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**Publisher's version / Version de l'éditeur:**

*The E-SIM 2010 Conference: 19 May 2010, Winnipeg, Canada [Proceedings], 2010-05-19*

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## NRCC-52659

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June 2010

A version of this document is published in / Une version de ce document se trouve dans:
The E-SIM 2010 Conference, Winnipeg, Canada, May 19-20, 2010



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Conseil national de recherches Canada
Canada

# IMPACTS OF BUILDING INFORMATION MODELING ON FACILITY MAINTENANCE MANAGEMENT

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## ABSTRACT

Building Information Modeling (BIM) has been a popular buzzword with architects, engineers and contractors (AEC) for a number of years and is now starting to be used by many stakeholders in different aspects of the building lifecycle. BIM is not only changing the way we design and construct a building but is also changing the way a facility is operated and maintained. Today's buildings are not just an assembly of component structures but a combination of passive and active interacting systems. The building components have composite behaviour attributable to its occupants and the external environment which has an impact on performance.

BIM is a digital representation of the physical and functional characteristics of a facility. The multidimensionality in BIM is achieved by creating digital models for different parts and assemblies which can incorporate additional information. BIM is a repository which can be used as a source of information for making decisions during a facility's entire lifecycle, and for the various downstream applications such as Facility Maintenance Management (FMM).

Major stakeholders in the capital facilities industry – the owners and the facility managers - are still managing the maintenance and operations of many facilities by using paper-based processes that include drawings and spreadsheets. Now with the use of BIM, the FMM can achieve significant benefits and efficiency. BIM, in the operations and maintenance phase, can be leveraged to perform what-if scenarios based on the dynamics of occupants and equipment in facilities, analyzing operational efficiency and minimizing energy usage, as well as operating and managing them virtually. Further, data integration of sensors and other monitoring devices can track equipment downtime and real-time occupancy levels.
In this paper, we'll discuss how BIM technology is impacting the construction industry, and, specifically how it can be used to make facility maintenance management more cost effective. The work reported here is a synopsis of ongoing work at our research lab in the nD modeling project.

## 1. INTRODUCTION

All organizations, whether public or private, use buildings, assets and facility services to support their primary activities. Facility Management (FM) and Real Estate (RE) activities contribute to about 5-10% of the gross domestic product of advanced industrialized countries (Madritsch and May, 2008). It is also reported that about 70% of US companies and 50% of European companies consider their buildings and real estate as a strategic resource. It is estimated that life cycle costs of the property could be as much as 5-7 times higher than the initial investment costs. Clearly, these numbers indicate the importance of optimizing the operating costs of running a facility.

According to the International Facility Management Association (IFMA), "Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating the 3P's (people, place, process) and technology". From an operational perspective, FM can be considered as an integrated process to support and improve the effectiveness of an organization's primary activities through the management and delivery of services.

The efficiency of FM depends solely on the use of data and information to make decisions based on specific needs. The process of facility documentation is high and continues to rise until the end of the construction stage (Eastman, 2008). Data handling of facilities is made easy by an information modeling framework, widely known as Building Information Modeling (BIM).

BIM is a new paradigm in the construction industry. It is strongly believed that such a detailed representation will be a significant benefit for facility managers both to operate and maintain a facility. BIM provides an integrated platform through which digitized design and construction information from diverse sources can be effectively communicated and coordinated.

In the future, it is believed that facility management will have increased scope, greater emphasis on life cycle sustainability and environmental reporting, increased regulatory and compliance requirements and deal with greater supply chain complexity (Hayward, 2007). For such complex systems a virtual prototype of the facility should simulate behaviour, provide indication of performance against set criteria and check compliance with set constraints (Elmaraghy and Bauer, 2005).

## 2. BACKGROUND

According to studies conducted at the U.S Environmental Protection Agency, FM influences an organization's ability to act proactively and to meet all requirements by coordinating assets and services (USEPA, 2009). Assets maintenance and its management are the core services to be rendered within a facility and will be the focal point in FM (Epstein, 2007). Considering the complexity and the sophistication of systems installed in modern facilities, understanding the operation and maintenance requirements of such systems by the maintenance staff is essential. BIM enables the capture of up to date and detailed descriptions of the equipment, including maintenance sheets and procedures. Service staff can access relevant information before performing maintenance, localize access points, or review past inspections made on the system. When BIM is coupled with simulation software or plug-in, training and what-if scenario simulation capabilities become available to the maintenance staff.

BIM can assist the implementation of Computer Aided Facility Management (CAFM). CAFM is a computer-assisted methodology, integrating with database and reporting tools to manage large built environments. CAFM gives decision makers the ability to automate many of the data intensive FM functions and results in cost savings and improved utilization of assets throughout the entire lifecycle. In particular, CAFM provide and maintain information on floor plans, space utilization, energy consumption and equipment location. They generate work orders, create activity charts, assign tasks and serve as a collaborative platform to communicate. Table 1 describes some tools used in FM applications.

Table I - List of some commercial software used in FM sector

| **Name and URL** | **Functions** |
|---|---|
| ACTIVEFACILITY www.activefacility.com | Building information server& storage. IFC compatible integrate with BIM. |
| ARCHIBUS www.archibus.com | Cost administration, space and move management, occupancy, building operations &emergency preparedness. IFC compatible and integrates with BIM. |
| EAGLE www.eaglecmms.com | Integrates with CMMS. Additional tools for building efficiency & comfort. |
| FM:Systems www.fmsystems.com | Strategic planning, asset, move and real estate portfolio management. |
| MAINSTREAM www.mainstreams.com | Enterprise FMS software. Assets and work order management. |
| MICROMAIN www.micromain.com | Preventive maintenance, asset management, capital planning, compute occupancy data, markup tools for FM project collaboration, plan for emergencies, track people, equipment and areas, and improve operations. |
| OCTAGA http://www.octaga.com | IFC based 3D interface to FM; FM enterprise suite for operation and maintenance. |
| ONUMA www.onuma.com | Enterprise web-based project management system and a model server for BIM. Planning tool, management of as built data for facilities. IFC compatible integrates with BIM. |
| PACRAT http://www.facilitydynamics.com/pacrat.html | Performance and re-commissioning analysis, diagnoses system and energy analysis. |
| RYHTI http://www.ryhti.net | Manage building systems, integrates with CMMS software. Tools for facility monitoring for building performance. |

| | |
|---|---|
| TOKMO www.tokmo.com | Operations & knowledge management optimization software, tracking, material and equipment management, collaboration,visualization, monitoring, quantity take-off and cost estimating. IFC compatible and integrates with BIM. |
| VFA www.vfa.com | Capital planning, management, energy assessment and budget management. |
| VIZELIA http://www.vizelia.com | Asset management, optimizes maintenance &repair budget, tracking occupants, IFC-based model driven. |
| QUBE www.fdsltd.co.uk | Outsourcing management, land and facilities management. |
| TMA SYSTEMS www.tmasystems.com | Maintenance management, asset, operation management and tracking. |

The present trend is to integrate these systems with innovative technologies to enhance the decision support (Chen, 2009 and Madritsch, 2009).

## 3. BUILDING INFORMATION MODELING AND FACILITY MANAGEMENT

Providing support to operations and improving operating conditions are important factors in FM productivity. Keys to FM success are quick response to changes and providing quality and reliable services to occupants/users. For example, in buildings this can be attributed to indoor air quality issues and human discomfort. BIM can provide a holistic understanding of the problem by linking and correlating the different variables. Alternately, by having a three-dimensional representation of the HVAC system, the engineer can see the connection to the impacted discomfort zone and take responsive action.

BIM is becoming widely accepted as an enabler for FM. The General Services Administration (GSA), the largest builder-owner of federal building and infrastructure assets in the US, has been in the forefront of BIM implementation (Khemlani, 2006). GSA now requires the delivery of spatial program information from BIM for major projects (Rundell, 2006).The GSA has made a lot of effort to explore the possibilities of using BIM in the area of emergency preparedness. They are exploring “avatars” - technology from the gaming and entertainment industry that can assist the simulation of humans in a virtual world. Integration of these avatars with the BIM models will provide the egress pattern in a facility to be studied, in the event of emergency (Khemlani, 2007).

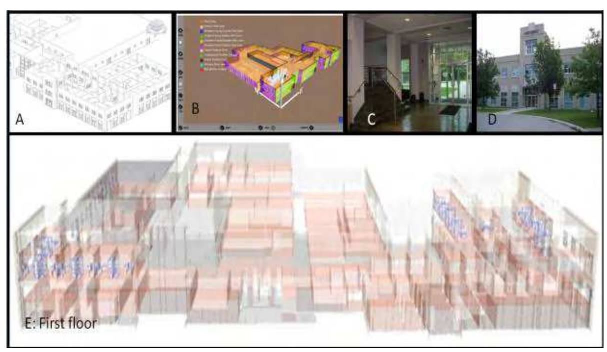
### 3.1 BUILDING INFORMATION MODELING (BIM)

BIM is a model-based technology for creating, co-ordinating, documenting and managing up-to-date information about a building and its components throughout the life cycle. It provides the ability to develop a “virtual building”, in which all building elements are digitally created to fit together.

By providing continuous and consistent information, BIM serves the construction community by increasing efficiency and reducing re-work. It serves as a platform for design, construction, procurement, facility operation and maintenance. Figure 1, below, shows exterior, interior and detailed 3D floor models extracted from BIM.

The key attribute of BIM is that its objects are robust and represented as parametric 3D geometry. Each of these objects is comprehensive and has extensible properties. They are semantic rich and hold relationships between objects. All objects are integrated and stored as a repository system to support lifecycle data requirements.

Figure 1 Building Information Model and its derived views




### 3.2 STANDARDS AND DATA EXCHANGE

Building Information Model (BIM) consists of data and information about building components, construction processes, properties and relationships. All these are to be digitally represented and stored. Also, data interoperability to exchange data from one vendor system to another should be possible. The two most important standards for data interoperability and data exchange are IFC (ISO/PAS 16739:2005) and Construction Operation Building Information Exchange (COBIE) (http://www.wbdg.org/resources/cobie.php). Many institutions are working towards creating standards and data exchange methodologies to provide a common model and enable easy sharing of information across the AEC industry. In North America organizations actively involved in this effort are:

- International Alliance for Interoperability : (http://www.iai-tech.org)
- Construction Specification Institute: (http://www.csinet.org)
- Whole Building Design Group: (http://www.wbdg.org)
- FIATECH: (www.fiatech.org)

## 3.3 THE MANAGEMENT AND MAINTENANCE OF FACILITIES

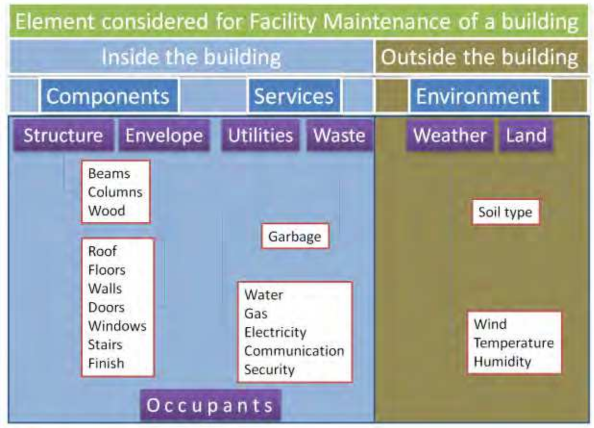
Apart from the regular maintenance and operation of the facility, FM encompasses many other activities such as budget planning, purchasing, contractual responsibilities, procedures, practices and processes. They ensure that facility operation, comfort and emergency preparedness are guaranteed while optimizing the operational cost and improving the system reliability. FM functions generally can be categorized into four main levels (Yu et al., 2000) as described in the table 2 below.

Table II List of some commercial software used in FM sector

| Levels | Functions |
|---|---|
| High level management | Budgeting and planning |
| Operational level management | Space planning, allocation of resources, move management, predictive maintenance, emergency preparedness and occupancy |
| Operation and services | Preventive and break-down maintenance, condition monitoring |
| Equipment & assets | Inventory management, telecommunication, water, gas and other utilities services |

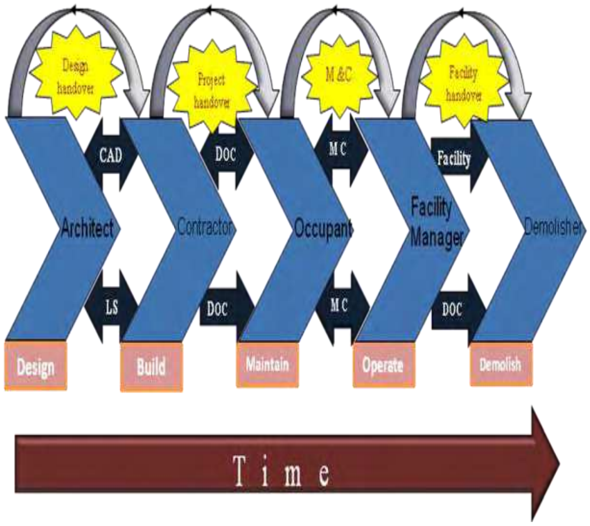
Each of the above functions depends on data within the facility, outside the facility, and the behaviour and performance of the facility. For example, in a typical building, facility maintenance depends on internal elements, external environmental elements and the occupants. Figure 2 shows a snapshot of those elements.

Figure 2 Elements considered for FM of a building




In a conventional sense, the FM activities start at the "project handover" stage as shown in Figure 3. At this stage, it is assumed that the "as-design" and "as-built" information is well documented using methodologies described in the previous section. As the occupants start to move in or start to use the facility, services have to be provided to suit their needs, safety and comfort. Once the facility becomes fully operational, data is collected from the monitoring and control devices. With these data sets in hand, namely, "as-design", "as-built" and "as-operational", the facility personnel are responsible thereafter for operating the facility. The building life cycle implies that facility management and operation should be part of the decision-making process from the design stage onward, relying on the BIM to collect and analyse information that can assist in achieving a properly performing building. This design handover does not contain information for the facility staff about how to maintain the facility; rather the information has to be derived based on the design data using appropriate methods such as IFC, COBIE, IFCXML or COBIE2XML.

Figure 3 Construction Life cycle




## 3.4 BIM ENABLED CONDITION MONITORED FACILITY MAINTENANCE

From a maintenance point of view, facility condition data can become stored as an integral part of the BIM (Shen et al., 2009). The use of wireless sensors that can monitor the various phases of the lifecycle can play a major role in achieving this mission. Sensor prompted Condition-Based Monitoring (CBM) as a maintenance strategy is being quickly embraced by facility managers across the industry. CBM assumes that prognostic parameters, that are indicative of trouble, can be detected and used to quantify the possible failure of the component before it actually occurs. Component conditions are useful metrics of possible faults and/or potential problems before the component failure actually occurs. As noted by (Neelamkavil, 2005), the trend in deterioration can be identified through a trend analysis of the component condition data, while the maintenance decisions depend very much on actual measured abnormalities, faults initiation, and the prediction of the trends in component deterioration.

Controlling the operational environments and hence the associated parameters can help extend the component life beyond what is normally expected. That is, the idea is to arrive at a plan to deal with the 'actual versus intended' operational environment, with a goal to define strategies in terms of life cycle and economic management of the total facility that is a summation of all the components. The bottom line is to reduce the number of unplanned failures by monitoring the component's condition to predict failures and enabling remedial actions to be taken. It is to be noted that, though maintenance is done at the component level, the facility maintenance strategy should take a holistic approach to the entire facility; note also that real-time data collection, data mining, systems integration, trending and statistical analysis are the building blocks of such a maintenance strategy. Invariably, since component deterioration is bound to occur, decisions based on condition-based fault diagnosis and the prediction of the trend of deterioration will become essential to an efficient facility maintenance management.

## 3.5 RFID-BASED MAINTENANCE AND BUILDING INFORMATION MANAGEMENT

A promising way of implementing the condition-based maintenance management philosophy is via embedding RFID tags in all the critical building components. This idea of attaching tags to building components is relatively new. The use of tags for lifecycle management has been investigated before, especially in the aerospace industry (Harrison, 2006), where the lifecycle information is stored on the tags. Similar to this and integral to the building components, it is envisaged to permanently attach tags to the components and store building information (BIM) at their fabrication stage; as well, the tag information may be complemented by component condition data and maintenance information. That is, the tag memory now includes BIM or part of it as well as maintenance data, and hence it may be treated as a kind of a distributed database, as described in (Motamedi and May, 2009). Having the lifecycle data pertaining to the building components readily available on the tags provides easy access to the data. It is to be noted that attaching a tag to each and every component in a building would be prohibitively expensive. To benefit from the concept of having essential information on critical items only, a subset of components may be selected based on the facility size, criticality of items, and the need for monitoring and maintenance to be performed on these components. The target components may be tagged during or just after their fabrication and can be scanned at various points in time. While the complete building information may be stored centrally in a sharable BIM database, appropriate applications copy the required information from the database to the tags, as suggested by (Cheng et al., 2007). As well, the stored data on the tags may be read, updated and changed by various RFID-based systems during the lifecycle.

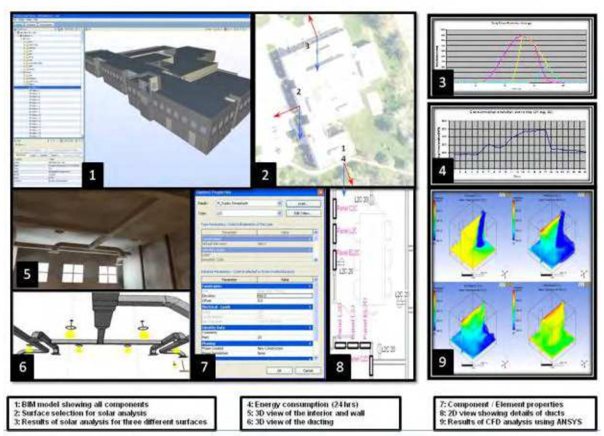
## 4. INTEGRATION OF BIM BUILDING PERFORMANCE AND FM

BIM provides information that has been captured during the design and construction phases. Most of it pertains to the shape, quantity, orientation, materials, component details, etc. This information is static and does not change during the lifecycle of the facility unless modifications are embedded. The building performance data is collected during the actual usage of the facility and is dynamic in nature; i.e., it changes depending on the usage, environment and even deterioration.

In the context of facility management, the building performance data is a measure of its health and a good indicator to trigger an action plan. Based on the action plan the required data is extracted from BIM.

A good example is the Letterman Digital Arts Centre and the Sydney Opera House facilities (Manning, and Mitchell, 2008 and Boryslawsk, 2006) wherein action plans for emergency preparedness were demonstrated with the use of BIM. Another example of the integration of BIM, building performance and FM was demonstrated in-house as a subset of the "nD modeling research project". One of the major tasks of the project is to compute the thermal comfort of the occupants in a building facility. The BIM model was used to compute the solar analysis of the building's external envelope. Based on the results, a portion was further analyzed for internal airflow. The BIM models provide all the data requirements for a Computational Fluid Analysis (CFD) using ANSYS®. The CFD analysis has shown that airflow quantity and temperature had to be increased at room spaces on the north-east corner of the building facility. Figure 4 shows a snapshot at various stages of the analysis.

Figure 4  Snapshots of Airflow Analysis




## 5. CONCLUSIONS

BIM introduces a paradigm shift in which facilities are designed and constructed. It also changes the way we operate and maintain the facility. The use of BIM offers many advantages, particularly as an integrated data source which is model-driven while providing absolute data consistency. With the increased use of BIM for design and construction, the owner's involvement and use of the building information from the view point of facility maintenance is increasing. With the use of RFID tags and/or sensors, building component condition information can now be stored as real time BIM data, which will become handy in making decisions in regards to facility management.

The widespread use of BIM demands data sharing among the various stakeholders, and this requires stable standards. Note that a lack of or inadequacy of standards can lead to interoperability problems. Accordingly, the scope of the supporting standards such as IFC, FMC and COBIE needs to be extended.

Currently, owners are looking primarily at facility performance rather than the physical structure. Complementing this, in North America large government facility owners, such as GSA, are now moving to introduce design-build-maintain contracts. This will change the way we have been doing things in the past. A constructed facility would be handed in "as-built" with the responsibility of maintaining it over a period of time. This means that the designers have to think ahead the cost of operating and maintaining the facility upfront. BIM is the natural way to iterate the design options and conduct "what-if" analysis prior to the construction of the physical facility.

In this paper we reported the use of BIM for facility operation and maintenance. Also, we emphasised the influence of building performance on facility operations. The case study and results described are the output of an on-going research project which aims to predict the building energy consumption with greater accuracy and to be able to provide feedback to the system's operating parameter to assess the comfort of the occupants.

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