INTEGRATING BUILDING INFORMATION MODELING AND CONCEPTUAL DESIGN TOWARDS EFFECTIVE FACILITIES MANAGEMENT: A FRAMEWORK TITLE

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Abstract: The engagement of Facilities Management (FM) during the conceptual design stage of building projects has been recently explored. Incorporating FM during the design stage through the concept of BIM has the potential to minimize the possible waste of project resources (time, money, materials, and sustainability impacts) especially during the operational stage while offering the essential tools to keep buildings running to the required living standards. This paper proposes a framework to develop an integrated conceptual design model towards effective FM. Based on an intense literature review and series of interviews with FM and design professionals, this innovative framework is created to fulfil the following basics attributes: (1) tackling the key factors that affect FM; (2) Identifying the most effective stage of design (conceptual design) to involve facility managers; and (3) Detecting the major aspects that will directly contribute in enhancing the quality of managing, operating and maintaining facilities at the early design stage of a project. The expected results of the integrated BIM-FM model should show the importance of facilities managers' contribution during the conceptual design stage that leads in reducing the operating and maintenance costs, while providing 3D Integrated Design within Building Information Modeling (BIM) environment by generating list of design alternatives through design simulations. An actual case project is used to test the models' capability and workability.

1 INTRODUCTION

The use of advanced materials and building technologies in the construction industry has been evolving, particularly in the past three decades. Consequently, complex building systems and supporting services are implemented, which have increased the need to bring the Facility Manager (FM) on board at the early design stage, known as the conceptual design stage (Mohammed & Hassanain, 2010). The International Facility Management Association (IFMA) defined facility management as "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, processes and technology" (Wang et al., 2013). The data required to operate and maintain any building is usually enormous and requires an advanced integrated platform to fill the existing gap that resides in missing, misleading and misplacing project information (Al-Hussein, 2000). BIM is an integrated process that is used to facilitate the exchange of design and construction information to project participants. It is the act of collecting and of using consistent, reliable and sufficient data to support any desired activity throughout the construction lifecycle (BIMCAN, 2011). All of the building information is translated into a digital format that is represented in the modeling process and it is used to support integrated data exchange in a secure reusable fashion. These models create a platform in which physical and functional features can be explored through visualization, simulation and analysis of the existence of the physical facility/building (BIMCAN, 2011). The use of BIM by facility managers will provide all the necessary information for the building components to keep buildings up to the required living standards, while minimizing possible wastes of resources (time, money, materials, and sustainability impacts) associated with managing those resources. Furthermore, BIM enables facility managers to obtain access to all life-cycle information of the project, especially during the planning and implementation phases by allowing them to supplement their professional inputs towards a more efficient FM (Sabol, 2008). Moreover, BIM is ideal to categorize, modify, monitor and integrate data gathered from various building systems and components throughout the entire lifespan of the project and to secure facilities' information and data (i.e., CAD drawings, operation instructions, maintenance manuals and schedule of equipment).

A study completed by BIM-Canada in 2011 indicated that most of the current commercial tools used in BIM focus on the needs of the planning and designing phases of a building project. Currently, other parts of the building lifecycle are being considered by various software developers to add the required tools to support the activities that take place during the construction and operation phases. These tools will offer access to new BIM tool functionality, either through add-on modules or through embedding the new BIM tools' functionality in their own main applications or through using existing BIM applications and applying their required improvements as add-ons. Add-ons will usually come from third party developers who have access to large vendors' databases. Although this approach has significant benefits to the user, such as effective workflow and seamless integration between modules, there are also disadvantages, such as the compatibility issues resulting from miscommunication and lack of integration (BIMCAN, 2011).

Mohammed & Hassanain (2010) stated that an increase in the cost of maintenance during the operation of systems and components can result as a consequence of deficiency in design. Currently, as buildings are designed to meet greater building standards, design can have a positive influence during the operating and maintenance stage of buildings. The effects of decisions made during the design stage can have far-reaching effects on future building maintainability (Mohammed & Hassanain, 2010).

In 2012, The British Institute of Facilities Management (BIFM) listed the following consequences of the British government's role in specifying the use of BIM in all governmental projects effective in the year 2016. These benefits will be spread across the globe as the benefits of BIM concepts and its tools starts to arise. BIM can support the creation and maintenance of facilities in a more efficient way, lower carbon emissions, lower and enhance operation costs, and create more effective and safer places to live and work. However, this is not achieved without the involvement of an integrated project team that includes the FM at the early stages. Moreover, while addressing the barriers to FM engagement, the following is stated (Tranced, 2012): "Databases are absolutely key to the issue of interoperability for different tools, to enable software from different manufacturers to talk to one another." They also added that, "In the UK the government is targeting level 2 BIM, which accepts a series of architectural, structural and MEP models requiring a tool to pull them together. The UK government cannot spend on any number of interfaces between current BIM applications (Planet FM, Maximo, Revit, Bentley, etc.), and it cannot support proprietary software so it has to have something that's open. Because, of this, it is adopting the freely available, non-proprietary system called Construction-Operations Building Information Exchange (COBie) as an information exchange mechanism between information models and asset management systems" (Tranced, 2012). This should encourage the use of one of the widely-used BIM applications, which in this paper will be Autodesk Revit.

Becerik-Gerber and Jazizadeh (2011) designed an online survey based on the outcomes of in-depth interviews with FM. The survey distributed to FM professionals to determine the current practices and interests related to the application of BIM in FM. The results, as illustrated in Figure 1, show that the most significant operational functions that FMs are looking to include in BIM are energy management, maintenance, and repair and space management. These results are going to be the basis of the proposed model, since those are the most measurable components that can affect FM during the conceptual design stage of a project.

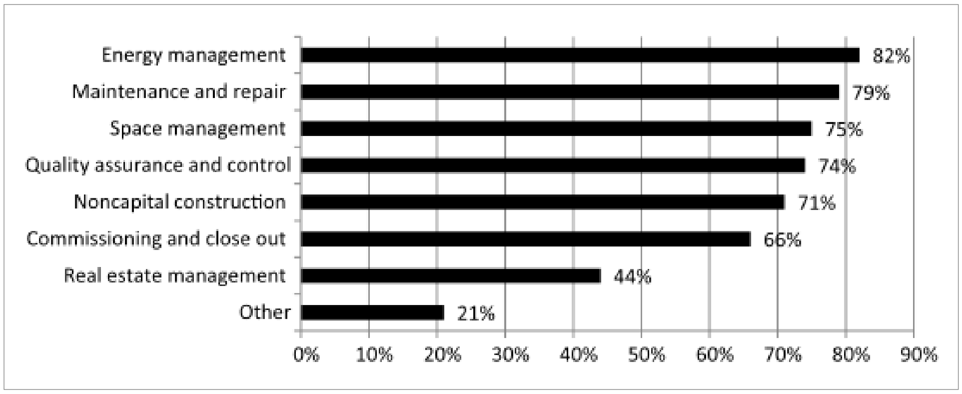

Figure1: Organizational Functions (Becerik-Gerber & Jazizadeh, 2011)

Furthermore, the participants of that survey were asked to share their comments and thoughts about the difficulties they are facing in implementing BIM in FM. The participants' responses were categorized as: 1) Unclear and invalidated benefits of BIM in ongoing FM practices (for example, unclear productivity gains, or benefits gained from reduced equipment failure and better-automated building energy usage); 2) The amount of work that has to be done in order to define the FM-specific needs for which a model is necessary and how that model should be prepared to meet these needs; 3) Lack of interoperability between BIM solutions themselves and between BIM solutions and FM systems; 4) Lack of demand for BIM deliverables by owners due to the uncertainty about the potentials of using BIM; 5) Lack of clarity about who will be responsible for project insurance and contracting; 6) Lack of FM standards and working process; and 7) Lack of experience among facility managers in using BIM technology.
The model's proposed framework will be created in an attempt to fill the gaps identified from the implemented literature review. It will explore the abilities of BIM concepts and the required role that FM should perform as early as possible during the conceptual design stage of building projects. At this stage all the design modifications will result in less impact on time and effort which means cost savings across the entire life cycle of the project. Creating a detailed database for the proposed model will also fill the gap of finding a comprehensive database that can integrate the various disciplines that deal with common projects. The proposed database will contain three main subcategories. The first stores information from the FM historical reports that reflect the experience and case studies that occurred in previous FM projects. The second incorporates the standards and guidelines used to implement FM in a BIM environment along with the systems and vendors' information available in the market. This innovative framework will consider the following basic attributes: (1) tackling the key factors that affect FM; (2) Identifying the design stage in which the involvement of facility managers will be more effective with respect to time, cost and quality; and (3) Detecting the major aspects that will directly contribute to enhancing the quality of managing, operating and maintaining facilities at the early design stage of a building project.

2 METHODOLOGY

The proposed methodology used to develop the framework starts with identifying the limitations of the existing FM software, followed by clarifying all the aspects of the anticipated model's components and architecture. An actual case project will then be implemented in a BIM tool to test the capabilities and workability of the developed framework.

2.1 Existing FM Software Limitations

Based on many reports and reviews, ten of the top existing FM software packages were explored and evaluated to find their limitations and capabilities as illustrated in Figure 2. Those ten software providers where chosen according to their customer base popularity, reviews and features provided (Business-Software, 2015).

Glossary SaaS Software as a Service CMMS Computerized Maintenance Management Software BIM Building Information Moiling CDS Conceptual Design Stage	IFS Enterprise Asset Management www.ifsworld.com	Real Asset Management EAM www.realassetmgt.com	eMaint X3 www.emaint.com	Infor EAM Enterprise www.infor.com	Maintenance Connection www.maintenanceconnection.com	McLaren CAFM Explorer www.cafmexplorer.com	ARCHIBUS Facilitator www.archibus.com	FM:Interact www.fmsystem.com.au	ManagerPlus www.managerplus.com	HippoFM www.hippofm.com
Key Features										
SaaS solution		⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	
On-premise solution	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿
Preventive maintenance	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿
Work order management	⦿	⦿	⦿	⦿	⦿	⦿		⦿	⦿	⦿
Planning & scheduling	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿
Cost Estimation			⦿		⦿	⦿	⦿	⦿	⦿	
Contract management	⦿	⦿			⦿	⦿		⦿	⦿	
Mobile maintenance	⦿	⦿	⦿	⦿	⦿			⦿	⦿	⦿
Reporting/ analytics	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿	⦿
Fully CMMS	⦿	⦿	⦿	⦿	⦿			⦿	⦿	⦿
Space management						⦿	⦿	⦿		
BIM Application								⦿		
CDS Integration										

Figure 2: Existing (top 10) FM Software Limitations & Capabilities (Business-Software, 2015)

Many vendors offer various services towards a goal of a more reliable FM practice; the key features selected in Figure 2 were based on the common services required by the FM and the available features of those tools that can be accordingly analyzed. The figure shows that the capabilities of most of the software are common when it comes to delivering a Software as a Service (SaaS) solution or on-premise solution: preventive maintenance, work order management, planning and scheduling, and reporting and analytics features. However, the limitations start to appear in fully applying Computerized Maintenance Management Software, in which the dependence on paperwork will be fully replaced by e-files. Moreover, applying BIM, Space Management was minimal comparing to the other provided features, while the integration of the Conceptual Design Stage was totally missing in all of the software. This increases the need to introduce a comprehensive platform that allow the supplement of professional inputs from facility managers during the conceptual design stage through the BIM concept towards a more efficient FM that will contribute in minimizing the possible waste of project resources (time, money, and materials), enables facility managers to obtain access to all of the life-cycle information of the project and offers the essential tools (i.e. monitoring, scheduling and integrating) to keep buildings running up to the required living standards.

2.2 Model Components

As illustrated in Figure 3 the proposed model consists of four interrelated modules that are developed within the BIM environment based on the most important factors FM required to include with BIM (Figure 1) and the limitations of the existing FM tools (Figure 2). The first module, the Operation & Maintenance Module, consists of different elements such as scheduling, building systems, parts/replacement, operational instructions and cost. This module combines all the FM technical information that can be affected or enhanced during the conceptual design of a project. The second module, Space Management Module, includes three elements which are: usable spaces, move management and non-usable spaces.

The focus of these three elements reflects time and cost savings. The usable spaces cover the utilization, circulation, accessibility, zones, future expansions and technical requirements, whereas the move management comprises the utilization, circulation, accessibility, zones, future expansions and special equipment allocation. The non-usable spaces, on the other hand, involve equipment, systems, circulation, accessibility, zones, future expansions and special equipment allocation. Moreover, the "Life Cycle Costing (LCC) Module" covers the capital costs, expenses, revenue, risk analysis, and forecasting.

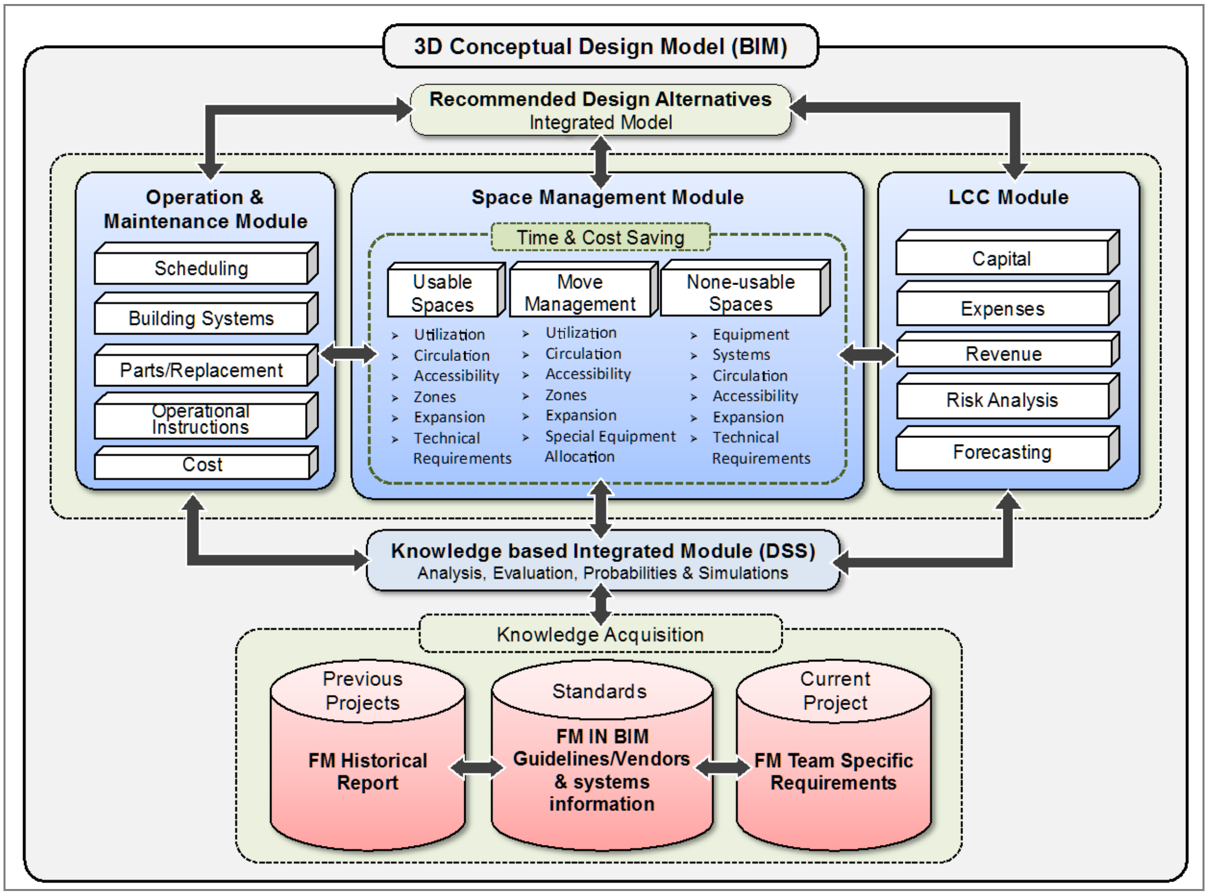

Figure 3: Proposed Model Components

The result of these modules is a list of recommendations that will be based on probability studies that will generate various design simulations in the "Knowledge Based Integration Module" to help the owner, architect and FM team to decide on the best design approach that will result in an effective FM practice. This module includes a Design Decision Support System that will collect all the results of the four modules and throughout the knowledge acquisition database. The Knowledge acquisition databank contains three main databases. The first stores information from the FM historical reports that reflect the experience and case studies that occurred in previous FM projects. The second incorporates the standards and guidelines used to implement FM in the BIM environment along with the systems and vendors' information available in the market. The FM team will reflect all the owners' requirements from the FM point of view, and their professional opinion to what specific requirements are needed for this specific project will generate the third database.

2.3 Model Architecture

The proposed model consists of several components and its architecture includes: data input, data analysis, criteria, and output, as illustrated in Figure 4. The data input is divided into three different parts. The first part is related to the project information. It will cover the project type (residential, commercial, hospitality, etc.), project program (users' information, required spaces for each zone, and their relation), conceptual plans, which should be in a BIM-supporting format. Additionally, site constraints (location, orientation, accessibility, geometry, weather, etc.) will be covered in the project information part, as well as the key issues and guidelines, construction and FM of the project, along with the specified budget to reflect on the sections of building techniques, materials, equipment and the entire LCC of the project. All the data in the first part will be gathered from the owner(s) and the project architect. The second part is the information related to technical standards and also input by the architect of the project. This input will cover all the required equipment specifications, the replacement circulation and special equipment whenever it is needed according to the project type, location, and stage. The third part is related specifically to the maintenance information that will be provided by the FM team. This part will cover the FM item requirements for this specific project, the essential systems data and equipment information. Moreover, the operational instructions, maintenance manuals and schedules will be gathered in this part of the input by the FM team.

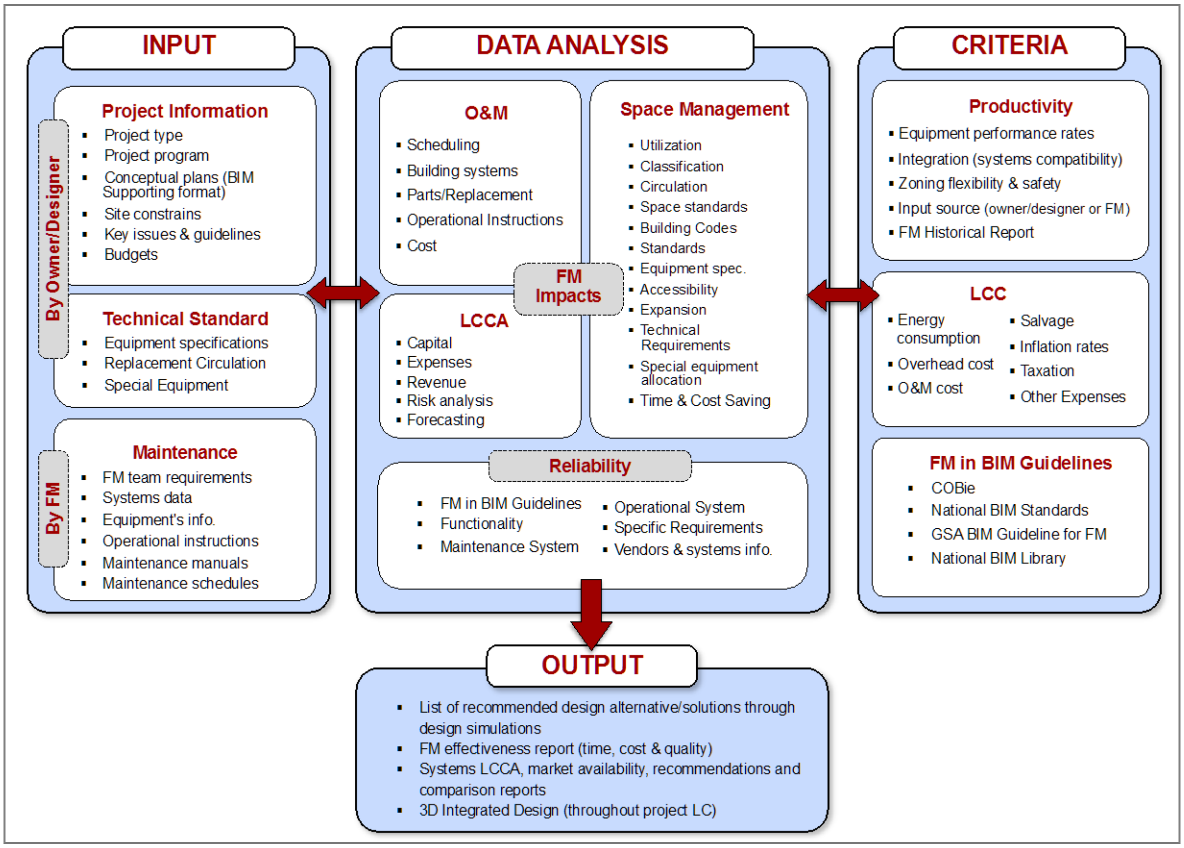

Figure 4: Proposed Model Architecture

The data analysis, in its turn, is divided into four sections. Three of those are: 1) Operation and Maintenance (O&M), 2) Space Management and 3) Life Cycle Cost Analysis (LCCA) has been classified as the data that will have a direct input to the FM practices which can be enhanced in the conceptual design of a project. However, the fourth section will focus on the reliability of the data to generate the required data analysis for such a complicated and multi-input model. The O&M section will involve data for scheduling, building systems, parts and replacement, operational instructions and cost data. However, the space management section will generate data regards the space utilization, zoning classifications, circulation for both usable and non-usable space, standards required for specific space, building codes and standards, equipment specifications, and accessibility. Moreover, the space management section will include the date for possible future expansions, specific technical requirements, special equipment allocation and time- and cost-saving practices from previous projects. The LCCA will contain data that is related to capital, expenses, revenue, risk analysis, and forecasting. The Reliability section of data analysis will gather the following information: FM in BIM guidelines, functionality, maintenance system, operational systems, specific project requirement, and the data of vendors and system information (availability, cost, location, durability, technical specifications, delivery dates, etc.).

The data analysis will be based on the following criteria: productivity, LCC, and FM in BIM guidelines. In the productivity section the equipment performance rates, systems integration compatibility, zoning flexibility, and safety (of allocating commonly-used zones to hazardous ones) will be examined. It is very important to verify the data input source, which in this model will be either from the project owner, architect, or FM. Knowing the input source will allow categorization of the requirements according to their importance. Moreover, the FM historical report will be filtering the data to provide solutions and insights based on comparing the current data input to comparable historical measurable. However, in the LCC section, the data analysis criteria will be energy consumption, overhead cost, O&M cost, salvage, inflation rates, taxation and other expenses that might be added to the LCC of the project. In the third section of the criteria, the data will be tested to check its validity with regards to FM in BIM Guidelines that consist of Construction-Operations Building Information Exchange (COBie), National BIM Standards, U.S. General Services Administration (GSA) BIM Guideline for FM, and the National BIM Library. Collecting all of those guidelines in one model will generate a comprehensive database that will contribute in savings of costs and time during the FM stage of the project.

The output of the proposed model will be a series of recommended design alternatives and solutions through design simulations. Moreover, FM effectiveness reports, will provide the facility manager with all the information related to the operation, maintenance, and evaluation of the facility in an effective way. Additionally, all the main building systems—LCCA, market availability, recommendations and comparison reports—will be generated along with the 3D integrated design that will allow all the professional inputs from various project parties throughout the entire project life-cycle. The platform of this model is developed using the BIM concept, in which systems integration is achieved by using an existing BIM model at the conceptual design stage and assuring data-updating from all the parties throughout the project life cycle, as described in the validation below.

3 VALIDATION

To validate the developed model, only the space management module will be tested in this study as part of the ongoing overall model validation, by using a sample project (AL Dammam Four Seasons Hotel), which is located in the eastern province of the Kingdom of Saudi Arabia. This project is currently at the conceptual design stage (30% of the design is completed). The authors created a 3D model of that project in the BIM tool, which is Autodesk Revit in this case, where the space management module is added into Revit's toolbar as a plug-in, as shown in Figure 4.

Once the conceptual design of that case project is done, the user will activate the space management module by clicking on the plug-in, which will generate an alert after analysing the data in the knowledge acquisition database to produce the following information: 1) Suspended scaffold equipment; 2) Data Input; 3) Impact; 4) Alert description; 5) Recommended actions; 6) Read More, which will provide an in-depth LCC, Vendors Information.

Figure 4 shows a list of recommended actions that will contribute in saving costs and energy during the operating stage and the FM practice. In this case the architect did not consider the location of the window-cleaning machine for the project because apparently the focus is on using every possible space in the project to reflect the owner's requirements. This required data is recorded in the model through the FM team. The model will then describe the problem after a process of filtering that will go through the database and according to the set of criteria (productivity, LCC, and FM in BIM guidelines) that are provided in the model architecture.

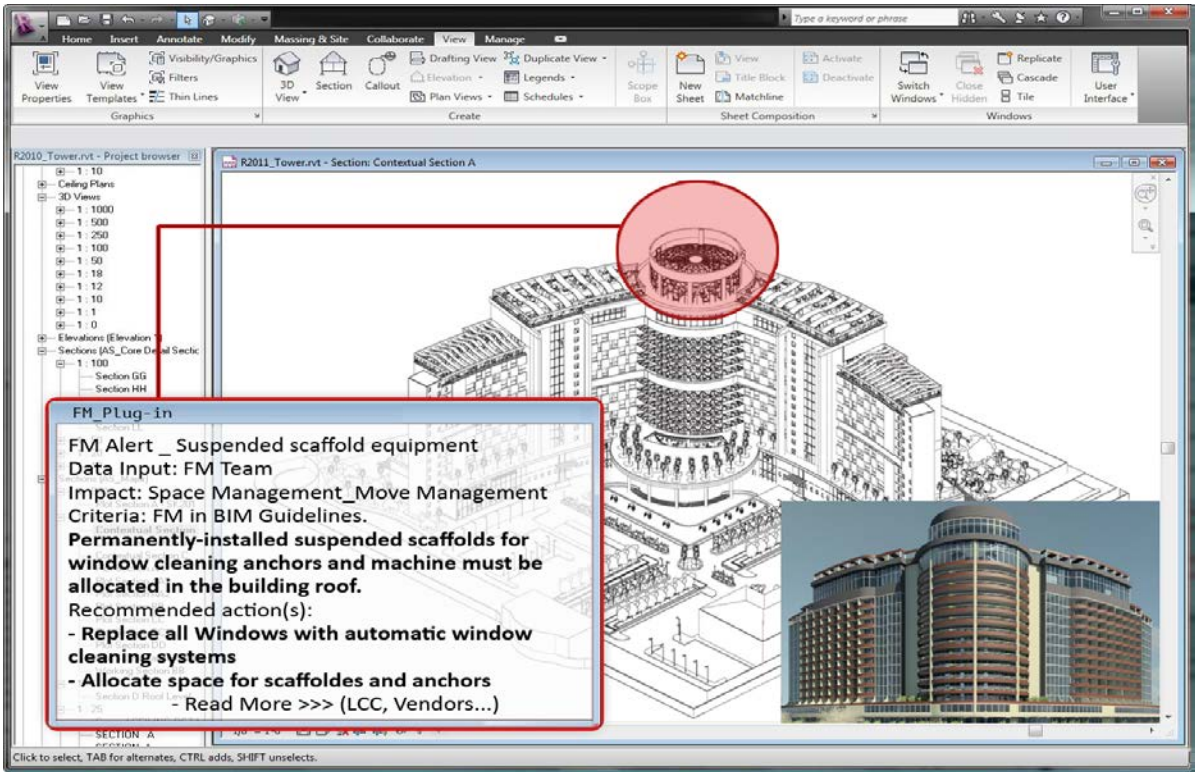

Figure 4: Model Validation – Move Management Alert

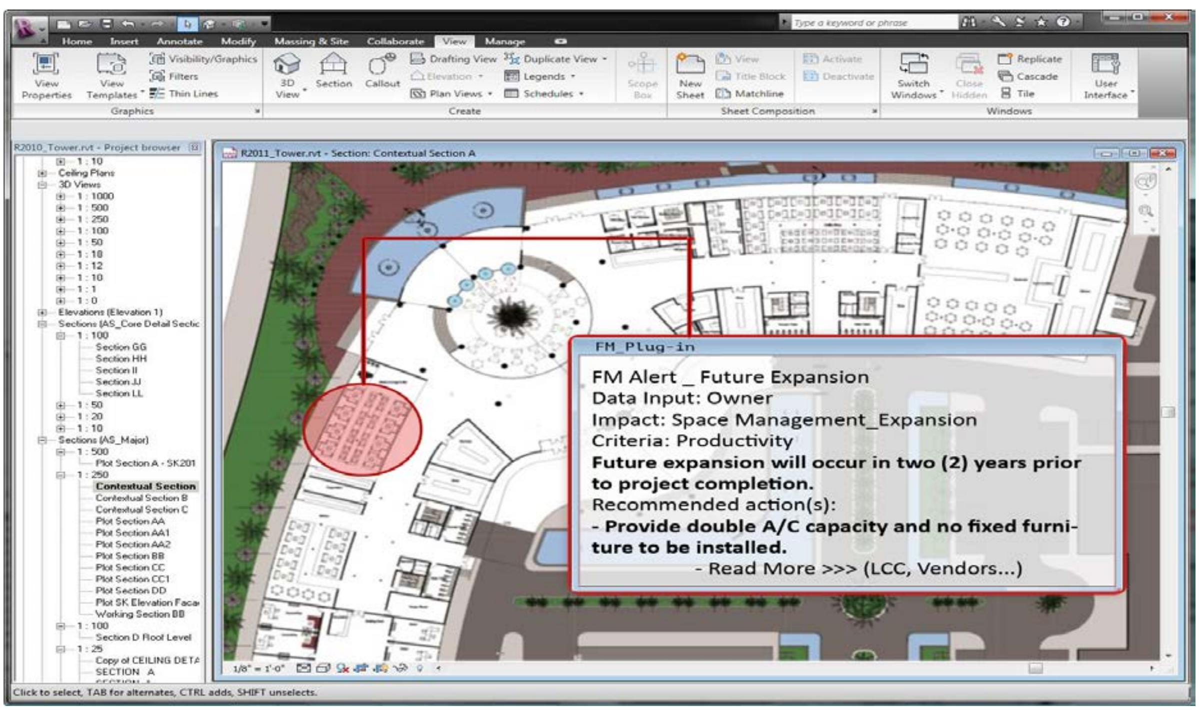

Figure 5: Model Validation – Future Expansion Alert

Figure 5 indicates that one of the owner's requirements is to expand this space. The model allows the architect to calculate the energy consumption aspect along with ensuring its workability and compatibility with other building systems.

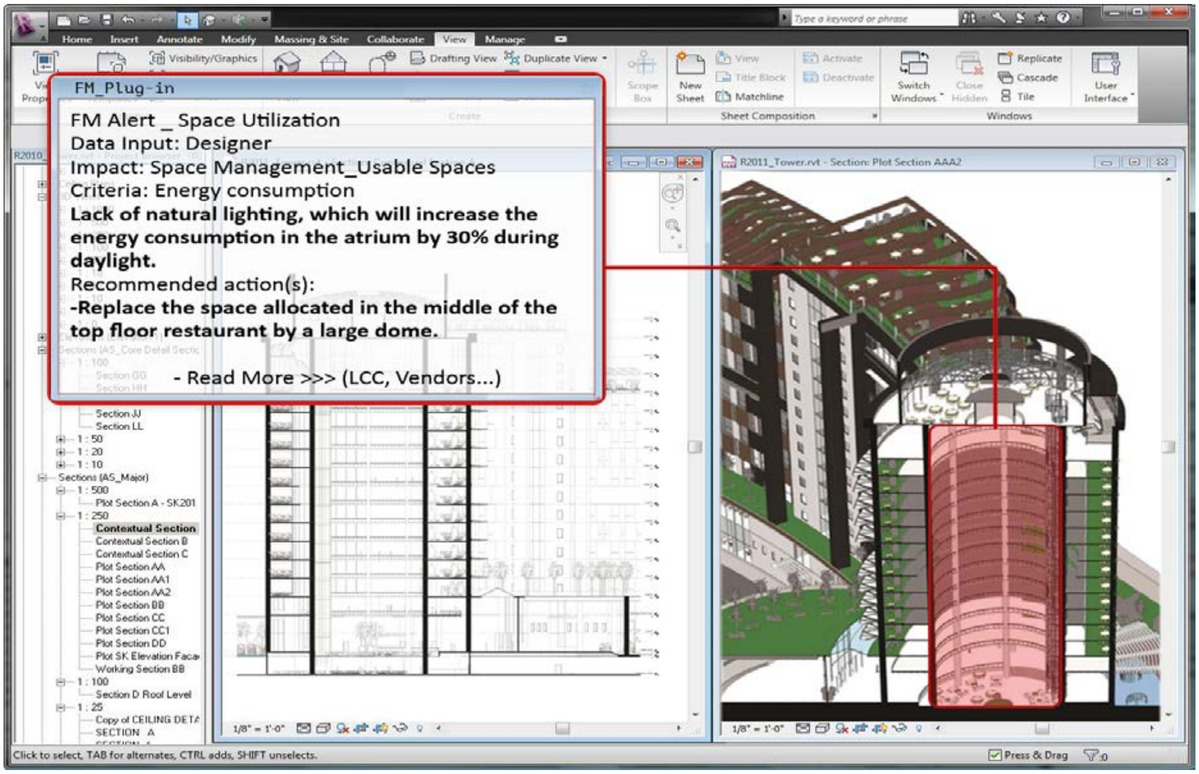

Figure 6: Model Validation – Space Utilization Alert

This is ongoing research that is still underway with the attempt to achieve a fully automated process that integrates BIM tools with other applications for scheduling and estimating, as well as data acquisition. The results of the proposed framework prove the importance of facilities managers' contributions during the conceptual design stage that potentially result in reducing the cost of operation and maintenance.

4 CONCLUSION

This paper described the framework used in developing a model that will be used by the project architect/ design team to integrate existing Building Information Modeling tools (Autodesk Revit) with the data that can be gathered and generated by the owner, architect, and FM at the conceptual design stage of a project towards effective facilities management, as has been discussed. As this paper conceptually illustrated testing the capabilities of one of the four proposed modules, the space management module that was chosen for the purpose of this conference paper only, future work will focus on programming this model towards testing its workability and validating it as a plug-in through Autodesk Revit using an actual case project.

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