IS THE AGE OF FACILITY MANAGERS' PAPER BOXES OVER?

Pouriya Parsanezhad[1], Väino Tarandi[2]

Abstract

Seamless and accurate hand-over of building information is a major bottleneck in promoting an automated facilities management (FM) practice and an integrated and life-cycle-oriented construction. Few Building Information Modelling (BIM) tools have so far been developed specifically for facility managers. Current data input methods applied for conventional Computerized Maintenance and Management Systems (CMMS) are prone to duplicate information entries and information loss. Such an approach to data management builds up additional costs and seriously hampers fulfilment of environmental goals.

In search of a thorough acknowledgement of both technical and process-based requirements for dealing with the aforementioned deficiencies, this descriptive theoretical study takes a qualitative approach and focuses on status quo and potentials for migration of building information and analytical capabilities from AEC-centric BIM tools to facility managers, owners, and users. Data has been collected mainly through literature and workshops. It has been complemented by a number of exploratory studies on existing technologies. This is a basic research aimed at illuminating the path for further applied research activities.

Results show that the bulk of the FM sector still confronts substantial challenges regarding appropriate access to building information that is often caused by deficiencies with current workflows, contracts, and IT infrastructure. Thorough implementation of established and developing standards such as IFC and COBie to be used in BIM-enabled FM systems entails a complete shift from as-designed and as-built documents to their as-commissioned and as-operated successors. In an interoperable FM information system based on or closely connected to post-constructional BIM technologies, performance data, and sensor data from Building Automation Systems (BAS's) will be cycled back to inform both better design and better operation.

Keywords: FM:BIM, facilities management, BIM, CMMS, FM:BIM:BAS

[1] Ph.D. candidate; Department of Real Estate and Construction Management; The Royal Institute of Technology (KTH); Brinellvägen 1 100 44 Stockholm; pouriya.parsa@abe.kth.se.
[2] Professor; Department of Real Estate and Construction Management; The Royal Institute of Technology (KTH); Brinellvägen 1 100 44 Stockholm; vaino.tarandi@abe.kth.se.

1. Introduction

The final destination of any construction project is its operation phase. Facilities management (FM) activities during the operation phase are key contributors to sustainable performance of the building (Ding et al., 2009). By average, every building operating firm annually spends $15 to $20 per square meter for energy purchase (Hodges & Elvey, 2005). Therefore, building owners increasingly strive for better control over resource utilization rates of their facilities (East, Bogen, & Rashid, 2012) aiming for a more economic, environment-friendly, and optimized FM experience. An efficient FM practice is also an influential business enabler that substantially increases corporation's return on investment (ROI) (Ding et al., 2009).

Implementation of Building Information Modelling (BIM) throughout the entire life cycle of the building benefits the owners the most among all stakeholders by significantly increasing the value of the information in their possession (Figure 1) and accruing the amount of ROI via an integrated project delivery process realized by use of BIM (Eastman, Teicholz, Sacks, & Liston, 2011; Khemlani, 2011; Sabol, 2008). The life cycle approach to building modelling and the ability for using the BIM model after design and construction also through the operation and maintenance (O&M) phase has been emphasized by many scholars (Tarandi, 2012; Khemlani, 2011; Young, Jones, & Bernstein, 2008).

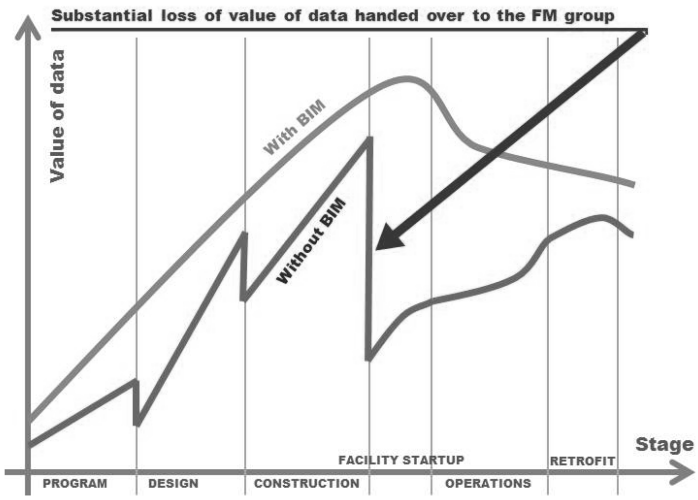

Figure 1: Comparative diagram of building information value degradation through the entire life cycle of the building with and without deploying BIM tools (after Eastman et al., 2011, p. 153).

The aim is to eliminate the delays, confusion, and inaccuracy generated by traditional O&M documents namely as-built drawings, O&M manuals, maintenance schedules, room datasheets, asset performance data documents, and cost datasheets in either paper format or static digital formats such as Portable Document Format (PDF) and scattered spreadsheets (Schevers et al., 2007). This enables the owners to make intelligent and informed decisions in the pursuit of strategic management e.g. choosing between in-house and external contractors and suppliers for specific services (Ding et al., 2009; Young et al., 2008).

1.1. Background

While the dominant challenge of recent decades for facilities knowledge management practitioners has been replacing paper documents by digital equivalents, now they seem to be keen to go even one step further towards more intelligent and interoperable tools and techniques by fully expelling manual data entry and retrieval work. Moreover, the ever-increasing capacity of computers perpetually underpins development of more complete and accurate building models (Ding et al., 2009) and FM systems.

Advert of BIM in building design and its propagation to construction both demanded and facilitated a better coordination and automated interaction among *as-designed* and *as-built* documents (Owen, 2009) and a reconciliation among design-intent and construction-intent building models (Young et al., 2008). The final destination is however gradual promotion of current BIM models to be also deployed as *as-commissioned*, *as-operated,* and *as-maintained* models (Ding et al., 2009).

There are a handful of success stories regarding use of BIM in FM: In the case of the Coast Guard Facility Planning, implementing BIM surprisingly helped reduce the time and effort to construct and update the FM database up to 98% (Eastman et al., 2011). The Sydney Opera House (SOH) is one of the most prominent examples of application of a BIM-enabled FM system (Ding et al., 2009). The integrated FM system for SOH is based on a spatial breakdown order of the facility components including location zones, functional spaces, stories, and rooms and subsequently propagating this hierarchical ontology to data exchange streams among various tools and databases (Schevers et al., 2007). A central data repository was created to accommodate all objects and their relationships (Sabol, 2008). Yet, such examples are not ubiquitous and do not represent the mainstream (Khemlani, 2011). Owners have traditionally been and still are far behind other actors in building industry with regard to use of BIM (Young et al., 2008).

1.2. Scope of the study

Facilities Management may cover a wide temporal and disciplinary range of activities ranging from ordinary O&M jobs through financial asset management, operation simulation, and performance monitoring to major refurbishments and upgrades (Eastman et al., 2011; Ding et al., 2009). From a *scale* point of view, it will be more appropriate to replace the term *facilities management* by its broader counterpart, *property management* where underground utility systems, parking lots, roads, drainage structures, and grounds are also included (Sapp, 2011).

A variety of disciplinary actors are involved in facilities management namely O&M directors, facility managers, facility engineers, O&M planners, maintenance supervisors, craftsmen, tradesmen, and janitorial, custodial, and housekeeping staff. Investigated characteristics of the BIM-enabled tools for FM such as user-friendliness, functionality, and interoperability are therefore studied and assessed with regard to the aforementioned user groups and the degree and scope of their need for building information.

The scope of this study is an analysis of BIM-enabled tools for facilities and operation management. *Owner* is alternately used instead of the *facility manager* agent of the owner. Among the variety of fields influencing use of BIM in FM, this study prioritizes and focuses on implications of information technology and building information modelling tools and techniques.

1.3. Our goal

This articles aims to report a thorough study on the importance, implications, and issues of implementing BIM-enabled tools in the facilities management and operation phase of the building's life cycle. Findings can be used for orienting and providing further applied research activities in the field with a comprehensive theoretic insight. The term "BIM-enabled" refers to those applications that are capable of interacting and exchanging information with BIM tools. As a matter of practicality, the term "BIM-enabled FM systems/tools" is alternately replaced by "FM:BIM systems/tools" in this paper.

1.4. Methodology

This basic research is a descriptive theoretical study totally based on the data collected from existing literature and complemented by inputs from workshops, interviews, webinars, face-to-face and online conversations, and exploratory studies on existing tools and technologies. In the closing sections of the article (*Solutions* and *Conclusion*), a qualitative comparative approach is taken for evaluating existing tools and applications.

2. BIM for facilities management

A BIM-enabled FM system dramatically enhances maintenance, business, and benchmarking processes (Mitchell, Ballesty, Drogemuller, Schevers, Linning, Singh, & Marchant, 2007) even at such highly detailed levels as inspection, updating, and recording of fire-rated walls and sealant condition between tiles (Ding et al., 2009). East et al. (2012) contend that FM-enabled tools are much more efficient for evaluation of environmental performance of buildings compared with methods such as *energy-reduction targets* and *checklists*. BIM solutions for FM (FM modules) are often developed in-house or by third-party developers (Khemlani, 2011). No BIM application is capable of undertaking the entire diversity of FM activities mentioned above. Instead, FM:BIM tools are in most cases designed to communicate, interact, and exchange data with domain-specific knowledge management FM systems.

Applications of BIM in FM can be alternatively categorized into the following groups of activities: **facility / property strategic management, financial management, building performance evaluation, cleaning services, end-user services, security schema, and renovation planning and management** (Jokela, Laine, & Hänninen, 2012; Eastman et al., 2011; Schevers et al., 2007). These major categories can in turn be broken down to activities such as move management, data mining, room scheduling, lease management, tendering, risk management, long-term planning, communication, operation simulation, management of maintenance, inspection planning, condition management, repair management, document management activities, financial operative planning, budgeting, and budget follow-up, monetary transactions, accounting, and pro-forma analysis. The aforementioned can be addressed, enhanced, and optimized using BIM.

2.1. Performance evaluation

Evaluation of program compliance, real-time monitoring of building performance, energy and environmental assessment, survey of hazardous wastes, consumption monitoring, sensor and control monitoring, and change tracking are some components of building performance evaluation. BIM helps automating registration of the variety of operational data pertaining to general appearance, tidiness, and cleanliness of rooms and spaces. Such data are regularly collected for evaluation of building performance. Timed values of *Building Condition Index* (BCI) are composed of *Building Fabric Index* (BFI) and *Building Presentation Index* (BPI) subcategories (Schevers et al., 2007). These are normally registered in a percentage-based scoring format in corporation's *Computerized Maintenance and Management System* (CMMS) (Sapp, 2011) and are deployed for contractual purposes. Ding et al. (2009) also mention *Key Performance Indicators* (KPI) criteria that are used for the purpose of internal benchmarking. KPIs address multidimensional non-financial parameters such as services quality, facility condition, energy consumption, accessibility, security, and response to urgent work (Ding et al., 2009; Mitchell et al., 2007). Implementation of tablets and Smart phones instead of printed forms for collecting data to populate BFI, BPI, and KPI databases will enhance automation of FM and further accelerate development of integrated FM:BIM applications.

2.2. BIM for operating and maintenance management

Operating and maintenance actions are performed on a daily basis in order to sustain the quality of acquisition of both fixed and dynamic facility and equipment assets in a way that they truly perform their intended function (Sapp, 2011). Incorrect, fallacious or non-optimized operation routines may result in unnecessary downtime, voiding warranties, and reduced service time of facilities and expected useful life (EUL) of their fixed assets (Sapp, 2011).

It is sometimes more practical to fully differentiate among digital systems that are used for maintenance and the rest of FM activities. In the case of Sydney Opera House, for instance, computer-aided facilities management (CAFM) and computer-aided maintenance management (CAMM) systems are devised as two separate sets of applications (Schevers et al., 2007). All in all, in order for an FM:BIM application to efficiently administer the operation phase of a building, the variety of facilities operation and maintenance activities e.g. reactive, predictive, and preventive maintenance should be addressed in the system and mapped onto a detailed schema encompassing their work order breakdown.

3. Shortcomings

Owners' cost estimations often include contingencies as high as 5-50% (Eastman et al., 2011); expenses that can be avoided by implementing an accurate, reliable, and information-rich building model for a more thorough control over financial resources prior to and during operation of the building. Yet few BIM-enabled tools have been developed specifically for owners (Eastman et al., 2011); while owners are exposed to the biggest loss among all stakeholders in building industry for inadequate interoperability and confronting errors and inaccuracy when using BIM (Young et al., 2008).

Problems that arise in sustaining a smooth flow of information through the entire life cycle of the building to the operation phase can be classified in the three areas of **workflows**, **contracts**, and **information technology**. This categorization is derived from a recapitulation of the variety of issues declared in the literature and can roughly be aligned to Owen (2009)'s three alleged industry foundations underpinning IFC standard: *processes*, *people,* and *technologies*.

3.1. Workflows

In general sense, throughout the varieties of disciplinary and sequential branches of AEC industry, change of workflows is perpetually recommended for acquisition of the full merits of BIM (Eastman et al., 2011; Young et al., 2008). Traditional work order sequences are quite time-consuming and inefficient. According to Eastman et al. (2011), payments to the employees who work with FM account for 92% of the life cycle costs of a building. Improvement of daily FM routines by means of insightful data management tools will dramatically cut such expenditures over time.

A major part of investments in operational phase corresponds to data inventory required for issuing and implementing scheduled and non-scheduled O&M work orders. There are indications that a 28% cut in the time spent on O&M work order process is perceived by use of BIM in the facilities management phase (Forns-Samso, 2010); yet further field studies, surveys, and interviews with practitioners are needed to confirm this finding. Short-sightedness of the owners is quite often mentioned as the main factor that impedes such an auspicious gain (Eastman et al., 2011). Khemlani (2011), too, notices the need for changing mind-sets of FM professionals. Established roles and practices, risk avoidance, short-term business relationships, document-based thinking, and silo mentalities (Owen, 2009) are major hindrances against improving and enhancing FM business processes using BIM.

3.2. Contracts

Drifting towards more collaborative and informed workflow configurations in building industry demands for new types of contracts. Some take on to mandate an integrated approach to design and construction, namely *Integrated Project Delivery* (IPD) (Eastman et al., 2011). In order that the owners can genuinely benefit from BIM, a number of changes in deliverables of design and construction business activities should be realized. As-built deliverables to the client and specifications should be substituted by updated as-built BIM models (Jokela et al., 2012; Eastman et al., 2011). It requires that owners are sufficiently perceptive about virtues of BIM and motivated and prepared to receive BIM models instead of traditional documents. Elsewise, consulting and construction bodies will end up in cumbersome and iterative workload of transforming their BIM models into traditional 2D documents which is a loss of time and money.

Problems associated with ownership of the building model should also be tackled in contracts. This entails introduction and implementation of contract forms radically different from traditional ones (Khemlani, 2011). Tarandi (2012) and Owen (2009), too, emphasize the importance of intellectual property management for promoting integrated design and delivery solutions.

3.3. Information technology and building models

Using traditional FM database systems and cumbersome manual procedures of setup of FM database systems, integration of FM with back-office systems and occasional use of outdated as-built documents are among the most serious loss-making factors for building owners during the post-construction era (Eastman et al., 2011; Smith & Tardiff, 2009). Disparate commercial FM applications should yet undergo sizable changes to be capable of receiving the full magnitude of building data from BIM models (Mitchell et al., 2007).

Failure in efficiently coupling BIM and FM systems is partly due to data handling issues. The inability for integrating diverse and sometimes redundant data sources is normally caused by inadequate interoperability which is in turn triggered by issues with standards and file formats (Eastman et al., 2011). Traditional space identification methods such as polylining should be replaced by more intelligent transfer of building information to FM (Khemlani, 2011). Besides, FM applications have been repeatedly criticised for not having graphical interfaces (Sabol, 2008). Competitive commercial interests, too much focus on technology rather than construction, and costly and time taking development procedures are some of the hurdles with developing virtuous digital FM:BIM solutions (Owen, 2009).

Deficiencies of BIM tools, FM applications and mediating software packages do not represent the full picture. Scarcity of information systems that are capable of embracing various data types through the entire life cycle of the building is also a major issue (Tarandi, 2012). Advert of even more sophisticated operational equipment, namely Building Automation Systems (BAS) further increases the need for more intelligent FM:BIM tools (Sapp, 2011). In practice, a considerable number of facility managers deactivate their sensor systems since owners cannot afford the high expenditures of purchase and use of data processing tools (East et al., 2012).

4. Solutions

The ultimate integrated FM:BIM solution should encompass a federated array of minor solutions for the problematic areas mentioned above. Owners’ constant supervision over the building process e.g. by means of IPD contract frameworks facilitates an integrated building design, construction, and operation practice (Young et al., 2008). This helps satisfying the client’s requirements and insures program compliance of the final product. Training FM staff also helps benefiting the most out of the built facilities (Sapp, 2011). This is however more a general prerequisite for a healthy FM practice indifferent of how informed and automated FM systems are and is thus not pertinent for the purpose of this study.

Development of IT-based initiatives is the lowest-level category of FM:BIM solutions, yet a substantial requirement which is the main focus of this study. Generally speaking, FM:BIM systems should be scalable and flexible enough to allow change in business plans. They should also be based on a flexible and extensible semantic system and ontology structure, since ontologies at different corporations are developed and enhanced so as to clearly address spatial decompositions of those firms and truly satisfy those corporations' specific business needs (Schevers et al., 2007; Mitchell et al., 2007).

4.1. Standards

As mentioned above, non-standard data transfer formats account for a large share of parted and non-compatible design, construction, and operation data authoring and management systems. Tarandi (2012) suggests that a building data model supporting Product Life Cycle Support (PLCS) is the key to a life cycle approach to building information management. Implementation of such systems requires established standards for building data models such as IFC and COBie.

4.1.1. IFC for FM

The most salient example of non-proprietary and object-based building data models is *Industry Foundation Classes* (IFC) which aims to help make the data more future-proof (Mitchell et al., 2007; Khemlani, 2004). IFC is developed by the international non-profit organization, buildingSMART and is a semantically rich model that bears the capacity for whole facility life cycle management. According to Schevers et al. (2007), the very first generation of IFC-compliant FM systems were already available half a decade ago.

IFC already supports FM activities such as performance evaluation, procurement, and service delivery (Mitchell et al., 2007). Sabol (2008) asserts that implementation of IFC fostered faster and more efficient FM practices at SOH in a variety of ways including sharing and reusing data by all contractors and staff, providing analytic capacity for design of upgrading and refurbishment projects, providing the ability for whole-life-cost-estimation thus better control over building performance and environmental data, and the ability for tighter budget planning. The ultimate IFC-compliant FM systems should also enable automated integration of the data in BFI, BPI, and KPI into the BIM model.

A very basic requirement of building modelling for use in FM is that native BIM models produced during design and construction phase can be exported to workable and accurate IFC files. Nevertheless, IFC models can never completely replace original disciplinary BIM models (Jokela et al., 2012). IFC-compliant viewers are greatly useful for owners / FM managers when used in combination with FM systems. TeklaBIMsight, Autodesk Navisworks, and Solibri Model Checker are some examples (Jokela et al., 2012). Furthermore, a variety of IFC-compliant data analysis tools including energy prediction models have been in place for a long time (Mitchell et al., 2007). Integrated implementation of IFC-compliant and semantic web applications (e.g. RDF and OWL) is a suggested approach for developing automated and informed FM knowledge management tools (Schevers et al., 2007).

4.1.2. COBie

As in any other multi-disciplinary career, a set of standardized data exchange protocols are required for facilitated handover of building data through sequential stages to the operation phase. Such standards will guarantee that the building information produced during design and construction by architects, contractors, and subcontractors will eventually be available and accessible for the FM team (Jokela et al., 2012). In search of a solution for regulating FM-specific data provision requirements, the COBie initiative (*Construction Operations Building information exchange*) was developed at CERL Lab of the Engineering and Construction Department of the U.S. Army Corps of Engineers (Young et al., 2008). COBie is an open data transfer specification for initiating registration of the information needed for FM early in the design and construction phase (Sabol, 2008).

A fundamental principle of COBie is that the designer should provide a set of conceptual information such as flow, space, and equipment layouts in the form of a BIM model, while the contractor complements it with more specific and market-based data namely make, model, and serial number (Eastman et al., 2011). Data that are not needed in the BIM model are delivered to the owner in the form of COBie documents i.e. low-level formats such as Excel spreadsheets (East & Carrasquillo-Mangual, 2012; Khemlani, 2011). The overall rationale behind the necessity for supplementing IFC with additional standards such as COBie is in fact what Tarandi (2012) articulates as not all types of information being manageable and transferable via neutral formats and geometry-based building models.

The main obstacle against discipline-wide implementation of COBie is provision of clear description of practical routines for evaluation and validation of deliverables and checking for discrepancies among COBie documents delivered by different actors at different stages. Moreover, problems with conflicting names will not be fully lifted before global standards such as International Framework for Dictionaries (IFDs – also termed as buildingSMART Data Dictionaries) are in place. More clarification is required on how to replace more detailed and more precise data in updated COBie sheets in practice as the project progresses.

4.2. FM:BIM tools and applications

Efficiency and profitability of an FM tool can be evaluated by meticulously measuring parameters such as the number of work orders per year, average time spent on work orders, ease of access to information, and accuracy of as-built / as-operated information (Forns-Samso, 2010). FM applications are often termed as Computerized Maintenance and Management Systems (CMMS). The most commonly used CMMS's are IBM Maximo, TMA, FAMIS, FM:Systems, Facilty Link, Facility Focus, Archibus, AssetWorks AiM, Vizelia, and Rhyti (Khemlani, 2011; Schevers et al., 2007). Not all of these are yet fully compatible with BIM applications.

As in the case of building modelling applications, a variety of proprietary FM:BIM tools have been introduced by prominent market actors namely Autodesk's FMDesktop (linked to Revit), Graphisoft's ArchiFM (connected to ArchCAD), and Bentley Facilities (built on top of MicroStation and linked to ProjectWise) (Khemlani, 2011).

4.2.1. FM:BIM:BAS tools and applications

One of the most recent approaches to FM:BIM is the mixed software / hardware solutions for also integrating sensor data to FM:BIM systems suggested by Cahill, Menzel, & Flynn (2012). They suggest a combined use of object-oriented and web-based ITOBO platform together with BiMserver data repository (van Berlo, Beetz, Bos, Hendriks, & van Tongeren, 2012) and Oracle's Berkeley Database. Information Technology for Optimized Building Operation (ITOBO) is a project conducted by a consortium of Irish and international agents from academia and industry including University College Cork and Environmental Research Institute. This initiative seeks solutions for integrating data such as CO2, humidity, lighting, wind speed, total, and diffuse solar radiation, air velocity and water flow sourced from wired and wireless sensors into the BIM system. The aim is automating FM practices to better satisfy specific business needs. Cahill et al. (2012) refer to documentation revision control and timed meter readings as two essential functionalities of the FM:BIM tool of tomorrow.

Sensor Fusion Platform initiative, introduced by East et al. (2012) follows a similar thread. The core idea is implementing a sensor data capturing system coupled by the open-source BiMserver engine and oBIX-based OX Framework. Onuma System's solution is another example that implements COBie format and benefits cloud computing for a faster and more collaborative building data management. They have developed platform-accustomed applications for smart-phones and tablets as well as a BIM tool for data exchange with BAS's (Khemlani, 2011). EcoDomus' products are perhaps the most interoperable contemporary FM:BIM solutions which are also coupled with BAS's (We refer to such integrated systems as FM:BIM:BAS systems in this article). They serve in fact as links among FM:BIM and CMMS tools. EcoDomus tools are compatible with a variety of BIM models, Geographic Information Systems (GIS), and BAS's, namely Revit, Bentley BIM, and IBM Maximo. They are COBie-compatible and also cover the construction phase – something that was missing in Autodesk and Graphisoft's FM:BIM solutions (Khemlani, 2011).

5. Conclusion

The user should be able to access O&M manuals, specifications, performance data, parts list, schedules, and relevant CMMS features right in the BIM model in a non-complicated, flexible, scalable, and visual fashion. However, creating a full scale FM:BIM system is neither feasible nor wanted (Schevers et al., 2007); rather – as in the case of contemporary FM:BIM and FM:BIM:BAS tools - an efficient integrated FM:BIM system would most probably be composed of a set of loosely coupled software applications with web-based interfaces where the FM application is capable of bidirectional exchange of data with updated as-built BIM applications. A BIM in sync with the latest building performance data further strengthens reliance on and use of BIM systems by all actors (Cahill et al., 2012).

A fully functional FM:BIM integration should also be usable for minor and major refurbishment construction works by enabling analysis of technical criteria such as structural feasibility, acoustic outcomes, smoke management in fire mode, etc. (Ding et al., 2009; Sabol, 2008). The ability of directly seizing the timed values of BPI, BFI, BCI, and KPI criteria as well as sensor and control data from BAS's underpins such an approach. This assortment should be complemented by a central BIM repository that performs document submission management and automated, yet controlled synchronization of documents throughout the entire life cycle of the building including facilities management and operations phase (Tarandi, 2012). The shift from proprietary and vendor-specific solutions to FM systems that are compatible with open standards for building data is thus a central requirement.

A more comprehensive outline for FM:BIM applications, however, requires a more thorough evaluation of effectiveness of contemporary FM routines, problematic areas, and the true sources of such deficiencies by means of interviews and surveys. The O&M staff is usually one of the best sources of information on how existing facilities are performing and how new equipment should be incorporated for a more efficient use of assets and raised ROI's (Sapp, 2011).

While maintaining the linkage among GIS and BIM applications is perhaps the most challenging area from a *scale* point of view, FM is at the time the final frontier of BIM from a *life cycle* perspective (Khemlani, 2011). The moment appropriate tools are in place and ubiquitously used by all actors, facility managers' paper documents will become obsolete the way their counterparts in design and construction are now about to vanish from offices and sites.

References

Cahill, B., Menzel, K., & Flynn, D. (2012). BIM as a centre piece for optimised building operation. *eWork and eBusiness in Architecture, Engineering and Construction. ISBN 978-0-415-62128-1.* Taylor & Francis Group.

Ding, L., Drogemuller, R., Akhurst, P., Hough, R., Bull, S., & Linning, C. (2009). Towards sustainable facilities management. In P. Newton, K. Hampson, & R. Drogemuller, *Technology, Design and Process Innovation in the Built Environment* (Vols. Pp. 373-392). Taylor & Francis.

East, B., & Carrasquillo-Mangual, M. (2012). *The COBie Guide: a commentary to the NBIMS-US COBie standard.*

East, E., Bogen, C., & Rashid, M. (2012). Life-cycle building control. *eWork and eBusiness in Architecture, Engineering and Construction. ISBN 978-0-415-62128-1.* Taylor & Francis Group.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM Handbook, a Guide to Building Information Modeling* (Vols. ISBN 978-0-470-18528-5). John Wiley & Sons, Inc.

Forns-Samso, F. (2010). *Masters thesis: Perceived value of building information modeling in facilities operations and maintenance.* University of New Mexico. Dept. of Civil Engineering.

Hodges, C. P., & Elvey, W. W. (2005). Making The Business Case For Sustainability: It's Not Just About Getting Points. *July/August 2005*.

Jokela, M., Laine, T., & Hänninen, R. (2012). COBIM - Common BIM Requirements 2012. *Series 12 - Use of models in facility management*. Olof Granlund Oy.

Khemlani, L. (2004). The IFC Building Model: A Look Under the Hood. *March 30*(Feature).

Khemlani, L. (2011). BIM for Facilities Management. *September 30, 2011*.

Mitchell, J., Ballesty, S., Drogemuller, R., Schevers, H., Linning, C., Singh, G., Marchant, D. (2007). *Adopting BIM for facilities management: Solutions for managing the Sydney Opera.* Cooperative Research Centre (CRC) for Construction Innovation and the Australian Government's Facilities Management Action Agenda.

Owen, R. (2009). *CIB White Paper on IDDS Integrated Design & Delivery Solutions.* Rotterdam. the Netherlands: CIB Publication 328.

Sabol, L. (2008). Building Information Modeling & Facility Management.

Sapp, D. (2011). *Facilities Operations & Maintenance*. (Plexus Scientific) Retrieved November 8, 2012, from Whole Building Design Guide: http://www.wbdg.org/om/om.php.

Schevers, H., Mitchell, J., Akhurst, P., Marchant, D., Bull, S., McDonald, K., Drogemuller, R. (2007). Towards Digital Facility modelling for Sydney Opera House using IFC and Semantic Web Technology. *12*(pp. 347-362).

Smith, D. K., & Tardiff, M. (2009). The Building Life Cycle (Chapter 5). In *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers.* John Wiley & Sons, Inc.

Tarandi, V. (2012). The BIM collaboration hub supporting IDDS: Research issues and their current status. *eWork and eBusiness in Architecture, Engineering and Construction. ISBN 978-0-415-62128-1.* Taylor & Francis Group.

van Berlo, L., Beetz, J., Bos, P., Hendriks, H., & van Tongeren, R. (2012). Collaborative engineering with IFC: new insights and technology. *The European Conference of Product and Process Modelling (ECPPM).* Reykjavik.

Young, N. W., Jones, S. A., & Bernstein, H. M. (2008). *SmartMarket Report, Building Information Modeling.* McGraw Hill Costruction.