussed the limited application areas of BIM in FM, and indicated that this is due to the required financial investment, interoperability issues between systems, lack of standardised tools and processes and lack of understanding of the required data for FM. Kassem et al. (2015) suggest that BIM adoption in FM has been too slow compared to other lifecycle phases, due to the lack of real-world case studies that show BIM's benefits in FM, the clients' lack of awareness and FM professional's lack of skills and understanding.

Bosch et al. (2015) explain that the added value of using BIM in FM is marginal, due to the lack of alignment between people, processes and technologies. One of the significant challenges mentioned by Ilter & Ergen (2015) is the level of understanding of the FM team, who should identify the FM required information. Similarly, Kassem et al. (2015) also stated that current BIM information for FM was insufficient and inaccurate due to the lack of a process that ensures that the model has been updated with any changes that have occurred after the design phase.

Shalabi & Turkan (2017) consider that the main challenges facing BIM adoption in FM practices are the "limited awareness of expected BIM benefits for FM among FM professionals, lack of data exchange standards, and unproven productivity gains illustrated by case studies". However, Nicał & Wodyński (2016) considered that the main barriers that are challenging to deal with are interoperability issues and cultural changes.

Ibrahim et al. (2016) summarised all the challenges identified in the literature that are slowing BIM adoption in FM practice and listed them in three main categories, which are business, legal, technical, human, and organizational.

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Adopting BIM in mainstream in FM that encompasses multiple discipline to ensure higher functionality of the built environment by integrating people, place, processes and technology. Essentially, BIM mostly used for operations phase and commercially available technologies focus on transferring information from the design and construction phase to the operation phase by enabling creation and capturing of digital facility information throughout the facility lifecycle (Akcamete et al., 2010; Volk et al., 2014). More attention is still needed to focus on solving interoperability issue between BIM and the existing facilities management systems to streamline facilities information transfer and provide an efficient facilities information management.

This section presented how BIM can be leveraged in FM practices and detailed the challenges and obstacles facing utilisation of BIM in FM. There are common challenges that have been presented in most of the research literature, which are interoperability and data exchange between BIM and FM technologies, lack of clear understanding of the required data for FM day-to-day activities and lack of real-world case studies. The next sections will focus on interoperability and the data exchange issues.

9. Data Exchange Approaches

Research on how to link FM and BIM has been conducted to overcome the interoperability barrier (Kang and Hong, 2015). Accordingly, different approaches have been developed to link BIM and FM, which suggest using one or more of the following methods (Ibrahim et al., 2016):

- Design pattern and application programming interface (API),
- Web service,
- Extract, transform & load (ETL) and data warehouse (DW),
- BIM-based neutral file format,
- Information delivery manual (IDM) and Model View Definition (MVD).

As mentioned above, there are different approaches currently being developed for linking BIM and FM to overcome the interoperability barrier. The four main approaches are:

1. **Manually and spread-sheets**: where owners are using CAFM and CMMS systems, they have two options: either to enter information manually or using customised digital spreadsheets that are compatible with the FM systems, including information from BIM data and hard copies of documents (Arayici, 2015). However, this approach is time and effort consuming.
2. **Industry Foundation Classes (IFC):** these were developed by the National BIM Standards (NBIMS) BuildingSMART, as an open, vendor-neutral and independent BIM data repository (Building-SMART-Alliance, 2015). IFC defines building objects including their geometry, properties and, relationships, to support multi-disciplinary coordination, information-sharing and exchange across IFC-compliant applications, and handover of information for analysis and other tasks (Thein, 2011). IFC is an object-oriented database that enables data sharing (through ifcXML and aecXML) to support analysis for heat loss, cooling loads, etc. and/or information handover to an FM team.

IFC has gone through a number of evolutions, the latest version of which is IFC4 which was issued in 2013 as ISO 16739:2013 (Building-SMART-Alliance, 2015). Currently, several BIM software vendors have considered IFC importers/exporters within their applications. This allows models to be imported/exported from BIM authoring applications i.e. Autodesk Revit into 5D estimating applications such as Exactal CostX (Dhillon, et al. 2014).

Redmon et al. (2012) claim that true interoperability will only be achieved when every software application being used on a project can read and write to and from a centralised web-hosted database, thus standardising the process of passing information between stakeholders and representing the latest information on the project.

However, IFC does not completely solve the interoperability problem. Some researchers have found that there is a degree of data loss during the information exchange using IFC between heterogeneous software applications (Eastman et al., 2011; Redmon et al., 2012). For example, Patacas et al. (2016) found geometry errors during the information exchange, while Motamedi et al. (2014) found that the exported IFC file of the model does not contain all the required logical relationships between the components, spaces, and distribution systems, and missing relationships have to be added manually. Other examples are presented by Yang & Ergan (2016), who revealed the limitations of IFC's representation for HVAC troubleshooting. Sampaio & Simões, (2014) who claim that the IFC format is not yet fully developed to properly implement the data exchange between BIM and FM, as they faced a problem in retaining the colour added to the model.

On the other hand, Shalabi & Turkan (2017) provided a schema that integrates corrective maintenance data in a 3D-IFC-BIM environment, and they did not report any problem. Although the IFC schema has geared the interoperability progress forward, the model does not provide an adequate condition for accurate interoperability (Sacks et al. 2010). Moreover, some applications are still not compatible, directly or indirectly, with IFC (Arayici, 2015).

3. **Construction Operation Building Information Exchange (COBie)**: this system was recently developed to support the collection of structured information during the design and construction phases and handover to the FM team (East et al., 2013). Although COBie looks promising for resolving the interoperability barrier between the design and construction phases and with the O&M phase (Open-BIM-Network, 2012), COBie "does not provide details on what information is to be provided, when and by whom" (East & Carrasquillo-Mangual, 2013).

   However, the main problem with COBie is that it is seen as a spreadsheet rather than an .xml-based information exchange (John et al. 2013). Apparently, an FM team may require more information than the information COBie can provide. Several studies have shown its capabilities if used during the early design and construction phases. For example, Lavy & Jawadekar (2014) conducted a study using three case studies where BIM and COBie were used. Their study concluded that BIM and COBie should be started earlier in the design phase. Although COBie outlines the required information specifications, it is static and should be extended by the professionals based on the project's requirements in the FM phase. Furthermore, COBie's capability related to spatial and system decomposition information is limited (Ilter & Ergen, 2015).

In addition to COBie, there are a number of different information exchange standards under development, such as 'Building Automation Modelling information exchange', 'HVAC information exchange', 'electrical system information exchange', 'lifecycle information exchange', and many others which are being developed (Building-SMART-Alliance, 2015).

4. **Proprietary Middleware**: this is a customised computer software provided by a single software vendor. This approach enables two independent systems (BIM and FM) to interact by providing a single information source and updating information systematically. This approach links BIM and FM systems (bi-directional link) using API, web services, design patterns, and a BIM-based neutral file format such as IFC and COBie. However, it is costly, complex, and its implementation is fixed during programming in the proprietary middleware approach (Kang and Choi, 2015). One of the most effective proprietary middleware packages for BIM integration in FM in the real-world market is "Ecodomus".

The inherent power of BIM for FM is mainly associated with streamlining information flow between the project stakeholders during the facility lifecycle and facilitating information handover to FM teams (Matarneha et al., 2018; Reza Hosseini et al., 2018). Yet information flow among project stakeholders is neither automated nor seamless. There are still technical issues to be overcome: mainly identifying the required FM information for data exchange purposes and boosting interoperability between BIM and FM systems (Gao and Pishdad-Bozorgi, 2019; Matarneha et al., 2019; Yalcinkaya and Singh, 2019).

Although standard data formats are capable of exchanging data between different platforms, particularly IFC and COBie schemas, the data exchange process between BIM and FM systems using open standard data formats is not a straightforward process. For example, the integration between BIM and the computer-aided facility management (CAFM) system has been actively criticized for inadequate data interoperability, particularly the inability to transfer semantic FM information properly (BIFM, 2013). The next section will discuss in depth the interoperability issue between BIM and FM systems.

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10. Interoperability

Throughout a facility's lifecycle, there are different stakeholders, resulting in various interactions, which makes the need for interoperability essential (Grilo and Jardim-Goncalves, 2010). Interoperability is defined as the ability of two or more systems or components to manage and exchange information to enable automation in information flow and to avoid the system errors resulting from manual data re-entry (Gallaher et al., 2004; Grilo & Jardim-Goncalves, 2010). In short, interoperability enables different vendors to share data within a heterogeneous environment with independent parties who share a common data model (Arayici et al., 2011).

Gallaher et al. (2004) point out that when interoperability problems occur, they form a fragmented organisational structure and business process. The estimated cost of inadequate interoperability of the U.S capital facilities supply chain in 2002 was $15.8 billion, where two-thirds of this cost was borne by owners and operators. According to the U.S. Census Bureau Report 2004b, the value of the capital facilities in the U.S in 2002 was over $374 billion. This means that even a small improvement in efficiency could achieve substantial economic benefits.

Comparing the associated costs of the O&M phase, it has higher costs than other life-cycle phases. This is due to the fact that information management and accessibility hinder efficient facilities operation. The major costs of inadequate interoperability for owners and operators are at the operation and maintenance stage, where the major costs of this stage are under the mitigation costs, which are usually incurred by owners and operators. Mitigation costs are the costs associated with the manual re-entry of information, information verification, and rework due to incorrect information, while avoidance costs are usually incurred by general contractors which are the costs associated with the use and maintenance of redundant information technology systems (i.e. training, IT support, data transfer and sharing). Quantified delay costs are mainly incurred by owners and operators. Inadequate interoperability issues in the capital facilities industry arise from the fragmented nature of the construction industry, the traditional practices which continue to be paper-based, a lack of standardization, and inconsistent technology adoption among stakeholders (Gallaher et al., 2004).

Interoperability is the key underpinning of BIM, since it enables participants from different disciplines who are using different applications of software to share information and work collaboratively (Cheung et al.. 2012). This collaboration cannot be achieved without having accurate and complete information, including specification, geometric shape, parametric properties, assembly data and the overall design intent (Eastman et al., 2011).

The AEC/FM industry has recently started looking for solutions to embrace software systems that support interoperability; nevertheless, they are lagging behind other industries (Shalabi & Turkan, 2017). Furthermore, interoperability between BIM and existing FM technologies is one of the main challenges in implementing BIM in FM practice and this is due to the diversity between the BIM platforms and the FM platforms (Ibrahim et al., 2016; Shalabi & Turkan, 2017).

The area of interoperability for BIM and FM is an ever-growing research domain. A number of researchers, FM practitioners, professional organizations and software vendors are focusing their efforts on overcoming the interoperability challenge by introducing a set of universal open data standards, such as the IFC and XML schemata, and COBie and its subsets, to facilitate data exchange (Sabol, 2013).

Although there are many solutions currently available which have made the BIM for FM process a reality there are still some ongoing challenges related to extracting information from BIM directly to CAFM systems, lack of interoperability between software applications and information overload.

At present, there is no ‘one size fits all’, and such a solution seems distant. Seamless interoperability does not yet exist (Grilo & Jardim-Goncalves, 2010; Ibrahim et al., 2016). Accordingly, well-established concrete strategies for the successful data exchange, interoperability and integration of the FM required information are required to overcome the interoperability problem and provide a seamless data exchange process (Kensek, 2015; Kassem et al., 2015; Ibrahim et al., 2016).

This section discussed the interoperability between different BIM and FM platforms, the industry still needs to provide more practical solution to streamline information exchange process between the various BIM and FM software applications. The next section will present the teaching map for BIM-Based facility management for undergraduate or postgraduate students.

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11. TEACHING MAP OF BIM-BASED FACILITY MANAGEMENT

In order to teach BIM-Based facility management to undergraduate or postgraduate students, the teaching process should be systematic to enable students to absorb the required theoretical knowledge before moving to the practical and sophisticated applications. Following steps should be followed to prepare/adapt BIM-Based facility management in educational institutes:

- **Teaching the Whole Life Cycle Costing (WLCC):** WLCC comprises of three main terms, which are capital cost, operating costs and the income, therefore, students should be aware of the traditional methods to calculate capital and operating costs before using BIM to implement the same process.
- **Teaching 5D BIM implementation process to calculate the capital cost:** Once students understand all essential theoretical knowledge, 5D BIM can then be introduced systematically through (1) teaching the process of retrieving cost information from the 3D BIM model, (2) teaching how the retrieved cost data (i.e. BoQ) can be used to estimate the

whole project cost, (3) teaching how the estimated cost can be used with other BIM documents such as 4D BIM to develop the project budget.

- **Teaching the utilization of BIM to estimate the operating cost:** 6D BIM refers to the facility management and sustainability using BIM tools, therefore, students should be introduced to a set of tools such as Revit and CostX.
- **Teaching the advanced BIM tools and other advanced technologies to automate the calculation process:** Since BIM can be integrated with several technologies such as blockchain and Internet of Things (IoT), it will be useful to show how BIM can be enhanced by using these technologies such as tracking the performance of an asset using the IoT.

12. Summary

This chapter has presented a general insight regarding the current FM information systems and highlighted the need for BIM integration in FM practices. It is believed that BIM can leverage FM performance and reduce the costs of the longest and most expensive phase – the operation and maintenance phase. To achieve this, information management should be considered as a priority to provide facility managers with the required information to enable them to work efficiently. BIM as a data pool is a promising tool for facilities management teams which can provide them with all required information for their day-to-day activities. However, to achieve successful integration of BIM into FM practice, several challenges have to be solved, of which the main challenges to be overcome are information exchange and interoperability between BIM and FM systems.Questions:

1. How BIM can enhance FM practice?
2. Name three facilities management systems.
3. What is the overall aim of integrating BIM in FM practice?
4. Name three BIM applications in FM practice.
5. What are some of the benefits of BIM integration in FM practice?
6. The main challenge facing BIM implementation in FM is?

7. Name three approaches to transfer information from BIM to FM systems.

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