EVOLVING A BUILDING INFORMATION MODEL

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ABSTRACT

Building Information Modeling (BIM) is often described as an interoperable means for the project team to exchange information. The motivation for using BIM is to streamline the project delivery process and to eliminate the need for those in the design, construction, and operations phases of a project to worry about how information is exchanged among individual proprietary software systems. From the point of view of large owners, such as federal government agencies, BIM is seen as the mechanism by which information needed to maintain and operate facilities and their assets could be captured.

Since the largest life-cycle costs associated with facilities occur during the operational phase, facility managers require building data to support their operational missions. This paper provides an overview of one effort in which United States federal government agencies are jointly working toward the development of BIM specifications to support information exchange between the construction and operations phases.

KEY WORDS

Building Information Modeling, Business Process, Modeling, Industry Foundation Classes, IFC, Commissioning, Submittal, COBIE

INTRODUCTION

Throughout each phase of the facility life-cycle information is created, transferred, augmented, and then typically lost. From an infrastructure owner's point of view, the loss of such information reduces the capability to efficiently operate the facility over the long term. On a given project, facility managers have anecdotally reported that information as simple as warranty contacts are frequently lost. Loss of such information directly increases the cost to operate the building and decreases the reliability of the facility for its users. Missing information also increase costs due to due to lack of operations instructions and spare parts data.

Given that public facility owners are required to manage multiple sites spread around the world, the total cost of the loss of even such simple warranty information must be staggering. The loss of information about spare parts and repair instructions for equipments and systems certainly leads to sub-optimal, jury rigged facilities operations. The loss of such information is surprising since the consistent use of methods as simple as paper index cards might be able to capture, collate, and retrieve equipment warranties and spare parts information.

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BACKGROUND

Owners have attempted a variety of different methods to capture facility/infrastructure information. The most commonly used method is the requirement for delivery of documents describing each piece of equipment, warranty, and spare parts information. These paper documents are provided by the construction contractor at the end of the construction phase during building commissioning. Once the boxes of paper documents are received and checked by the owner's construction management agent, the documents are transferred to the facility management office. Once at the facility management office, the documents are most often placed in a storage room with documents from other projects. According to anecdotal evidence given by facility managers these documents are stored and never used again.

During the commissioning process, or as part of the contract requirements, construction contractors are also required to installed paper documents in equipment rooms. System startup instructions, valve schedules, and other documents are often found in plastic sleeves in mechanical rooms. Facility maintenance personnel use these reference documents to assist them in operating the related equipment and systems. Documents that pertain to systems are frequently removed from the equipment room as system component inspections or repairs are made. Once removed from the equipment room, there is no guarantee that the information will be returned.

Since the advent of the personal computer, owners have tried various methods to capture facility information electronically. One of the most accepted of these methods in the U.S. public sector is the "Operations and Maintenance System Information" or OMSI project [UFGS 2001]. OMSI requires the construction contractor to provide an electronic copy of all product and system information at the end of the construction phase. The Naval Facilities Engineer Command, NAVFAC, OMSI Support office manager has reported to the authors of this paper that the cost of producing the OMSI document is approximately $40K per large project. Given this potential saving, the use of the OMSI is not as widespread as would be expected.

There are, however, several difficulties with the OMSI approach. The most critical problem with OMSI is that cost controls during design and construction restrict the ability spend the money for OMSI even though having such information will reduce life-cycle costs. The next most important negative issue with OMSI is that the compact disk storage media utilized can be very easily lost or misplaced. Boxes of paper documents may be hard to look through but, unless a building burns down, the paper documents will be available if needed. The final problem with the OMSI approach is that data is provided in an 'e-paper' format via Portable Document Format (PDF). Because of the format utilized, finding specific documents requires either additional search engine technology or hand review of individual documents. The OMSI documents do not allow information to be directly exchanged with other system, such as Computerized Maintenance Management Systems (CMMS).

PROBLEM

The problem addressed by the authors is how to foster the smooth exchange of needed construction information to facility/infrastructure operators. This exchange will need to occur within the context of existing contract language and not be an added cost item or time intensive action for either the project mangers or facility operators. If the results of this work

are to impact the U.S. construction industry, then the tools developed must also be easy to use for small and large contractors and facility managers.

APPROACH

A series of projects are underway, using a spiral-development approach, that should result in the real-time rapid exchange of construction-operations information. These projects jointly are called the "Construction Operations Building Information Exchange" or COBIE project. The contribution of COBIE will be to recommend modifications to current business processes and define the technical contents of information exchanged. COBIE software tools will provide one example of how such processes and standards could be implemented.

The spiral-development approach is also being used to minimize disruptions of existing contracting procedures that will be modified to test COBIE. Based on these experiences, contract language, processes, standards, and software may be updated through the next spiral-development cycle.

To guide these efforts the Information Delivery Manual (IDM) [Aas-Jakobsen 2006] process will be used. This process includes three components. At the lowest level is a translation of business rules and data exchange elements directly into the IFC model. At the middle level is an identification of the data exchange elements and constraints on their use. At the top level is a business process model that motivates the need for information exchange and allows validation of the effort. For the COBIE project, the Business Process Modeling Language (BPMN) [BPMI 2004] will be used for business process modeling.

Readers familiar with BIM as a life-cycle tool will recognize that COBIE does not require that information be provided by designers to initialize the model. The transfer of BIM from the design stage will reduce the meta-data collection that is identified as part of COBIE but is not mandatory for COBIE to be successful. The value of the COBIE, to those working on the design-side of BIM is to define minimum data sets that should be included in performance specifications to ensure specification compliance.

PHASE 1.1 REAL-TIME SUBMITTAL PROCESSING

When construction related computer applications for personal computers first began to be created in the late 1980's, submittal registers were one of the first applications to be created. Submittal registers are a key component of the Corps of Engineers, Resident Management System [UFGS 2005] and Naval Facility Engineer Command's, WebCM [UFGS 2004]. These submittal registers contain the information needed to identify the location of each submittal, find late or missing submittals, and identify submittals whose review times are exceeding expectations. In these state-of-practice systems submittals are still provided in paper format and manually routed for approval.

The first project to reduce loss of data between construction and operations is a real-time submittal processing application developed as part of the Project Extranet (ProjNet^{sm}) suite of tools. This tool allows submittal content in PDF format and specific meta-data to be exchanged along with the administrative tracking of submittals. Allowing the project team to capture this information begins the process of documenting project turn-over records.

Key to the use of the enhanced submittal register is the development of contract specifications that require the submission of electronic information by the construction

contractor. These specifications and pilot projects from the Corps of Engineers and the National Aeronautics and Space Administration (NASA) are being identified at the time that this paper is being prepared. The specification will identify the technology that will be provided to support the information exchange, and document the required information to be exchanged. Given the differences among projects, the specification will not attempt to prescribe specific business processes. Over time, best-practices will emerge that can be documented independently from the contractual obligations associated with contract language.

Facility managers need to know the specifics of each piece of equipment including serial number, location, installer, and warrantor of each piece of equipment. This information is typically provided by the contractor during the commissioning or project turnover phase but through COBIE will be captured during the appropriate step in the process of building construction.

An example of the type of meta-data needed for a given submittal is provided in Table 1. Table 1 lists some of the data that may be required, in addition to the valve cut-sheets. The Reference field directly links the meta-data provided to specific submittals allowing the cut-sheet for the valves data to be retrieved. Next, the type of valve should be provided. The system in which the valve operates will next be identified. Finally, the expected number of values of this type will be listed. Some, if not all of this general design information, could but is not required to be contained within a designer-provided BIM.

Table 1. Valve Cut-Sheet Attributes

Field Name
Cut-Sheet Reference
Valve Type
Valve System
Valve Count

PHASE 1.2 EQUIPMENT SERIAL NUMBER CAPTURE

After the contractor has ordered the equipment it will be delivered. This delivery may be to the jobsite or to the contractor's warehouse depending on the status of the project and size of equipment. Either when delivered or installed the contractor will know the serial number for each piece of equipment. The next step in COBIE process is for the contractor to select the corresponding submittal and enter the equipment's serial number and name plate data.

PHASE 1.3 EQUIPMENT AND MATERIAL PLACEMENT

Rather than wait until the end of a construction project to recollect information known by the contractor during equipment installation phase, this third COBIE phase requires contractors to provide equipment locations as the equipment is installed. This requirement is consistent with that specified in the OMSI guide specification. OMSI requires the contractor to conduct a site survey to gather equipment and material placement data.

When the valve is installed and (possibly later) tagged, the contactor will provide data augmenting that provided in Table 1. An example of the type of location specific information that will be required by COBIE is shown in Table 2. The Cut-Sheet Reference value allows

the cut-sheet and Table 1 data to be retrieved. The room where the valve was installed, its normal operating position, and a brief description or a phrase that will help to locate the valve in the room are provided. Once the valve tags arrive on the site, each individual valve tag can be referenced to its appropriate valve.

Table 2. Valve Location Attributes

Field Name
Cut-Sheet Reference
Room Number
Valve Normal Position
Valve Location Description
Valve Tag Number

Construction contractors will also be the ultimate beneficiaries of process as this information as it will decrease the cost currently expended to gather such information at the end of the project. For example, documenting valve tag data during construction provides automated valve tag lists which are difficult to create after valves are hidden by ceiling tiles or other obstructions during the commissioning phase. The decrease in cost to conduct a site surveys to gather this information during commissioning will more than offset the increase in cost required to collect the data when it is initially available.

PHASE 1.4 WARRANTY CAPTURE

A type of submittal provided by the construction contractor that is best provided at the end of a project is warranty information. The capture of this information by the owner is critical to allow that owner to take advantage of the protections offered by the warranty. To capture this information, COBIE will allow the contractor to identify the name of the party holding the warranty, link to a specific warranty certificate, identify corresponding equipment, and identify the terms of the warranty.

PHASE 1.5 MAINTENANCE INSTRUCTIONS CAPTURE

Another type of submittal provided by the construction contractor that is best provided at the end of a project is that of system related information. This type of information includes manufacturers' instructions, start-up and emergency operations procedures, maintenance schedules, and spare parts information. To capture such information Phase 1 of COBIE will only require the contractor to link data provided in PDF format to the related type of equipment found in the submittal register. Capturing this information in a central repository, although not in computable format, will still provide easy access for operators and will decrease the duration accomplishing of work orders and down time due to lack readily available schematics and part lists.

PHASE 1.6 MAINTENANCE SYSTEM EXCHANGE

The COBIE project is being developed to support the exchange of information from construction to operations. Ensuring that the information gathered during construction is

captured was the requirement of Phases 1.1 through 1.6. If this project is successful, then at the end of construction, equipment information and location, system descriptions and warranty information will all be captured. This information provides the minimum information needed by facility managers to more effectively operate their facilities. Facility maintenance offices who utilize CMMS should be able to accept/exchange information captured through the submittal register.

Prior to Phase 1.6 COBIE team members representing CMMS's will implement data import functionality that allows IFC data import formats to directly populate, or augment the population of CMMS systems. This exchange will be simple for new facilities or infrastructure; however, for infrastructure already part of CMMS systems, work will need to be accomplished to ensure that imported data can be linked to these existing database models.

PHASE 2 CENTRALIZED EQUIPMENT CATALOGUE

According to anecdotal evidence gathered by the authors, construction contractors often are required to collate submittal packages for their entire teams to ensure completeness and compliance with individual client's requirements. Often prime contractors go directly to product manufactures to gather data such as cut-sheets to include in submittals. In Phase 2 of the COBIE project we will support the processes used by construction contractors to prepare submittals. Tools will be constructed that allow the collation of submission of various submittal documents from the complete set of team members. These tools will also provide the capability to prepare submittals that are forwarded following prime contractor draft review. Drafting of submittals may, of course, be accomplished by either the prime or any of his subcontractors.

Meta-data needed for various pieces of equipment and building materials during Phase 2 will be transitioned from contractor manually entered limited meta-data to a full data description provided by manufacturers. The set of required data will be based on a number of established sources. One such source is the Industry Foundation Classes (IFC) [Liebich 2004].

The IFC Model provides a guideline of the minimum essential attributes for the design and construction of equipment. Table 3 provides, for example, a list of those attributes needed for the IfcFan object. Requiring such information manually is unsustainable since the information could be directly submitted from equipment manufactures.

To assist manufactures to provide complete and correct sets of product data the National Institute of Building Sciences (NIBS) has developed "ProductGuide" as part of its Whole Building Design Guide [NIBS 2006]. The objective of the ProductGuide is to work with equipment manufacturers to create a centralized equipment catalog. As of December 2005, the ProductGuide is available through the collaboration between NIBS and McGraw-Hill Construction.

The contents of the ProductGuide are currently the cut-sheets provided by manufacturers to suppliers and contractors for submittals. The manufacture supplied information will be expanded over time to include meta-data needed for a given submittal and to verify compliance with performance specifications. A web service provided by NIBS will allow the

automated submission of ProductGuide documents and metadata into enhanced submittal registers such as that being included in ProjNet[sm].

Table 3. Partial Listing of IfcFan Attributes

Field Name	Data Type	Size
PrimaryEnergySource	Text	50
ImpellerDiameter	Number	Double
AirFlowType	Text	50
StaticPressure	Number	Double
FanPressureClass	Text	50
FanWheelType	Text	50
WheelMaterial	Text	50
WheelTipSpeed	Number	Double
DischargeVelocity	Number	Double
HousingMaterial	Text	50
DischargePressureLoss	Number	Double
FanDischargeType	Text	50
FanArrangement	Text	50
FanRotation	Text	50
FanDriveArrangement	Text	50
DrivePowerLoss	Number	Double
MotorDriveType	Text	50
MotorInAirstream	Yes/No	-
FanMountingType	Text	50

PHASE 3- PERFORMANCE SPECIFICATION COMPLIANCE

Specifications used by federal government are performance-based. These specifications require that products and equipment perform to standards identified in the specifications. Manufacturer's current submittals reference these standards to signal to approving officials that the equipment meets the specification requirements. COBIE Phase 3 will validate IFC, and other data requirements, to ensure that meta-data provided allows the automated evaluation of performance specification compliance. It is expected that manufacturers will provide this data, along with their cut-sheets, to the ProductGuide. When a critical mass of information begins to appear on the ProductGuide any final barriers to contractor use of COBIE should be eliminated.

MIXED-MODE OPERATIONS

One of the critical constraints on the capture of all building information into a standard model will be the mixed types of submittals required. While the coverage of equipment and product data included in the ProductGuide will increase over time, it may never exceed 80%

of the manufacturer's information required on a given project. Physical samples such as those needed for color selections or to provide example system constructions, will also need to be included. As a result any BIM-based submittal procedure must also consider the implication of such physical submittals.

Unwillingness to participate in owner-based information systems will also be a barrier to use of a centralized submittal repository. To resolve this issue, a simple form may be developed using a spreadsheet or word processing document template. By providing the information in the template and forwarding the template to a specific email address, team members may be able to send in the PDF product or equipment information and meta-data necessary.

AS-MAINTAINED FACILITY INVENTORY

During the operational phase of the project, which may last well over fifty years, a facility is upgraded and renovated many times. To ensure that the information in the building model is accurate over time, operations and maintenance personnel will also need to update the model to reflect changes. Future projects will identify streamlined methods for service and other small contractors to interact with the model as part of their standard business process.

While the efforts presented in this paper address requirements for gathering information on new construction and during repair or renovation projects, most owners have a large pool of existing facilities. To support the As-Maintained facility inventory a survey tool is planned to allow interns to conduct inexpensive facility surveys. The survey tool will be extended to allow maintainers to quickly gather information as they perform routine maintenance activities.

CONCLUSIONS

Given the size of the effort required to create, populate, and maintain Building Information Models within the context of regulatory and legal constraints, an evolutionary approach is required. This paper's approach emphasizes the incremental creation of BIM data by those contracted to provide the corresponding physical or conceptual facility components. Rather than a new activity, creating the BIM becomes a replacement for existing paper-based data exchange requirements. This paper provides an example of this approach can be economically accomplished by the use of material and equipment submittals.

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