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Whole Building Design Approach for University Facility Managers: A Template Using Building Information Modeling

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Abstract
The use of Building Information Modeling (BIM) has significantly influenced workflow in the architecture, engineering and construction sector. This technology can be used from inception of a project all the way through facility maintenance and operation. This paper examines the processes of design, construction and maintenance of facilities at XXX University in USA. The use of BIM in implementing the 'Whole Building Design Guide' in the processes of design, construction and maintenance of a facility at a university is examined. The offices of 'campus planning and space management', 'design and construction services', 'facility maintenance and operations', 'life safety' and the 'university administration' play a key role in the life of a university building. The processes and internal interactions between the various departments are examined by conducting interviews of key personnel. A flow chart analysis of all processes will be used to document the workflow of the various departments. Strategies for the successful implementation of BIM for facility management are presented.

Keywords
Whole building design, Facility maintenance and management, Building information modeling.

1. Introduction

In the United States, the construction industry accounts for over 8% of gross domestic product, and is second only to the US Government in number of people under employment (Bogdan, 2000). Yet, as vast as the economic impact of this industry is, it is still fragmented in many ways. Within every construction project delivery system, enormous communication gaps exist between the designer, the builder, the owner and the operator. It has been shown that information technology can solve some of the problems caused by inefficiencies that exist due to these communication gaps (Ahmed et al, 1995).

Arguably, the largest gap that exists is between the builder and the owner/operator (Mendez, 2006). Upon completion of a building, the builder hands off to the owner and operator an enormous amount of project information, including as-built plans, equipment information and warranties, among many other documents. Then, as is usually the case, the owner/operator spends vast amounts of time and money sifting through the countless documents in order to implement the information into an operations and maintenance system. Due to the flaws in this process, the information being handed off by the builder is often incomplete, and the means by which the owner/operator organizes the information is often inefficient. Using Building Information Modeling (BIM), the communication gaps can be filled and the operations and management system streamlined (Mendez, 2006).

Based on a study funded in 2004 by the US National Institute of Standards and Technology, the capital facilities construction industry wastes $15.8 billion annually due to interoperability inefficiencies. Within these $15.8 billion worth of losses, $5.2 billion is attributed to the participants within AEC industry, such as the architects, general contractors and suppliers. These inefficiencies include the re-entry and re-creation of information and data, and a duplication of business functions (Newton, 2004). The other $10.6 billion in losses is attributed to the owner/operator during the operations and maintenance phase of a building. The inefficiencies in this phase consist of obsolete information technology systems, time consuming information verification and validation, inefficient business process management, and information delays.

XXX University is ranked in the top fifty public institutions in the United States. The university has approximately twenty five thousand students and three thousand employees. The university has nearly eight million square feet of managed space across various building on and off campus. The university is currently going through a construction boom and is currently in the process of adding several more thousands of square feet on and off campus. Various facilities departments are considering the use of BIM technology in the construction of these new projects. At this time, one project has been completed using BIM in the design and construction phases. Another construction project is in progress using this technology and it anticipated that future projects would also use this technology. This paper addresses the use of the BIM models by the facility maintenance and operations department on campus. The information presented in this paper is based on detailed interviews of the staff of various facilities departments conducted by the authors.

1.1 Building Information Modeling

The National Institute of Building Science defines a Building Information Model (BIM) as a digital representation of physical and functional characteristics of a facility (NIBS, 2006). Several differences exist between BIM and the two-dimensional drawings. 2D drawings require multiple views in order to depict a 3D object in adequate detail for construction or facility maintenance, making them highly redundant and open to errors. In addition, 2D drawings are stored as lines, arcs and text, making them un-interpretable by computer software (Eastman, 2007). Another advantage of BIM design tools is that they are able to define objects parametrically. This means that objects are "defined through embedded rules and parameters, and in relation to other objects (Eastman, 2007)." Due to parametric modeling, once an element of a building is changed in one view, it is automatically changed in every other view (Eastman, 2007).

Using BIM technology all pertinent information about a building can be stored and visually displayed in a multitude of three-dimensional views. Changes and revisions to the building information can be automatically interrelated throughout the project due to the parametric modeling feature (Rundell and Stowe 2005,). The goal of BIM is to create a faster, cheaper, and more accurate project from the design phase to the facilities management phase (Mendez, 2006). The adoption of open standards such as the 'Industry Foundation Classes' (IFC) and the 'National BIM Standard' by software companies will enhance the use of BIM among the various stakeholders in the building industry.

The construction industry has been somewhat leery of fully implementing BIM technology. For this reason, the technology has been primarily used in the design and construction phases of only a few building projects. This study intends to explore the use of BIM in the occupancy and facilities management phase of the building project. The current facilities management system employs paper drawings, paper manuals, 2D AutoCAD drawings, and Microsoft Excel Spreadsheets. Using a BIM based facilities management process, the owner/operator would be provided with all applicable building information in an accessible, well-organized and easily understandable format.

1.2 Whole Building Design

To manage the effective design, construction and operation of buildings the National Institute of Building Sciences has proposed a 'Whole Building Design Guide'. There are two main aspects to this approach of looking at buildings. One is the use of an "Integrated Design Approach" and the other is the use of an "Integrated Team Process"

The integrated design approach calls for the members of the building stakeholder community, and the technical planning, design, and construction team to look at the project objectives, and building materials, systems, and assemblies from many different perspectives (Prowler and Vierra, 2008). This approach is different from the typical design and construction process where the experts work independently on their respective areas.

The integrated team approach class for all participants in the process including the designers, owners, planners, builders and operators to work collectively and to understand the concerns of each other during the design phase of the project. It is in this context that BIM will be most valuable to all participants in communicating their thoughts to the rest of the team.

1.3 Facility Management and BIM

A BIM model has the capability to replace 'As-Built Drawings' used by the operations and maintenance staff of buildings. Each element within the model can have attributes added to it that will assist the design, construction and operations team to take the model from the conception of the project to the eventual demolition of the project. A model turned into to facility managers upon construction may have all the information in it that may be readily used for periodic and preventive maintenance.

An example could be the client in a building could report a problem by clicking on a mechanical equipment on a web-based BIM model and a maintenance request is sent to the facility manager. The facility manager can respond to the maintenance request by quickly referring to the 'As-Built' BIM model which contains all relevant information about the equipment such as operations manual, warranty information, past maintenance performed and tools required to perform maintenance. The operator may then visit the site to repair the equipment. The authors are unaware of any organization using a BIM model for all aspects of maintenance as described above. The authors are also unaware of any software that allows BIM to used as described in this illustration. The US General Services Administration (GSA) which requires the use of a BIM model for all new construction projects also does not use BIM from a maintenance and operations point of view.

2. Facility Management at XXX University

A complex structure for managing facilities is in place at XXX university with a staff totaling over five hundred members. While the staff is responsible for most of the duties that are typically associated with the facilities division of a large owner such as XXX university, some functions such as janitorial services are outsourced to private contractors. This section of the paper discusses the organizational structure and the typical process in place for the design, construction, maintenance and operations at XXX university.

2.1 Organizational Structure and Responsibilities of Participants in Facilities Management

XXX is a state funded university and has a 'Board of Trustees' appointed by the governor of the state. The president of the university works with his staff to assist the board in all administrative matters, as shown in Figure 1. The board, headed by the governor, has the ultimate authority at XXX university to approve the construction of new capital facilities associated with the university. The executive vice

president for finance oversees the facilities division as well as the campus planning and space management offices. A brief description of the duties and roles of various offices shown in the organizational structure in figure 1 are discussed in the following sections.

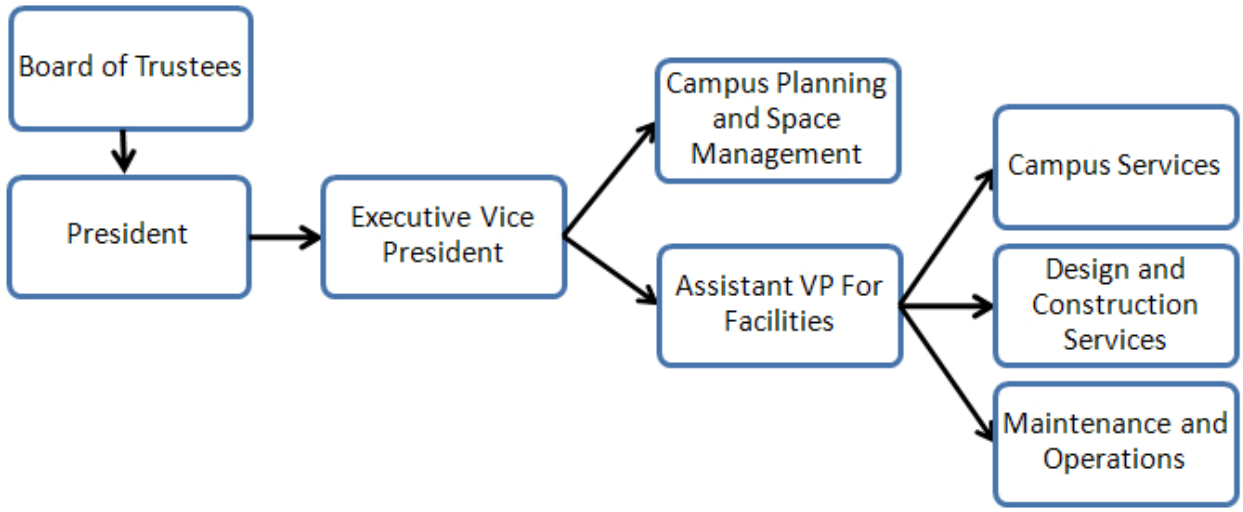

Figure 1: Organizational Structure of Facilities Division at XXX University

2.1.1 Design and Construction Services

Design and construction services includes the office of the engineering design services, architectural design services, the project manager for new construction and the project manager for in-house construction services. The university designers are involved from the early stages of new capital construction projects all the way through the commissioning process. The design services department is also consulted for any major modifications to existing structures. The construction services department serves as the owners' representative in the construction of capital projects and ensures that contractors adhere to the university guidelines during the construction project. Construction services department also co-ordinates the participation of various university facilities departments with the contractors during the construction project.

2.1.2 Maintenance and Operations

The office of maintenance and operations includes the various trade shops such as the carpentry shop and the paint shop. The staff in this department are in-charge of all the utilities on campus, the maintenance of all buildings affiliated to the university, all automobiles associated with the university and perform periodic preventive maintenance of all facilities and equipment on campus. The staff in the department is responsible for any corrective maintenance on campus and also handles energy usage and energy optimization on campus. The staff is involved in the design of new facilities from the maintenance and energy point of view.

2.1.3 Campus Services

The office of campus services is responsible for janitorial services, landscape services, waste management and recycling on campus. Some of these services are performed by university staff while some are outsourced to private contractors.

2.1.4 Campus Planning and Space Management

The office campus planning and space management is responsible for the overall master plan of the university, real estate management for the university, infrastructure projects on campus and is responsible for the early planning of capital projects on campus. The university architect works under this office and

is responsible for coordinating new capital facilities with the university board of trustees and the university administration.

The office of space management has prime responsibility for the inventory, utilization and evaluation of academic and administrative facilities on campus and at off-campus facilities. The role of the office of space management with regard to assignment of space is advisory. The office is responsible for optimization of space usage on campus.

2.2 New Construction and Involvement of Facilities Management staff at XXX University

The processes involved in the construction of new projects at XXX University are shown below in flow chart presented in figure 2. Particular attention is paid to the involvement of facility managers in the process. The process described below deviates from the 'Whole Building Design' philosophy in many ways as far as the integrated design and integrated team approach are concerned. However, the flow chart does indicate that facility managers are included in a traditional sense and have their input in design. Several contractual methods have been employed by the university in past projects but the current one used is 'Construction Manager at Risk'.

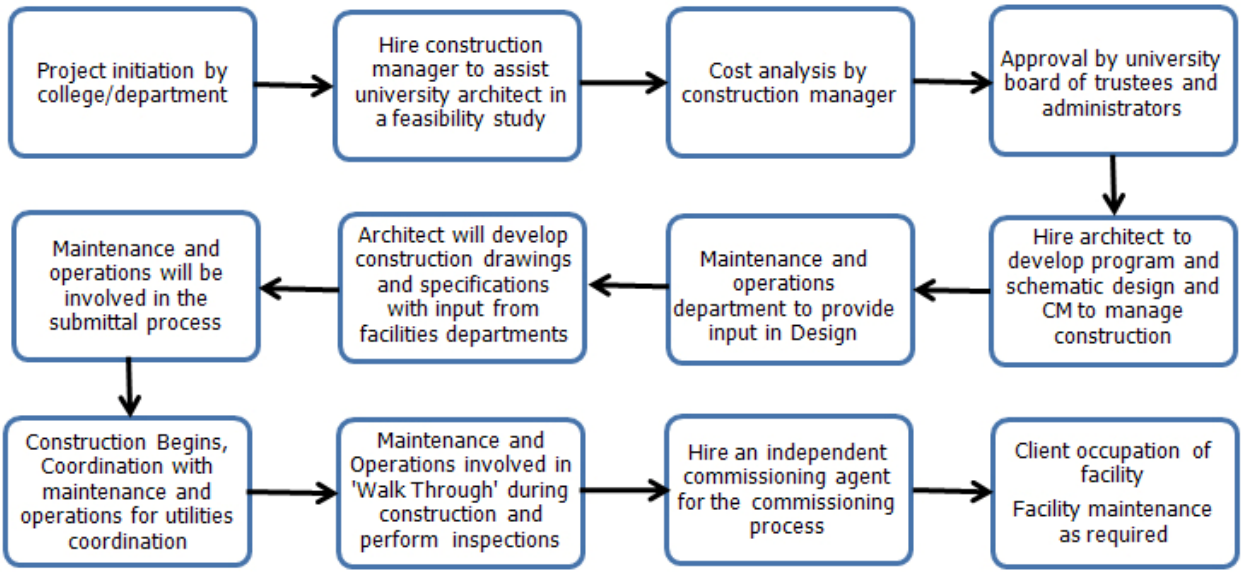

Figure 2: Work Flow for New Construction Projects at XXX University

3. Use of Technology in Facility Management at XXX University

The facilities division at XXX University involves many different offices with several hundred staff members. The use of software is abundant in the various departments. The design and construction services department uses a myriad of technologies from simple spreadsheets to BIM models. The office of space management uses software called 'ARCHIBUS' for management of space. The software allows users to import CAD drawings as external objects. The focus of the software is to manage the existing space on campus. The office of space management intends to replace the two-dimensional CAD drawings with BIM models to manage the existing space.

The maintenance and operations department is the largest within the facility division. The department uses software named 'FacilityMAX' to keep track of maintenance work that is performed. The software

allows any staff or faculty member on campus to report or request maintenance issues via a web portal. Each reported item is electronically routed to the relevant department or staff member for action. The software requires the maintenance and operations staff to input all relevant information for each facility on campus to make it easier for the clients to report or request maintenance issues. Currently this information is manually entered into a database. Instead of manually inputting the data the staff intends to extract this information directly from the BIM model.

3.1 Implementing BIM for Facility Management

The use of BIM software is often cited as a tool for managing a building during its entire lifetime (Azhar et al, 2008). The future expectation is that facility managers will be able to take the BIM model developed during the design and construction stage and use it for the maintenance during the lifetime of the project. However there exist no software programs that can completely replace the existing facility management software and use the BIM model as the base for performing all aspects of facility management. An example of future facility management with the use of BIM was described earlier in this paper.

BIM models however do have a place within the context of facility management. The BIM model may contain information about facility management which may be directly imported into a space management or facility management tool, without having to manually re-enter that data into those programs. It may be recalled that a 2004 study showed that annually $10.6 billion is wasted in the US due to interoperability inefficiencies in the facility management phase of a project. By importing data from BIM models into facility management software a significant part of that waste may be eliminated.

Construction-Operations Building Information Exchange (COBIE) is an open-standard format for the exchange of the equipment lists, replacement parts, warranties, test reports, preventative maintenance schedules and other information currently delivered to facility managers (Buildsmart.org). The information that is defined in this open standard is built on the IFC based facility management data. Information must be submitted by the contractor in the form of a spreadsheet, for the implementation of COBIE. Governmental organizations within the US that required the use of BIM technology such as U.S. Army, Corps of Engineers, General Services Administration, and the Department of State are now requiring the use of COBIE for facility management information extraction. It has also been successfully shown that commercially available BIM software such as ‘Autodesk REVIT’ and ‘Bentley Architecture’ have been used for directly extracting COBIE data into a spreadsheet (Buildsmart.org).

3.2 Future Road Map for Integrating BIM for Facility Management at XXX University

The staff in the various departments within the facilities division have varying and occasionally conflicting goals for implementing BIM at XXX University. This is partly due the individual comfort level and attitude towards adopting new technology. The department of design and construction services at the university has slowly started to use BIM in the design and construction phase. The designers hired are now being required to do their work in a BIM environment and share that information with other relevant stakeholders. The models are being checked for accuracy and are used for collision detection. These BIM models and related information may be conceivably passed on to the other departments upon construction of the project. However, such information is currently not in a usable format as it must be manually input into systems such as ‘FacilityMAX’ and ‘ARCHIBUS’. Consequently the BIM models have not been used by XXX University past the design and construction phases.

In an effort to address this situation the university has started a pilot project with the authors by taking an existing building on campus and creating a BIM model for it. The model will be built in order to be able to import all the data that is needed by the maintenance and operations department and the campus planning and space management departments. It is anticipated that the use of COBIE spreadsheet as a model for extracting facility management information from the BIM model will be considered. Based on

the results of the project, the university will modify the BIM contractual language in its documents for future projects to facilitate seamless transfer of data into their accompanying software. Upon completion of this project, the model will also be tested for its use by the department of life safety to examine its use in case of an emergency.

4. Conclusion

Building Information Modeling is fast establishing itself as the brand new approach to design-build-operate buildings in the twenty first century. Decades of efforts by academic and research institutions have resulted in this technology become a reality in the Architectural-Engineering-Construction (AEC) circles. BIM creates an environment for all participants in the AEC industry to produce buildings that are better, cheaper and built faster. The advent of BIM technology has prompted new approaches for all the stakeholders in the built environment such as 'Whole Building Design'. This philosophy calls for integrated design and team methodology for the successful creation and use of building projects. The technology is still at its infancy and is not being fully utilized in the maintenance and operations aspect of new buildings. Several hurdles still exist in making the technology a common thread in the industry that may continued into the facility maintenance and operations aspects.

The facilities division at a large university such as XXX is inherently complex in nature as they have several hundred employees and manage almost eight million square feet of built space. Implementing BIM for facility management is also complicated in such an environment. BIM is being implemented during the design and construction phases. The software tools necessary for using BIM in life cycle maintenance currently do not exist. However, simple strategies may be adopted to save time and money by avoiding dual entry of data into various systems. The university is currently in the process of modifying its contractual language so that future BIM models may have information that may be directly imported into its facility maintenance and space management software.

The future of BIM for the use of facility management has several innovative possibilities. The use of the internet to report maintenance issues using a BIM model may soon be a reality. BIM technology is in the process of merging with several ancillary industries such as fabricators to build projects faster and cheaper. This BIM model may soon be used from within facility management software for the purpose of day-to-day preventive and responsive maintenance. It may seem futuristic but current technology allows for the development of a system by which a design goes from the BIM model to the fabricator and upon construction, all the building elements may be able to self-diagnose and report any maintenance issues to back to the BIM model and the concerned department.

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