the exchange of information between different tasks during all phases of the project lifecycle. BIM implementation varies significantly from project to project, and so the project team must effectively design an execution strategy by understanding the goals and capabilities of all stakeholders.

Owner organizations are only beginning to outline their BIM implementation strategy for the design and construction process, as well into facility operations. In order to effectively plan for the integration of BIM into their facility management processes, a facility owner must develop their information requirements from a set of core values which align with best practices of their organization (CIC, 2012). Currently, there is no standard methodology to assess and develop owner requirements within the AEC industry. Each facility owner will have a unique data set and must look internally within their organization to understand their operating systems, identify best practices, define their essential information needs, and then contractually obligate project teams to deliver these requirements at different phases during the project lifecycle.

To achieve maximum benefit from project BIM implementation, all project stakeholders must collaboratively develop a strategy which allows for streamlined information exchanges. This can ultimately be achieved by encouraging continuous owner input and participation.

The Pennsylvania State University

As owner, designer, and construction manager, the Office of Physical Plant (OPP) at the Pennsylvania State University (PSU) has been successful with accelerating BIM technology in both new construction projects and facility operations. The OPP currently requires the use of BIM on all projects valuing over $5 million and any other major facility renovation. Using the recommended processes and templates from the BIM Project Execution Planning Guide, the OPP has developed an effective BIM implementation strategy for project stakeholders to collaborate during all phases of a facility project (CIC, 2009). For the purpose of this research, the researchers focused on the development of a procedure to streamline the information exchanges between outside consultants and several departments within the OPP.

MODEL AUDITING RESEARCH METHODOLOGY

The focal point of this research is to develop a standard procedure for the verification of the completeness and accuracy of modeled facility information. When documenting the research findings, the first step was to review and compare any ongoing projects with a similar approach. Next, the facility information requirements were determined along with the priority of each attribute. Finally, a case study was used to validate the required facility information and document the appropriate method for auditing the accuracy and completeness of the asset data. The following detailed research steps were conducted to develop the concepts addressed in this paper:

1. Interviews were conducted with various institutional owners collecting building information throughout the US to determine the initial value of the research.

2. Relevant literature was reviewed to document previous studies as well as ongoing quality control initiatives.
3. Standard facility information requirements for PSU projects were documented using previous completed work by the Virtual Facilities Group.
4. Key members of the OPP were interviewed to prioritize the required facility information for future use in operations.
5. An initial model auditing process was developed to qualify facility information and geometry on new and major renovation projects.
6. The developed model auditing procedure was then tested on a large dormitory project on a PSU campus.

The case study results were gathered during meetings with the project stakeholders. A research team member attended each of the following meetings to integrate facility information into the BIM Model: BIM Execution Planning kick-off meeting, Pre-Coordination meeting, and 3D Coordination meetings. In addition to meetings, the project engineer responsible for BIM implementation was helpful in collecting data on the project. This structure was used to determine the attribute requirements for each maintained asset considered critical in the case study project.

QUALITY MANAGEMENT FOR DOCUMENT TURNOVER

Efforts to manage, assure, and assess the quality of information at facility handover have been ongoing since the adoption of BIM as a project tool. A significant number of case studies from the past have documented the use of 3D Laser Technology and other tools to help capture as-built facility information for operations (Woo et al, 2010). While these have been effective in the capture of spatial and geometric data, there have been few examples of owner organizations capturing and handing over information seamlessly for daily maintenance and operations. With increased reliance on the automated delivery of digital data for operations, the industry has been pushing towards the use of applications that would allow the verification of the accuracy of facility information. Solibri model checkers are commonly implemented on projects with a purpose for automated code compliance verification. Compliance to specified standards and model integrity are verified using vendor based applications, as are spatial programs for zoning and circulation for design validation.

For effective implementation, these automated tools require a standard set of rule set for comparison. The purpose of these tools is to verify the accuracy of information for a particular use case. To effectively develop these rule sets, owner organizations will have to begin with an understanding of the purpose of requiring accurate information and the need for managing its quality for operational uses.

Value of Information for Facilities Management

Facilities Management (FM) ensures that the built environment performs the functions for which the facility was designed and constructed. The overarching goal of this service is to improve equipment effectiveness, return equipment to proper functioning conditions, control Life-Cycle cost and provide a safe and functional system for its occupants (WBDG, 2011) (NASA, 2008).

BIM is increasingly recognized as one of the ways of handing over accurate information that would be of value (Jordani, 2010). The accuracy of this information assists in the decision making process to properly maintain and operate a facility. Reliable and optimized decisions for operations can be made using known and accurate data (Whyte et. al, 2010). Apart from the accuracy and completeness of facility data, owner and operator knowledge of information management is another ongoing challenge. A method to develop an understanding of the required information for operations and optimizing this information would benefit a team with developing ground rules for the auditing procedure.

Data & Process Standardization: Challenges

The Construction Operations Building Information Exchange (COBie), developed by the United States Army Corps of Engineers was one of the first documented information capturing mechanism for facilities data. This industry open standard for delivering information from construction to operations provides an opportunity to capture and handover complete and accurate information. Organizations developing their own requirements for their facility information must specify a proprietary format for the capturing and delivering of the information (CIC, 2012). In either of these cases, best value is achieved when the required information for operations and maintenance is obtained and delivered at the required time and of the desired quality.

As efforts to standardize data and processes move forward, process challenges must be understood by the entire project team in order to achieve maximum results. From the surveys and interviews that were conducted as part of this study, one of the biggest challenges for industry implementation is the current level of understanding and knowledge of the end users, the same users who require and use the information for operations. Some of the other challenges mentioned to the standardization, improvement and betterment of quality were: lack of adequate quality assurance and control mechanisms; inadequate definition of responsibilities for information handover; incomplete definition of deliverables or requirements and lack of a tested process to ensure desired handover of information from design and construction to operations. The purpose of this survey was to understand the challenges with the information handover and address possible methods to address these issues.

DEVELOPING OWNER LEVEL OF DETAIL REQUIREMENTS

Project teams must not only consider the information requirements for the project, but also recognize their responsibility for providing the owner with much of the operational data required to maintain a facility. However, few owners have defined these needs and how this information can be effectively integrated into their facility management systems. An owner organization must develop an understanding of their operating systems and procedures to identify where project information can add value to their daily operational tasks, recognize areas of improvement within their current processes, and then develop their facility information requirements (Kasprzak et al. 2011).

In order to develop a comprehensive data set, the owner organization must address the following: what information is considered essential and high priority to their operations processes; when and by whom should this information be developed during the project lifecycle; and what are the contractual and legal concerns associated with the development of this information. Other considerations include who is responsible for auditing and maintaining the data and what systems will be used to manage the acquired data throughout the lifetime of the facility (Fallon et all, 2007). After performing this assessment, the owner organization should explicitly request the facility information requirements as part of the contracted project deliverables. With this knowledge evident during project onset, the project stakeholders can develop an effective information exchange strategy to streamline and validate information exchange processes between the facility lifecycle and facility operations.

OPP Development of Standards

After participating as an owner representative for several projects implementing BIM on the PSU University Park campus, OPP recognized a need to further develop their contract language to include owner data requirements. Concurrently with an initiative to upgrade their existing facility management system, OPP began an assessment of internal operations processes cross departmentally and identified where additional information captured during the project lifecycle to add value to the existing workflows. Ultimately, the goal was to develop a data exchange solution to eliminate the duplication of effort and information that seemed to be occurring when multiple parties were accessing this information.

The established owner requirements document contains the facility asset requirements for all campus projects implementing BIM at PSU. At a minimum, each asset is to include a listed set of parameters, a barcode, O&M manual, installation guide, submittal information, warranty documentation, and commissioning report. It is the responsibility of the appropriate project stakeholder to provide and verify design, construction, or commissioning information to meet the deliverable standards for the project. Per the developed contract language, these information sets must be provided to PSU at different points during the project lifecycle to audit and validate content.

PLANNING THE MODEL AUDIT PROCEDURES

Facilities Management services, for both public and private organizations have employed either directly or a version of the following maintenance programs: Preventive Maintenance, Condition-Based Monitoring and/or Reliability-Centered Maintenance (NASA, 2008). The goal of these maintenance programs, as they evolved, was to mitigate the risk of occupation and use of facilities in the case of equipment, system or facility function failure. With the FM industry focusing on reducing the risk of occupancy, the quality planning procedure adopts risk analysis as the root of the method.

Risk Analysis for Informed Decision Making

Risk analysis (risk assessment) has been adopted across a wide number of industries for the benefit of reducing unforeseen risks or mitigating their impact. The construction industry has used risk assessment for managing risks on international projects to improve project performance (cost, schedule and scope) (IPRA, 2003). The facilities maintenance industry has used risk analysis to make informed maintenance and operations decisions and prioritize maintenance activities (Backlund and Hannu, 2002).

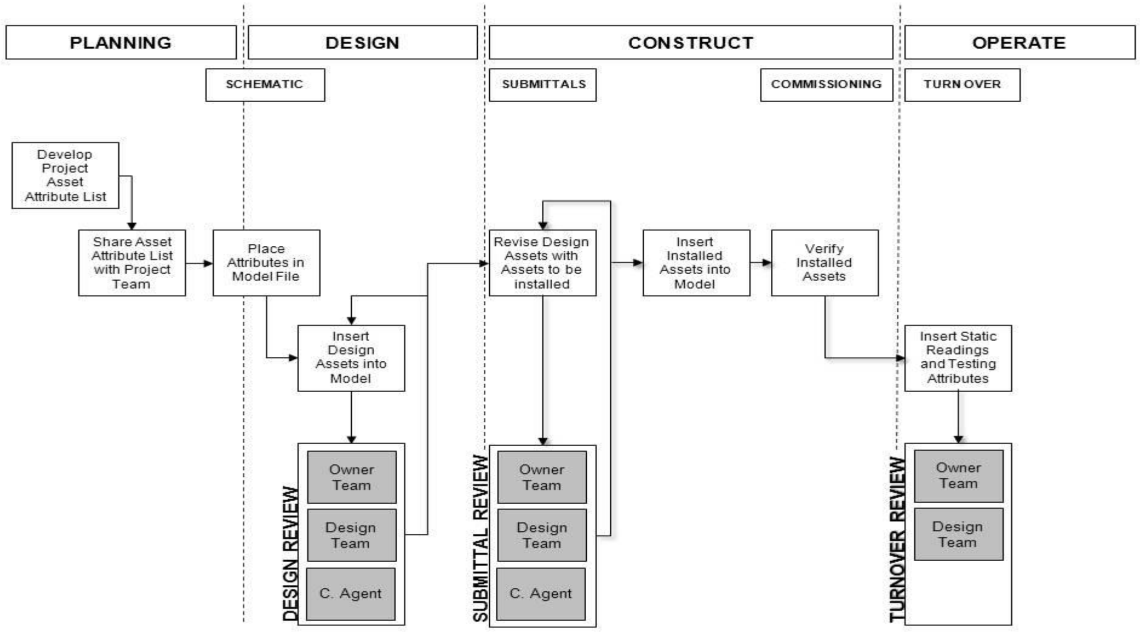

Figure 1: Model auditing process for a typical Penn State project

The risk analysis procedure has a number of variations that exist to cater to the specific needs of a project, technology or end user. However, it is important to understand that the procedure intends to help plan and make decisions based on: potential hazards or risks, risk frequencies, and risk impacts. To assist with the planning and decision making for developing the model and information auditing procedure, these issues were modified to address the needs of facilities management, operations and maintenance:

- What facility information is required for regular and reliable operations of a facility?
- How do facility elements relate to one another? (based on hierarchy, naming, tracking, etc)
- What systems and components pose the biggest threat in a facility? (in terms of cost, frequency of failure, time and expertise required for maintenance)
- What information for these prioritized system and components is required for the reliable maintenance and to reduce risk?

The risk analysis approach could be either qualitative or quantitative, with the former basing decisions off of experience and know how, and the latter on recorded information and numbers. The choice of the method to be adopted will ideally be based on the availability of information and the experience of the facility owner's team implementing the procedure. At PSU, a qualitative approach to risk analysis was adopted while developing and documenting the initial model auditing procedure. From an initial run of the procedure at OPP, the steps required for the planning of the model auditing procedure that was documented for further validation are:

1. Determine and document facility information required for operations
2. Identify the relationship between different elements of the facility
3. Classify information based on task or use case for facility operations, as seen in Table 1.
4. Prioritize information using the risk analysis procedure- qualitative or quantitative, as seen in Figure 2.
5. Identify and require responsibilities for model and information auditing on projects

Risk Level	Definition
High	Information cannot be accepted until it has undergone a rigorous quality management process to verify and validate the information
Medium	Information can be accepted before validation through a quality management program, but has to be observed and resolved as its use progresses through operations.
Low	Information can be accepted before validation through a quality management program, but has to be observed as services progress through operations.

Table 1. Information risk classes and definitions

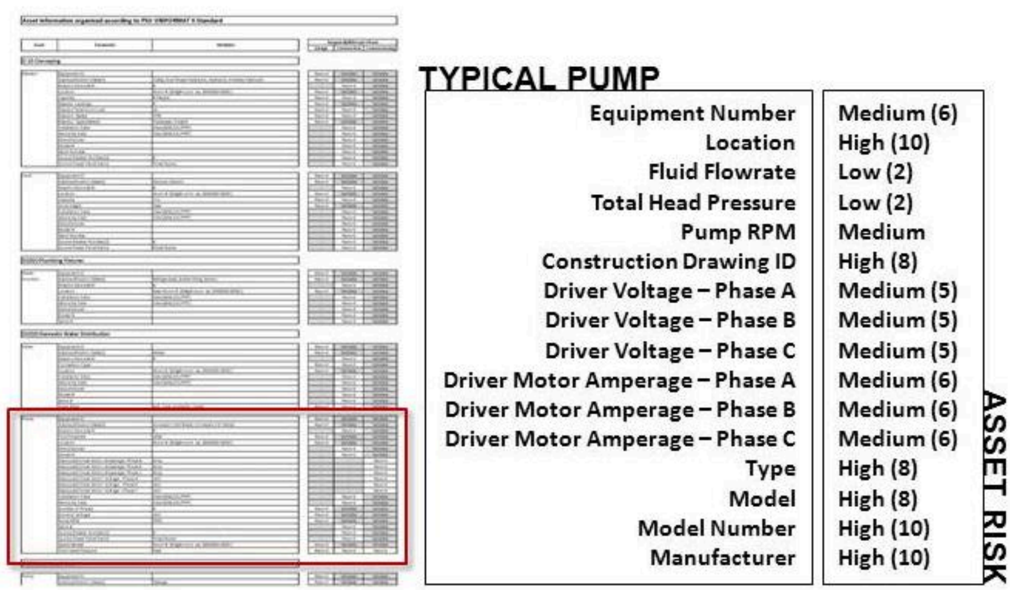

Figure 2: Asset attributes for a typical pump including level of risk for each

These are an initial set of steps that would be required to plan the model and information auditing procedures for an owner organization. This process will be further validated and documented on other projects for continuous improvement.

MODEL AUDITING CASE STUDY

In order to test the developed model auditing process, OPP chose the South Halls Complex project at University Park, PA. Totaling $94.1 million, this project, shown in Figure 1, will be completed in four phases. This project includes significant facility renovations to the four existing duplex residence hall buildings and dining commons, as well as the addition of a new residence hall. The major facility infrastructure upgrades will include new energy-efficient systems, new roofs, private bathroom clusters, and suites that include a kitchenette, dining, and lounge areas. The new residence hall, incorporated into the overall plan will add 45,000 square feet in four above-ground floors and house 211 beds in 108 rooms.

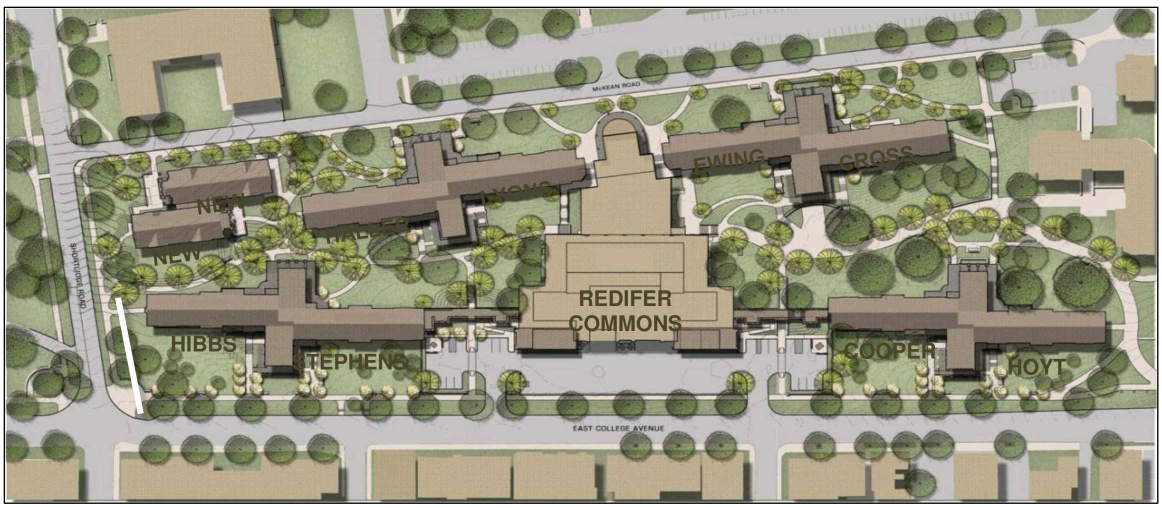

Figure 3: Validation Case Study- South Halls Complex Project, Penn State University, University Park, PA. Image courtesy of Barton Malow.

Initial Findings and Challenges

The OPP was able to establish a functional information hierarchy for campus facility projects based on the level of risk it imposes on current operation processes, as shown in Figure 2. Generally, a facility contains spaces which are served by systems. These systems are comprised of different components and assets which have a location. A particular asset may assist one system and serve many spaces. The OPP uses both a functional and system based hierarchy within their current facilities management systems; thus, location data is considered high priority information and is even standardized within the naming convention of the assets.

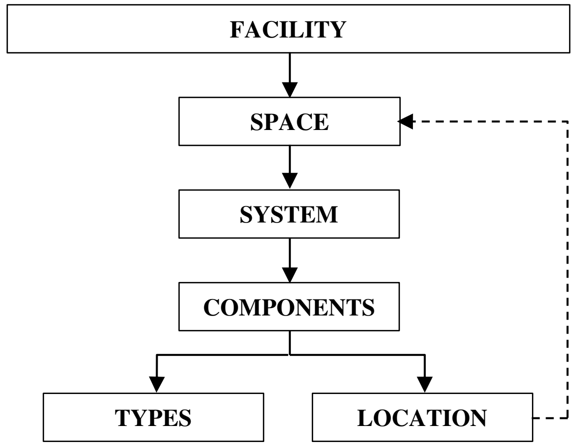

Figure 4: OPP facility element hierarchy

An important lesson learned during the initial implementation and development of the procedure was the way information had to be assessed and categorized. While developing the strategy to implement and contractually require model auditing, it was understood that information had to be managed on a use or facility maintenance task basis, as shown in Table 1. The following departments were involved with the validation of the facility information: Virtual Facilities Group (VFG), Work Control Center (WCC), Facility Resource and Planning (FIS), Energy and Engineering Group (EE), and Building Automation Group (BAS). This helps identify the responsible parties for auditing and approving the set of information tracked to maintain the facility.

Mark	Barcode Number	Model	Manuf.	Serial Number	Space: Level	Space: Name	Space: Number	FCU Cooling Capacity	FCU Heating Capacity	Equip. Type	BAS Control?	BAS Identifier
FCU-7	28127	CXB06	IECINT.L ENVIR	005690-4565	HALLER GROUND FLOOR	MAINT. SHOP	H012	0.0 Bty/hr	0.0 Bty/hr	2-PIPE	NO	---
FCU-6	28128	CPY02	IECINT.L ENVIR	0096845-6254	HALLER GROUND FLOOR	OFFICE	H006	0.0 Bty.hr	0.0 Bty.hr	4-PIPE	YES	FCU004
VFG		WCC			FIS			EE			BAS	

Table 2: This is an example of the OPP Task Based Information List.

FUTURE WORK

After seeing the initial results of the case study, the OPP is planning to require these information deliverables on all campus facility projects, not just those implementing BIM. This effort will require another revision to the existing contract language and evaluation of information exchange processes for projects under $5 million, as well as facility construction projects developed internally in the Design Services department. The OPP will also continue to develop an integrated BIM to FM data exchange solution in order to improve and automate information exchange processes. While experience and technological capabilities may vary between specific owner organizations, developing thorough owner requirements is necessary for creating a more effective facility design and operations workflows during the lifetime of a facility. The model auditing process should also be tested with an inexperienced owner to thoroughly validate the developed procedure.

In regards to the risk analysis procedure, an investigation needs to be performed to identify the different effects of the choice of the approach (qualitative versus quantitative) on analysis results. However, a quantitative approach would be more challenging to implement if an owner has yet to establish a formal facilities management program that maintains a record of facility operations.

CONCLUSIONS

Prior to the development of this procedure, facility information was typically handled by project teams with little regard to its use in facility operations. This model auditing procedure revised this process and has developed a task or user based approach to the creation and validation of the project data sets. This method is an alternative approach to planning quality assurance and control procedures, minimizing risk while adding value when using facility information during operation processes. This project's outcome will, in time, continue to support the effort to implement improved operational strategies and begin to streamline facility information across all OPP departments at the University Park campus. The information exchange procedures implemented by the Office of Physical Plant at The Pennsylvania State University represent an excellent opportunity to identify and develop best practices solutions for facility delivery and facility operations within the AEC and FM Industries.

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