# Understanding Owner Information Need for Facility Management Asset Data in a Large Education Institute

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**Abstract**

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For large facility owners with multiple capital projects and facilities to manage, effective information management is critical to the success of facility operations. Literature has shown the complexity of information deliverable in the perspective of structure, format, content and facility maintenance infrastructure to fit owner's need and the necessities of defining owner's information requirement. However, owners still have difficulties in understanding the requirement of building information deliverable to ensure the usefulness of the closeout information. This thesis presents a view from the user after implementation of COBie in a university project and reviews the general industry standard and university information deliverable specification development to bridge the gap between national standard and industry implementation. The findings are valuable to help practitioners to define information requirement for asset data to support facility management and are beneficial to support standardization efforts for data exchange in the FM industry.

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# Dedication

Dedicate my thesis to

my parents and one of the important person
in my life, Anthony, for his support

# Acknowledgements

I would first like to thank my thesis advisor Dr. Carrie S. Dossick of the University of Washington Department of Construction Management for her guidance, suggestions, consistently steered me in the right direction whenever she thought I needed it.

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# Chapter 1: Introduction

For large facility owners with multiple capital projects and facilities to manage, effective information management is critical to the success of facility operations. According to the report of NIST (2004), owner's decision making relied on a range of information available to them, and therefore incomplete, inaccurate or vaguely defined information leads to a poor decision.

Despite the importance of information management, the most owner does not have precise requirements for information deliverable to ensure the usefulness of the closeout information. Thabet et al. (2016) summarized the challenges of current process of collecting information from closeout deliverable: the challenges of retrieving information from as-built drawings; the difficulties of searching information from unstructured documents and reports; 50% of asset data is missing due to the manual process; unaware the existence of submittal information; no data verification because all stakeholders are gone after project is complete. Clayton (1999) mentioned several issues exist in the closeout documents including inappropriate format and mismatch between structure and content.

To address those issues, the first objective of this research is to explore the information handover usefulness for FM practices from the perspective of information handover format, structure, content, pathway, timing and facility management in the university setting. The second objective of this research is to bridge the gap between industry implementation and national standard and explore how current standard could support facility owner to address the information management challenges. Chapter 2 reviews the current state of the owner Facility maintenance (FM) information deliverable from the perspective of format, structure, content, pathway, timing and organization facility maintenance infrastructure. Chapter 3 provides the overall methodology utilized in this project. Chapter 4 presents digital information deliverable usefulness in case university. Chapter 5 compares UW Standard with National Standard in terms of format & structure, content, pathway, facility maintenance and operation. Chapter 6 includes the significant finding of this research and future recommendations.

# Chapter 2: Literature Review

## Introduction

Information management is critical to the success of facility operations. The owner has realized that information is critical to efficient facility management, and several researchers have identified the challenge of managing unrequired information for facility maintenance and operation. Mayo and Issa (2015) stated that "overload of information causes a lack of purpose, and therefore what could be information is, simply unused data." It is essential to define and formalize the required FM information to identify what information is useful.

There is growing interest in how detailed handover information collected from construction and design stage can be specified, delivered and consumed to be used to support facility maintenance and operation. The information needs are diverse for different organizations. (Teicholz, 2013) The first step of implementing building information modeling (BIM) into facility operation is defining and formalizing the information required by Facility Maintenance (FM) personnel. (Liu & Issa, 2015) Thabet et al. (2016) also identified that it is necessary and critical to identify information needs that correlate with facility operations related tasks. Many studies have conducted to implement BIM for FM. However, few case studies provide in-depth information on information deliverable requirement for BIM-enabled FM. (Pishdad-Bozorgi et al. ,2017)

To understand the current state of the owner information deliverable, this section summaries the owner's information deliverable requirement from the perspective of format, structure, content, pathway, timing and organization facility maintenance infrastructure.

## 2.1 Format and Structure of Information Deliverable

### Format

Fallon et al. (2006) categorized four types of electronic information deliverable forms and formats: proprietary format, standard format, structured data and unstructured. Proprietary format, created by specific software applications such as CAD or Revit, is the property of a single software vendor. A standard format can be categorized as ad hoc standard ad and formal format. 'ad hoc standards' means it may come from a single vendor, but are supported by multiple vendors and products.

Formal standards are those maintained by an official standards development organization like ISO. For structured data, it can be accessed and manipulated directly by computer programs without human interventions, but any data that cannot be machine interpreted are unstructured. Then they discussed the pros and cons of each format and suggested that when selecting format, one should consider information priority-the importance of information, information type-if the information needs to be updated, retention type-how long it needs to be saved, software application(s) to be used downstream and which format they support, need of sharing with external organizations, update frequency, costs and difficulties in getting the information into the preferred form and format and capability of the creator of the information to deliver the information in the preferred form and format. Further discussion will be carried on in the pathway of information deliverable to discuss the influence of format of information deliverable.

**Structure**

The number of researchers has focused on addressing ontology concept for facility information. Becerik-Gerber (2011) proposed FM digital assets captured in BIM could categorize as equipment and system, data and documents and provided a data structure of nongeometric data requirement. Wang (2013) developed the taxonomy to calssify facility information based on the work of Becerik-Gerber (2011) as shown in figure 1.

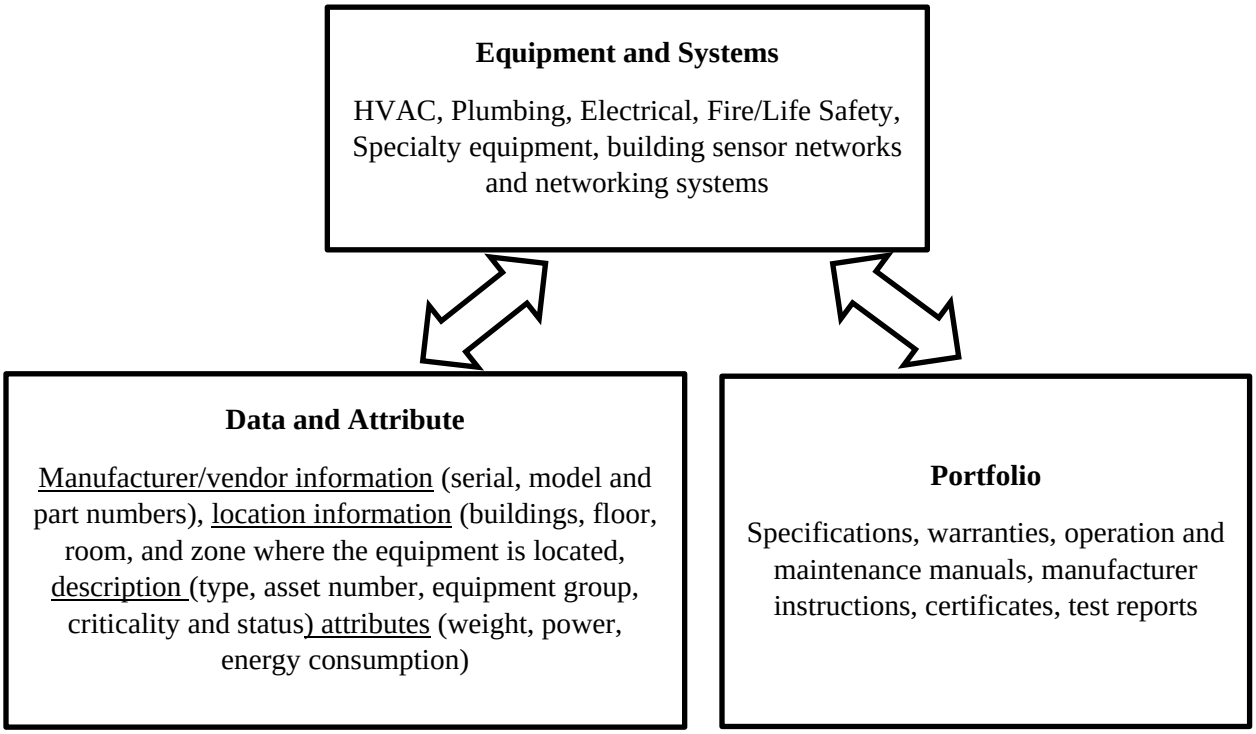

**Figure 2 Data Taxonomy (Wang et al., 2013)**

Hunt (2016) further categorized operation and maintenance (O&M) deliverable into system level information (physical description, functional descriptions, troubleshooting, preventive maintenance, corrective maintenance, parts list and operation/maintenance significant drawings) and equipment specific information (organized into manufacturer data library).

Current standardized systems for organizing data including MasterFormat (CSI, 2013), UniFormat (CSI, 2013) and OmniClass tables (CSI, 2013). Uniformat and MasterFormat may not be suitable for organizing closeout information because owner requires more detail information in a system. OmniClass has been rapidly developed in recent years and widely used as a standard for organizing BIM data. OmniClass has a more detailed view of specific components needed for O&M compared to Uniformat/MasterFormat. (Mayo & Issa, 2016) In the Penn State Office of Physical Plant case study, they presented a sample of PSU OPP Asset Attribute List organized according to PSU UNIFORMATT II Standard shown in Figure 2. (Messner & Kreider, 2013)

**Asset Information organized according to PSU UNIFORMAT II Standard**

| Asset | Parameter | Attribute |
|---|---|---|
| **D3020 Heat Generating Systems** | | |
| Closed Loop | Equipment ID | |
| | Subclassification (Select) | Hot Water |
| | Maximo Barcode # | # |
| | Location | Room # (bldg#-room ex. 0000000-000X ) |
| | Installation Date | Date (MM,DD,YYYY) |
| | Warranty Date | Date (MM,DD,YYYY) |
| | Percent/Type Glycol | % |
| | System Volume | GAL |
| | Type Glycol | Ethylene Glycol, N/A |
| | Water Loop Number | # |
| Boiler | Equipment ID | |
| | Subclassification (Select) | Cast Iron, Water Tube, Hot Water, Steam, Fire Tube, |
| | Maximo Barcode # | # |
| | Location | Room # (bldg#-room ex. 0000000-000X ) |
| | Boiler Size | BTU/HR |
| | Source Breaker Number(s) | # |
| | Installation Date | Date (MM,DD,YYYY) |
| | Warranty Date | Date (MM,DD,YYYY) |
| | Fuel Type | |
| | Manufacturer | |
| | Maximum Working Pressure | PSIG |
| | Model # | |
| | National Board Number | |
| | Safety Relief Pressure | PSIG |
| | Serial # | PSIG |
| | Source Power Panel Name | Panel Name |
| | Type | Hot Water, Steam |

**Figure 2: PSU Asset Information (Messner, 2013)**

Mayo & Issa (2016) concluded that the attempts to classify facility information lead to discussions about the how the owner uses the information and what is the preferred format for retrieval. The owner might choose any format if they can understand the impact of inventories on their operations.

## 2.2 Content of Information Deliverable

Several researches have been done to investigate more detailed deliverable requirement from the perspective of the information exchange content. Mayo & Issa (2014) provided an established base list of product information needs for specifying project deliverables. The results showed that a strong perceived need for information by owner is facility and occupant protection and HVAC-specific products and equipment. Dias & Ergan (2016) reported the initial findings of the requirements and level of detail (LOD) of the information for HVAC system maintenance. In addition, the quality of information deliverable content is important. Ghosh et al. stated that it is essential to take into consideration information accuracy and relevance from the perspective of information management. Aside from research studies, US Army Corps of Engineers, Construction Engineering Research Laboratory attempted to address the properties needed by facility operators and maintenance technician in 2011. (National BIM Standard-United States, V3 (NBIMS-US V3), 2015) However, due to lack of industry interest, buildingSMART alliance has never initialized the project.

## 2.3 Pathway of Information Deliverable

Researchers have attempted to providing integrated technical solutions to address the information exchange problem between systems. The Construction Operations Building Information Exchange (COBie) data format is a standard format to provide system-to-system exchange of space and equipment information without user intervention (Construction-Operations Building Information Exchange (COBie),2014). Parsanezhad & Dimyadi (2013) summarized today's technical solution for optimizing information transfer from BIM to facility management and operation (FM&O) software as shown in Table 1.

**Table 1 Technical solution for optimizing information transfer from BIM to facility management and operation software (Parsanezhad & Dimyadi, 2013)**

| Solution | Technical approaches for linking information |
|---|---|
| Using spreadsheets as simple document indexing tools | Hyperlinking |
| Using spreadsheets according to COBie guidelines | Hyperlinking, exchanging and synchronizing data |
| Using the IFC format for exchanging building information among BIM and FM&O systems | Exchanging and synchronizing data (embedding and integrating data to the recipient system) |
| Coupling CMMS's with BIMs via Application Programming Interfaces (APIs) | "Portal solution" |
| Using proprietary middleware such as EcoDomus, Onuma Systems and FM: Interact | "Portal solution" |

Parsanezhad & Dimyadi (2013) reviewed benefits and drawbacks of current integrated solution for information exchange. They pointed out some problems of implementing COBie as a standard format, for example, COBie information field has mismatches with organizational business goals and lack of incentives for manufacturers to provide product information in COBie-compatible format. They argue that IFC format and its associated Coordination Model View, on the other hand, has been failed in providing consistent semantics for all stakeholders. Middleware solutions are relatively expansive and mostly used by NASA or GSA projects. Portals solutions are relatively inexpensive and flexible to use. They find some issues in implementing BIM for FM are due to a lack of guidelines and efficient technologies for capturing BIM models of existing facilities, non-consistent terminologies and taxonomies that identify which information and what level of detail is desired by FM personnel. Therefore, choosing appropriate pathway and deliverables format and structure depend on lots of complex factors such cost, technical availability and owner's business goal.

## 2.4 Timing of Information Deliverable

Researchers have found the information deliverable delay is a big challenge for facility maintenance and operations. Thabet et al. (2016) stated that the delay of information received by the owner at the end of construction and project closeout were the biggest problem identified in

their research. Several case studies including Mathworks (Teicholz, 2012) and University of Washington (Aghazarian, 2013) have demonstrated that using COBie as deliverable guidelines to create a collaboration process could help transfer digital documents and FM data before project completion and project turnover. Using COBie process to deliver information handover has proven to have capabilities to provide faster project turnover compared to traditional paper-based turnover process.

## 2.5 Facility Maintenance Management Infrastructure

Most owners employ one of the following FM information strategies (Thabet et al.): a collection of drawings files and electronic data to manage facility maintenance, operation, and assets; simple spreadsheet with data that is manually entered and irregularly updated; Customized software platform solutions such as Maximo, AiM, and Archibus. Some researchers try to integrate facility data to enable BIM information deliverable exchange. Yu et al. (2000) presented a framework for developing Computer-Integrated Facilities Management (CIFM) supported by Facilities Management Classes (FMCs) and the Industry Foundation Classes (IFCs). Shen et al. (2012) provided a loosely coupled system integration platform to integrate building information modeling (BIM) with facility management. The technology is promising. However, in the real-world application, owners usually have a limited amount of budget to change their facility maintenance infrastructure. Therefore, it is important for the owner to develop facility lifecycle information requirement that can fit current facility owner's infrastructure.

## 2.6 Owner Requirement Guide and National Standard

The previous section has identified the complexity of information deliverable in the perspective of structure, format, content and facility maintenance infrastructure to fit owner's need and the necessities of defining owner's information requirement. A review of how leading organization defines information deliverable requirement including PennState, GSA, and USC is summarized in the following section.

The BIM Planning Guide for Facility Owners from Penn State University (Messner and Kreider, 2013) provided a general outline for documenting the information needs of an organization. Four steps in the guide are 1) choose a model element breakdown structure for the organization such as OmniClass, CSI UniFormat, and MasterFormat. 2) Determine model needs for example if the geometric model information is necessary for each facility element 3) Determine level of development that describes the level of completeness to a model element 4) Specify facility data, attributes, and properties. 5) Determine infrastructure needs. Also, the guide mentioned standard term for the facility property should select from OmniClass or COBie spreadsheet when available.

GSA National BIM Program required exchange facility information using COBie. GSA National BIM program focused on providing owner guidance on planning BIM process and standard format that streamlines the process. University of Southern California (USC) BIM Guide defined detailed information deliverable requirement such as data requirements, model LOD, required COBie worksheets and modeling requirements.

Ruiz (2012) proposed a concept of Integrated Model State (IMS) to assist the owner to identify BIM project information requirement. The second step of IMS framework is data survey that uses a data survey tool to create the data dictionary for the project and enables and assists COBie deliverables.

Open standard has potential to protect owner's data integrity. However, BIM-enabled information exchange using open standard still has some issues to be resolved (Cavka et al., 2017).

## 2.6 Conclusion

Literature has shown that there are a range of efforts from research studies, guidelines and standard and case studies to assist owners implementation of BIM and organization of deliverable information for O&M. However, previous case studies have been focusing on presenting the possibilities of BIM-enabled handover/technique solutions for FM and presents the lesson learnt in the process, it is unclear if owners pre-defined deliverable is useful to facility operators in the real-world projects. Therefore, owners still have difficulties in understanding the requirement of building information deliverable structure, format, pathway, timing and consideration of their

facility maintenance management infrastructure because the complexity of specifying information to fit facility owner's need.

This thesis presents a view from user after implementation of COBie in a university project and reviews the general industry standard and university information deliverable specification development to bridge the gap between national standard and industry implementation. The subsequent sections of this paper describe the objective, and methodology of the research.

# Chapter 3: Methodology

## 3.1 Research Objective

Literature review has shown that current research has focused on defining and providing general guidance on the project digital information deliverables requirement in content, format, and structure, however, it is not clear how useful the defined information deliverable is for FM practices and if current national standards or guidelines are useful for owner to determine COBie information deliverable requirement. Therefore, the specific goals of this study are (1) to explore the information handover usefulness for FM practices from the perspective of information handover format, structure, content, pathway, timing and facility management in the university setting (2) to bridge the gap between industry implementation and national standard and explore how current standard could support facility owner to address the information management challenges.

## 3.2 Research Methodology

Few studies having been conducted to determine how digitized information deliverable is used in the facility operation and maintenance stage of a project. This research examines how digitalized deliverables are consumed in a UW pilot project. According to Yu (2014), case study research is appropriate when investigating the contemporary phenomenon in its real-world context.

In phase 1, to develop an in-depth understanding of the project, we have acquired and studied the UW FM Data requirement specification and thesis/research paper based on previous case studies at the University of Washington. Then we conducted multiple informal interviews to understand organizational contexts including current UW facility data management infrastructure and information deliverable implementation in several UW capital projects.

Based on the analysis of the informal interview and documents review in phase 1, ARCF project was identified as the subject of this case study in phase 2. This project is chosen for two reasons: first, COBie is implemented at the beginning of the project; second, facility personnel has used facility asset data and documentation deliverables for a year at the time of research. Several key persons that participate in COBie digital information deliverable exchange project and digital

deliverable users in ARCF project are identified. Next, we generated an interview tool to perform structured interview to understand how digital deliverable information is created and then used in the actual projects. Two times of job shadowing were conducted to observe how facility operators use the digital information deliverable.

In phase 3, to understand the connection between national standard in the US and information requirement in the university setting, the researcher compared information deliverable requirements from the university specification with the published national standard in the US. Each of the previously mentioned phases is described in detail in the following subsection.

**Phase 1**

Research starts by understanding the background of UW facility management environment and COBie implementation in the real-world project. To understand the current facility management environment at the University of Washington, I started to conduct informal interviews with FS personnel (two individual) from facility maintenance and operations (FMS) department. UW had three pilot projects to study COBie implementation from different perspectives. To understand the COBie implementation process and identify case study subject, I interviewed a prior research team member who works on COBie pilot III.

In this round of study, the key interviewed questions were designed to correspond to the following topics: 1) history of university facility information management infrastructure 2) status of university facility information management infrastructure 3) general project information. Each interview took between one and two hours. All the interviews were audio-recorded.

**Phase 2**

After identifying the ARCF project as the subject of this case study, semi-structured interviews with key stakeholders were carried out to get further insights into the process of developing and delivering information deliverable. The stakeholders interviewed included the BIM consultant team, project manager, institute asset management. This round of interviews took place between January and February 2018. To investigate the usefulness of digital information deliverable in ARCF project, facility manager from ARCF and facility operator interviews were conducted

individually and focused on each interviewee's insights on the experience of using digital information deliverable and lessons learned. To ensure the objective of the research, two days of job shadowing were conducted to observe how facility personnel interact with digital information deliverable. The job shadowing sheet is attached in Appendix A. Each interview took between one and two hours. All the interviews were audio-recorded. Semi-structured interviews were designed related to the following topic: 1) the process of capturing, managing, and exchanging digital information deliverable 2) the usefulness of digital information deliverable for facility operator and facility manager in ARCF project. To further explore the usefulness of the content of digital information deliverable, research asked the following question specifically: 1) How often do you use the information. 2) Why do you think the information is useful. 3) Who else you think will use the information. A summary of interviewees list is posted in Table 2.

**Table 2 Summary of interviewees by department**

| Summary of Interviewees & Job shadowing days | |
|---|---|
| Capital Projects Office | 1 |
| Facility Services (Campus) | 2 |
| Facility Services (ARCF) | 3 |
| Consultants | 2 |
| **Total Interviews** | **8** |
| **Total Job Shadowing days (ARCF)** | **2** |

**Phase 3**

To develop an in-depth understanding of connection between national standard and industry implementation, I acquired and studied 1) the BIM contractual and implementation guidelines, 2) owner's FM data requirement specification, 3) the spreadsheet used to import into the CMMS, 4) digital operation and maintenance manual, and 5) published national standard and Building Smart Alliance project documentation. A discussion of these national standards and recommendations are in Chapter 5. The case study is presented in Chapter 4.

# Chapter 4: Case Study Analysis: Information Needs at the University of Washington (UW) for Facilities Management

## Introduction:

This chapter of the research aims to analyze how digital information deliverable is used for facility operation and maintenance at the University of Washington and how useful these deliverables are. This section starts with introducing current FM practices at the university and the project information. To study digital information deliverable usefulness, this chapter is organized in terms of structure, format, content, pathway, timing and facility maintenance and operation and each of the section is carried in detail.

## 4.1 Current FM Practices at the University of Washington

University of Washington (UW) is founded in 1861. As one of the oldest universities in the west coast, UW owns over five hundred buildings and occupied more than 20 million gross square footage of space. UW Facility Services support power, HVAC, cleaning, waste, maintenance, and construction for more than 15 million square feet. To provide better services, they are organized in eight departments including building services department, campus engineering & operations, emergency management, facilities employee services, facilities maintenance & construction, finance & business services, integrated operations, and engagement and transportation services. Of which, the scope of work from facilities maintenance and construction department is divided into planned work and corrective work. Planned work includes building-based preventive maintenance such as air fan and filter replacement and preventive maintenance on equipment etc. Corrective work is mainly to respond requests from customers to address emerging issues which need to be resolved.

UW Facility Services operate as separate facility zones like many large institutions. As theses zone practices have evolved over time, each zone manages documents and FM data differently. To manage construction handover documents such as as-built drawings, commissioning documents, warranty document and O&M manuals, UW uses a centralized database called Innovator which has a web-based portal called FS-DOS. However, not all the documents are uploaded in the FS-

DOS and most of uploaded scanned documents are not searchable. Due to the challenges of looking up information in FS-DOS, most of facility management zones in UW still look up information in paper-based format and each zone has a room called the print room where all the paper document and digital files of the new construction are kept. Since 2009, UW Facility Services started to use AiM from Assetworks as CMMS system to manage asset data. However, asset information recorded in AiM is either incomplete, inaccurate or lacks attribute information. The typical use of AiM is limited to the generation of timesheet and work order request because of inconsistent and inaccurate data input by different zone managers. Consequently, facility maintenance zones organize and manage operation and maintenance manuals (O&Ms) in an inconsistent way with a mix of digital documents and paper documents.

In 2011, UW Capital Project Office (CPO) and Facility Service (FS) collaborated with Dr. Carrie Sturts Dossick to implement COBie at UW to address the current facility management challenge. Total of three pilot projects are initialed including 1) Dempsey Hall project 2) COBie standard establishment 3) COBie implementation on ARCF project and rebaseling Foege Building. The pilot project information was documented separately in thesis from Astaneh Asl (2015), Masania (2015) Aghazatian (2012) and Masters (2011).

Now UW is working on standardizing the process of collecting the asset data and digitized documentations from the design and construction stage to support more efficient facility operations. AiM can use the data to develop preventive maintenance plans and generate work orders. Facility staff who move to other projects on campus would have a consistent way of looking up facility information. The Animal Research and Care Facility (ARCF) was part of that effort, and all the current and following capital projects on campus that are over 10 million will use this standardized process.

### 4.1.1 Introduction to the Project

The new Animal Research and Care Facility (ARCF) project was the UW COBie Pilot III project. The project had a total of 88,000 square feet including two occupied floors with interstitial space above. The substantial completion date was May 4th, 2017. The complexity of the mechanical, electrical and plumbing system in the building has led to the higher requirement of facility asset

data and documentation deliverables for operation and maintenance management. Figure 3 shows the general location of ARCF project.


**Figure 3 ARCF project location (Reference: eO&M)**

### 4.1.2 O&M Documentation and FM Asset Data Deliverables

Two types of operation and maintenance data were collected and delivered in the ARCF project to support UW facility information management. One part was facility maintenance (FM) asset data, and the other part was operation and maintenance (O&M) documentation. UW hired Broaddus & Associati as a third-party consultant to identify, collect and provide support to import FM asset data into AiM. Wilson Jones Commissioning was another entity that was responsible for helping project teams to collect O&M documentation and create a user interface for facility operations. In the following section, how O&M Documentation and asset data are identified, managed and delivered is introduced.

The consultant from Broaddus & Associates described how they identified the needs of facility staff, put together a standard, implement it in the project and support FM data exchange to AiM. “We sat down with facility shops; you know forks are responsible for maintaining the equipment

at the University and make sure that we understand their needs as far as what type of equipment that they are responsible for maintaining and what information they need to do their work efficiently. We put together a standard and even put together a process about how that should be collected in a project, identifying who is the responsible party to collect that information and what time during the project...Next effort that we did is actually implement that into the project, taking the standard, presenting it to the project team, architect, engineer, contractor, explain and answer their questions and helping with setting up a process related to collecting the information that the facility was needing…The third part that we did was to work with IT group [in UW] who manages their asset management system called AiM made by asset-works. We discussed how we are going to get the information from project team into AiM, what are the options for that, what are particular needs or preference that IT groups have and how they support that process…"

Wilson Jones Commissioning mentioned how they decided what information to collect for electronic documentation deliverables. "[UW research team][1] did lots of interviews a few years back...we used that mostly to create the content that we are gonna include in eO&M. We based on what we thought will be useful for everybody, we actually went to the Washington state capital because we want to know what legally the University of Washington was required to have and keep the records, so we went to the person to find that out from Washington state government, they basically told us that they did not have a standard. Whatever you decide is gonna be your standard and so we decide we will keep O&M documents in pdf form, A/E records in pdf form, keep contractors' as-built in pdf form, those were the legal document that we will keep to satisfy legal requirement, then we decide there is also another document that comes from construction that we think it will be useful, the warranty information, the description, the contact information, we just kind of adding into that so it is not legally required but we thought it would be useful. Based on some of our own experience of having to deal with the construction issues after project as well as UW research team's research and my own experience...Traditionally, facility people have not got a good document, that is one that we have a standard that we gonna capture the information each time…" When he was asked about the general workflow of collecting data for creating eO&M, he explained that "To make the process easier, we set up a template. The template

[1] Anderson, Anne; Andrew Marsters, Carrie Sturts Dossick, and Gina Neff, (2012) "Construction to Operations Exchange: Challenges of Implementation COBie and BIM in a Large Owner Organization" Construction Research Congress, Purdue University, West Lafayette, IN, May 21-23

contains all the navigation built into a framework. All of the subfolders are there; all the navigations are built in already. That way, when the contractor comes on board, all they have to do is to fit the file into subfolders and then create the hyperlink on the correct page to open up that file. What ends up happening is at the beginning of the project, when we sit down with the contractors, I will show them the eO&M had login to it, they will usually give me email for the people that they need, so that they can have access right to have edited to eO&M so that they can do this work…"

In short, the requirement for FM equipment asset data and related attributes were determined through interviews with facility personnel as well as the consultants' previous experience. O&M digital documentation format and contents were based on a combination of experience obtained from a previous pilot project and the consultants' work experience.

## 4.2 Format & Structure of Information Deliverables

### 4.2.1 O&M Documentation Format

O&M documentation was submitted in two types of formats: print and electronic versions. Electronic operation and maintenance documentation (eO&M) version was a 67 pages single pdf file user interface section and a folder section that stores actual documents. Table 3 shows the hierarchical structure and documentation format of eO&M and compares it with traditional O&M physical closeout documentation delivery structure and format.

**Table 3 Comparison between traditional O&M closeout documentation deliverables and electronic eO&M documentation deliverables**

| **Electronic eO&M Closeout Documentation Delivery Structure** | **Naming** | **Format** | **Traditional O&M Closeout Documentation Delivery Structure[1]** | **Format** |
|---|---|---|---|---|
| Project General Information | Brief project description | pdf | No requirement | |
| | Contact Information for owner and major consultants | pdf | No requirement | |
| | Contact information for major contractors, subcontractors and | pdf | No requirement | |

| | | | | |
|---|---|---|---|---|
| | vendors | | | |
| O&M Product and System Data | Final, conformed submittal | pdf | No requirement | |
| | Operation and maintenance documents (O&M data) | pdf | Yes | paper/pdf |
| As-Built Drawing and Specification by Contractor | As-built drawing by trade | pdf | Yes | paper/pdf |
| | As-built specification | pdf | Yes | paper/pdf |
| | Folder of digitally-posted construction drawings | pdf | No requirement | |
| | Folder of digitally-posted construction specification | pdf | No requirement | |
| | Folder of "Request for Information" (RFI's) with index | .pdf for each | No requirement | |
| | Folder of contract change documents (ASI's, etc.) with index | .pdf for each | No requirement | |
| | Folder of original, final electronic files used to create the coordination and as-built drawings including "superlots", BIM etc. (in native electronic file format) | rvt./dwg. | No requirement | |
| Final Project Record Set by A/E Consultants | Final updated record set design drawings | pdf | Yes | |
| | Final updated record set design specification | pdf | Yes | |
| | Final design calculation files | na | No requirement | |
| | Folder of original, final electronic files used to create the design drawings and specifications | na | No requirement | |
| Warranties | warranty summary matrix | pdf | No requirement | |
| | warranty claim instructions | pdf | No requirement | |
| | warranty documents by trade | pdf | Special warranties | pdf/paper |
| Training | Training plan | pdf | No requirement | |
| | Training videos | mp4 | Sometimes | CD |

| | | | | |
|---|---|---|---|---|
| Commissioning | OPR-Owner's project requirements document | pdf | No requirement | |
| | BOD-Basis of design document | pdf | No requirement | |
| | Commissioning plan | pdf | No requirement | |
| | Installation audits by trade | .pdf | No requirement | |
| | Startup and Contractor Testing documentation by trade | .pdf | No requirement | |
| | Functional performance tests | .pdf | No requirement | |
| | System manuals | .pdf with associated folder of original electronic files | No requirement | |
| | Final issues logs | .pdf | No requirement | |
| | Activity reports | .pdf | No requirement | |
| | Final commissioning report | .pdf | No requirement | |
| Extra Stock | Index of extra stock provided | .pdf | Yes | pdf/paper |

**note: 1 (Construction Specification Institute, 2011)**

Table 3 shows that eO&M required more information in content compared to traditional project deliverable which is discussed in the content section of the chapter. Traditional project deliverable required documentation in hard copy. Researchers have found this documentation was the most difficult to manage and the most expansive to secure (Fallon et al., 2006). In this case study, the advantage of electronic format was that it is much easier to look for information compared to look for information from binders and shelves using traditional physical paper/CD deliverable. One interviewee from ARCF stated that "Just the fact that the information about the project is here, whether it takes me a while to find or not, I know where it." Another advantage of electronic documentation format was portability. Facility staff can carry an iPad or laptop with them so that they can open up eO&M any time when they need the information. However, when facility technician in ARCF was asked if they would like to carry iPad or tablet with him to perform maintenance work, he said "iPad or tablet is expansive, and they are easy to drop, I have broken

one iPad in my previous job. Paper is light and cheap". Also, a lot of maintenance staff on campus do not currently have tablets.

The format of those documents in eO&M mostly requires PDF. PDF is ad hoc standards format which means it may originated with a single vendor, but have been made publicly available and are supported by multiple vendors and products (Fallon et al., 2006). The advantage of ad hoc standard format is that it data longevity because anyone can write an application to access data stored in that format. Folder of original, final electronic files used to create the coordination and as-built drawings requires data in rvt/dwg format. This format is proprietary format which means that the format is the property of a single software vender. The disadvantage of proprietary format is that it limits the ability to share the information with other organizations or use the information when the current generation of software is replaced.

In general, digital format is much easier to search, manage or handle than hard copy. When considering which electronic format to select, as discussed in the literature review section, the use of the data through the life cycle of the asset should be the prime consideration.

### 4.2.2 User Interface

eO&M provided a user interface for facility operation navigating information. The user interface could be navigated through using embedding hyperlink. Clicking on the hyperlink would activate a predefined view of the eO&M document or open a file, a folder, or a video. The purpose of the pdf user interface was to help the user to find the desired information intuitively. The document had a home page as well as subpages for each major section of the document. Figure 4 shows the example of the eO&M interface. In addition to the single pdf file, eO&M also had a folder section that stores actual documents. The files for the documents and the eO&M navigation pages were organized in a similar hierarchical structure.

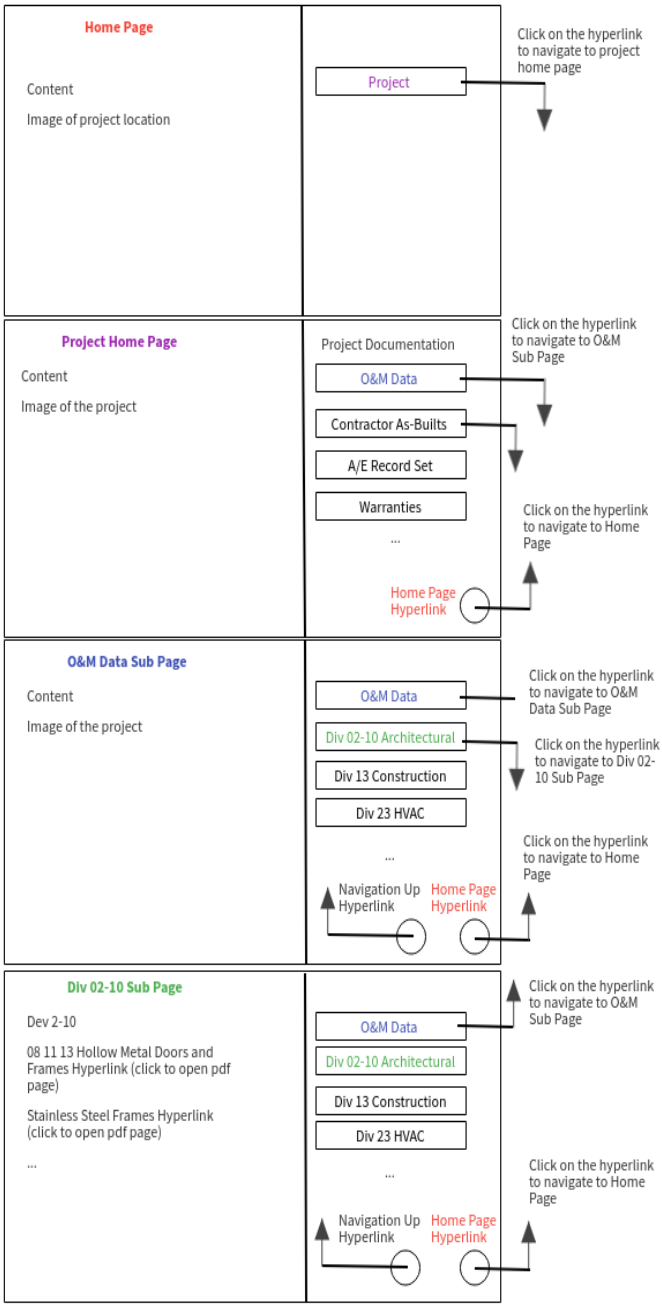


**Figure 4 User interface of eO&M**

According to the interviews, eO&M provided much better user experience than paper documentation. Facility staff who work at ARCF gave very positive feedback on the eO&M user interface. When they were asked about how they like eO&M user interface, one interviewee said, "This format and this layout works well..." However, there were some confusion as to how to use eO&M when they were observed looking for information in eO&M. One of the problems that were

brought up during the interview and observational study was that some of the hyperlinks were still not working. The technician who worked there was getting used to looking up information using file folder section instead of using user interface when he needed to look for information in as-built drawing. Another facility manager said "Everything that I need is available. O&M manual, submittal data, etc. But there is one that I was looking for the other day, let me see. There is something that I was looking for; the link was not there." Also, the eO&M function was not well understood by facility maintenance staff. It was debatable that eO&M interface provides an intuitive user experience. When one interviewee was asked to perform a task on looking for certain information in as-built drawing, he did not know how to use the search function in eO&M interface. One interviewee said, "We need a little bit more training on how to use it. Like I have said, I fumble through it and find things, but we have not had any experience on how to use it." However, eO&M did have a training section that explains how to use eO&M. Another technician did not use eO&M user interface at all because he is not used to using technology. When he needed information, he would ask his colleague to find information for him.

To summarize, the digital format was easier to manage, secure and access than paper document. The user interface was more useful for facility operator perform work if the link function works well and more training is provided.

### 4.2.3 FM Asset Data Format

FM Asset data were collected using COBie format and then convert it into a single page spreadsheet format (XLSX, XSL, or CSV) to import it into AiM. An example of spreadsheet formatted deliverables is shown in Table 4.

**Table 4 Spreadsheet formatted deliverables for asset equipment**

| **Equipment Information - Tab** | |
|---|---|
| **Name** | AHU-1 |
| **Location** | xxx |
| **Description** | Air Handling Unit |
| **Asset Group** | AHU-LARGE |
| **Installer** | TD INDUSTRIES |
| **Manufacturer** | YORK |
| **Model** | ITF-BD20 |
| **Original Cost** | xxxxx |

| | |
|---|---|
| **Expected Life** | x years |
| **Warranty Term** | x years |
| **Submittal** | xxxx.pdf |
| **Serial** | FCJxxxxxx-x |
| **NamePlate Photo** | xxx.jpg |
| **Equipment Photo** | xxx.jpg |
| **O&M Files** | xxx.pdf |
| **Cx Files** | xxx.pdf |
| **Elec Parant** | N1L1 |
| **HVAC Parent** | |
| **Support Locations** | 100, 101 etc |
| **Attributes 1** | air filter |
| **Attributes 2** | belt |

When asked about how equipment information was transmitted to AiM, the consultant from Broaddus stated that "they collected it in a COBie format and we had to take out of it from COBie format and import it into AiM. So they were finished. There were far away along the project and then we realized it was not going to work to import into AiM and then [we decide to] do something simpler. But having the team communicated in COBie format and have consistency over period, I felt like it was not right to change how we are collecting the data mid-way through, people already understand the system and understood the expectations, we should finish with what we have started with. At the end of the project. Broaddus, my company, we would take it and convert it into the simpler format and import it into AiM." Seemingly, interoperability issues still existed even though COBie was developed as an open format to address the interoperability problem. Further discussion will be carried on in Chapter 5.

### 4.2.4 Structure

The information categorization system for eO&M is shown in Table 2.

Electronic file naming in ARCF follows following format: +xxxxx***XXXXXX--------.pdf

(+) stands for campus location, (xxxxx) stands for five-digit U.W. building facility number, (***) stands for the type of documentation, (i.e. INF refers to the general information section, ONM refers to the O&M documentation section etc.) (XXXXXX) refers to the six-digit specification number (--------) refers to the content describe (i.e. "VFD" "HVAC_Fir1_Plan etc.)

The structure and naming convention of the eO&M was not aligned with UW information management system at the time of the research because UW had not established an official document management system to replace previous FS-DOS. When the creator of the eO&M was asked if the file naming convention is consistent with the University naming convention, he said "When I started, I asked university if they have a naming convention, there was no naming convention, so I made it up. We made it up and we distributed to many people, we pretty much get no feedback on, so we went with what we came up with...I hope that engineering record will give us feedback on the naming convention. We tried to create a naming convention that can uniquely identify files and have some contexts that what it is applied to" Also, he was not sure if the naming convention was efficient enough for people to understand. He mentioned that "I do not know if we did a good job because the contractor has a hard time to understand." Therefore, there is a gap between traditional information deliverable naming convention and digital information deliverable naming convention.

In addition, the need of aligning document naming conventions with UW maintenance and operation practice was identified. For facility asset data, ARCF started to use smart naming convention for the assets. The asset manager from UW explained it "So 6403 is the facility number for ARCF. So every asset for ARCF is start with 6403. TR means transformer. Looks like they have 4 transformers on there. Every building on this campus have different facility number. They establish it long time ago. So every time a new building comes online, it will receive a new number. In the past, you just have some random number for the asset. 203406 is backflow assembly. 26402 could be something completely different. They are making it easier to search, track and find asset. They are grouped together." To manage FM asset data, UW used smart naming convention to provide more intuitive information to facility operator when they search for information.

To summarize, eO&M had its own information hierarch and naming convention. UW may need to consider incorporating it when decides to build new documentation management system. A gap between traditional information deliverable naming convention and digital information deliverable naming convention was identified because there is a lack of consensus in the industry. This owner found it useful to have intuitive naming convention to manage asset da

## 4.3 Content of Information Deliverables (Usefulness for FS)

### 4.3.1 eO&M

Unlike traditional information deliverables, a lot more information was captured in the design and construction process and then delivered in ARCF project. Table 4 shows the summary of the usefulness of eO&M content based on the answers of the three questions mentioned in the methodology section that was collected from facility operator and eO&M consultant. The usefulness is defined as five level: not useful, not very useful, useful, very useful and useful as history record and the potential party that might need to access the content of the information is grouped based on professionals that might need the information content in the life cycle of the project including facility staff, owner, contractor, architect, engineer, GIS Specialist, consultant, space planning specialist. For each level of usefulness, not useful means interviewee identify that they have not used that information and they do not think anyone else will need the information in the future; not very useful means interviewee identify that they have not used that information and they think someone/themselves might need to access that information but not very often (less than one time per year); useful means interviewee identifies that they have used that information and the frequency that they need to access the information is less than one time per month but more than one time per year.; very useful means interviewee identify that they used the information more than one time per month; useful as history record means interviewee identifies that they have not used that information but they believe they information is useful to keep as history record and some potential party might need to access the information in the future.

**Table 5 Summary of usefulness identified by facility operator and consultant in ARCF**

| Electronic O&M Documentation Structure | Document Name | Usefulness | Potential Party that will use the information |
|---|---|---|---|
| Project General Information | Brief project description | Useful | Facility Staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | Contact Information for owner and major consultants | Useful | Facility Staff |
| | Contact information for major contractors, subcontractors and vendors | Useful | Facility Staff |

| | | | |
|---|---|---|---|
| O&M Product and System Data | Final, conformed submittal (Action submittals and Informational submittals) | Useful | Facility Staff |
| | Operation and maintenance documents | Useful | Facility Staff |
| As-Built Drawing and Specification by Contractor | As-built drawing by trade | Useful | Facility Staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | As-built specification | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | Folder of digitally-posted construction drawings | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | Folder of digitally-posted construction specification | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | Folder of "Request for Information" (RFI's) with index | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | Folder of contract change documents (ASI's, etc.) with index | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | Folder of original, final electronic files used to create the coordination and as-built drawings including "superlots", BIM etc. (in native electronic file format) | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| Final Project Record Set by A/E Consultants | Final updated record set design drawings | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | Final updated record set design specification | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning |

| | | | |
|---|---|---|---|
| | | | Specialists |
| | Final design calculation files | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| | Folder of original, final electronic files used to create the design drawings and specifications | Useful | Facility staff/Architect/Engineers/GIS Specialist Consultants/Space Planning Specialists |
| Warranties | warranty summary matrix | Very useful | Facility staff |
| | warranty claim instructions | Very useful | Facility staff |
| | warranty documents by trade | Useful as history record | Owner/Contractor |
| Training | Training plan | Useful as history record | Facility staff |
| | Training videos | Very useful | Facility staff |
| Commissioning | OPR-Owner's project requirements document | Useful as history record | Owner/Contractor |
| | BOD-Basis of design document | Useful as history record | Owner/Contractor |
| | Commissioning plan | Useful as history record | Owner/Contractor |
| | Installation audits by trade | Useful as history record | Owner/Contractor |
| | Startup and Contractor Testing documentation by trade | Useful as history record | Owner/Contractor |
| | Functional performance tests | Useful | Facility staff/Owner/Contractor |
| | System manuals | Useful as history record | Owner/Contractor |
| | Final issues logs | Useful as history record | Owner/Contractor |
| | Activity reports | Useful as history record | Owner/Contractor |
| | Final commissioning report | Useful as history record | Owner/Contractor |
| Extra Stock | Index of extra stock provided | Useful | Facility staff |

Each section of eO&M content usefulness is discussed in detail in the following section.

The content of traditional information deliverable generally includes O&M data, bonds, special warranties, record documents (shop drawings, record drawings and specifications, addenda, change orders, field orders, photographs), spare parts and maintenance materials (also called attic stock) and keying. (CSI, 2010) The additional content that is added into eO&M is general project information, submittal, original, final electronic files used to create the coordination and as-built drawings such as BIM files, warranty claim instruction, high quality training video and commissioning documents.

In the first section of eO&M, **general project information** includes a brief project description, contact information for the owner and major consultants, major contractors, subcontractors, and vendors. Facility manager in ARCF stated that he used this part of the information to contact project teams.

The next section is **O&M product and system data** including submittal data and O&M data. Submittal data in this section includes the manufacturer's product brochure and technical literature assembled specifically for the project. Submittal in this section refers to action submittal. Action submittals include product data, shop drawings and samples, samples and shop drawings are not included in this section of eO&M. Submittal information is useful for facility management activities and when future facility modifications or replacement are being considered. As one of facility manager explained "...for example, we replaced some of the access sign of the building, the access sign of the building, we are going to swap those with the combination of emergency light, so if you lose the power, you can get light to the building, and I need submittal information to compare what was actually specified and we can get the same sign model again." Another example that he gave was rewatered optimize water system in ARCF. "The submittal information will contain everything that manufactures purchase and put together to build system. So you can take a look at that information to get a full flavorful everything that was reviewed and also characteristics of that equipment. There are maybe four different pumps that could be used but they select pump B, and if you have a question why it was selected, you can go to the submittal information. Or they select this one instead of that one because this works better as application" One facilities staff from ARCF provided an example as well "...for instance, there is container problem for a particular pump, the O&M data only gonna tell you how to maintain the pump, it

will not tell you the characteristic and specification on the pump. That gonna include in the submittal data as a general rule. Sometimes it is in O&M, but it is not." Also, he mentioned that the submittal information was useful for some equipment but for some equipment, it might not be the case. Part of the problem is that there is no consistency between the manufactures. "For example, pumps, motors, fans, etc., the manufacturer has lots of things about that equipment, that is very consistent because they do not change it very often…[but] lighting control system, modules, switches, etc. are constantly changing. So if there is a problem three years from now, four years from now, you can go to that manufacturer, you may not be able to find that information, because it is discontinued, it may not be available for whatever the reason…those products change dramatically almost annually. It comes and goes like General Electric (GE), so the submittal information can be super important." It can be seen that submittal information is a supplement of O&M when manufacture information is not available or hard to acquire.

For the section of **as-built drawing and specification** by contractor and final project record set by A/E consultants, as-built drawing and specification show new information that the actual installation where the installation varies substantially from the work as originally shown. Project record set documents refer to the final design drawings and specification that have been updated by the A/E, and it includes all the RFI, ASI, and other changes to the contract documents as well as the changes indicated on the contractor's final red-line as-built drawings and as-built specification. Apart from traditional project record documents, AutoCAD and BIM drawings are included in the folder of original, final electronic files used to create the coordination and as-built drawings. Current campus environments do not have software capabilities to use BIM drawings. Some facility zones in UW can use AutoCAD software to read dwg. format. As concluded in CSI (2010), the electronic model has the potential of becoming a virtual representation of the physical facility. Design and construction electronic model may be able to integrate with the many other building monitoring systems such as the fire alarm system, the security and access control systems, the building mechanical and electrical systems, vertical transportation, etc. to form a single model of the facility.

**Warranty section** has three parts of information: warranty summary matrix, warranty claim instruction and warranty documents by trade. Warranty summary matrix summaries a list of all the warranties that are provided for the project in one spreadsheet. It includes information such as a brief description of the warrantied items, the specification reference stating the warranty, the

start date of the warranty, the end date of the warranty and the name and contact information of the installing contractor/vendor pertaining to the warrantied item. When eO&M creator was asked about the initiative of creating warranty matrices, he said "You might have fifty different warranties on a different project, one of the problems that we have in the past is a lot of times, the warranty will be contained in the O&M document itself. If you are trying to find specific warranty information, you are going through a big volume of O&M binder to find warranty information. So we decide to put them on one page, it will be easy to find." When facility manager in ARCF was asked about how did they find the usefulness of the warranty matrix, he said "I find contact information from warranty matrix, and I copy this into my one-drive, so I can have it at home in case I need it..……For my previous job, you will get general contractor information, but you will rarely get subcontractor information. Sometimes I do need subcontractor information, as an example, we had animal watering system problems over the three-day weekend, even though Skanska is general superintendent stated in the instruction, if you need an immediate response, you can go straight to the subcontractor. So I reached out directly the subcontractor, I copy Skanska, and I get the response from subcontractor because I had information. It cuts out the middleman; it will save time" Warranty claim instruction includes the contact information and procedures for owner's use in making a warranty claim. The creator of the eO&M explained the initiative of making a warranty claim instruction "When you have to make a claim, often you are not making a claim to the manufactures to that piece of equipment because their warranty probably already expired by the time the project is turned over to the owner. So the person carries the warranty is usually the contractor, the contractor has to fix things in warranty period. As an owner, if you need to make a claim for the warranty, you need to know who to go to make that claim, that has not been spelled out in the past. So we think it would be useful if you have this warranty to call out this general contractor, gives him the information for this project and say I need to make a claim on this project, it is still within warranty period, and then they will subsequently point to the person to that company to make that warranty service. Before, nobody even knows where to make a warranty claim." Facility manager gave very positive feedback on the content of warranty instruction claim "In my previous experience, it was verbally said that you had to do it, no one produces anything like this. This is great; if you have any questions about the warranty, it explains the process, if there is an urgent problem, I can go straight to one of this directly" Warranty documents were saved in eO&M as record. If actual warranties or letters were needed, it can be

found in eO&M file. Warranty instruction is useful because it documents a specific process that is unclear or verbally decided in the past.

**For training section**, the owner specified the requirement of high-quality training video. There are three types of training sessions: the initial design overview training session, contractor/vendor training sessions, and video instructions. The initial design overview training session was performed by a member of the design team to give a broad overview of the design intent for each discipline. The contractor training session used the service of a professional videographer to video record the instructional training and demonstrations required for the project.

Facility staff did benefit from the high-quality training video. One technician from ARCF stated that "we use the training video and it is beneficial. I learned quite a bit from it…." Another interviewee said "Traditionally I did attend training from the general contractor, but it was not professional. The quality is poor. They may use iPhone, or someone shows up with a video camera, you get background noise, the video is all shaking, you cannot hear what is going on. These are very professional; the person is almost like a movie production. He showed up with his camera and lighting equipment." The training video was very helpful especially for training new staff. The facility manager from ARCF mentioned that "we used training video very often. I have a new guy who is started Jan 22, and he watched all of them...when the training was given to the staff, I was the only person who as a staff in ARCF knows that. I do not have any trade people in here. Because that knowledge was documented, as new staff comes, they can sit and learn about the building. I can also refresh my memory even I attend most of the training class…there is a lot of detail that I need to refresh my memory." When he was asked about how often he used training video, he said: "For me, I have one-year experience in here, I would say once a month on average." The training video was very helpful especially in training new staff. Even though training video is part of deliverable in traditional deliver method, the quality of information record influences the usefulness of the information.

In ARCF, all the information that comes out of commissioning was documented. Because the content of commissioning documents are not included traditional deliverable method, table 6 lists the general content description of commissioning document deliverables and its responsible party in ARCF project.

**Table 6 General content description of commissioning document**

| Document | Responsible Party | Content |
|---|---|---|
| Owner's Project Requirements (OPR) | Owner | Owner's goal and criteria for the expected performance and operation of the project, how the owner intends to use the building and the system |
| Basis of Design (BOD) | Architect/Engineer | Criteria that the design team will use will developing the design documentation |
| Commissioning Plan | Commission Authority[2] | Framework of the commissioning process |
| Installation Audit Documentation by trade | Commission Authority, Commissioning Manager[3], Contractor | Manufacturer's installation instructions, installation checklists, pre-startup checklists (filled up during the process) |
| Startup and Contractor Testing Documentation by trade | Commission Authority, Commissioning Manager, Contractor | manufacturer's startup forms/checklists |
| Functional Performance Tests | Commission Authority, Commissioning Manager, Contractor | Step-by-step procedure for testing the equipment and systems and expected results |
| Final Issues Logs | Commissioning Authority | Track issues discovered during the commissioning process |
| System Manual | Commissioning Authority | explain how particular system operates |

[2] Commissioning Authority from owner is responsible for providing quality assurance by ensuring that the contractor performs their required quality control activities

[3] Commissioning Manager from contractor is responsible for providing communication and directing the contractor's participation in the commissioning process

| | | |
|---|---|---|
| Activity Reports | Commissioning Authority | Activities that can not effectively presented via commissioning issues log |
| Final Commissioning Report | Commissioning Authority | Comply with Seattle Energy Code requirements and satisfy the LEED Energy and Atmosphere Commissioning Prerequisite credit |

**Commissioning information** can be used by different stakeholders during the project life cycle. When asked how commissioning information can be used, commissioning agent provided a use case that commissioning document was used as history record, "We had a building that we commission and we had a steam heating coil in it and there is control device and we call it freeze-step, we had this heating vault does not work correctly. For freeze-step, it shuts down the unit, so it does not freeze the other water in cooling coil in the unit. So we tested that, we had documentation that it works correctly, but one of water coil flows into the unit in winter time, it causes a lot of money to fix that, tens of thousands of dollars to fix that coil. Initially, the contractor came back and said well; I think we install it correctly and they went back to our documentation and said, yes, it worked because our documents show it worked. It turns out that somebody closes the steam-vault to the coil. That leads us to do some further investigation then we figure out what goes wrong in that case. It is a record of what is tested out in the past, and it also shows you what did not meet operational intend too. Because often time, when we finish our commissioning process, there are still things that in the building does not work correctly, but we find out that as the result of our testing. But mainly the owner was not able to fix it because there is no budget left for the project. So we have known that there is known operation issue that needs to be addressed somewhere down the line and that is captured in the documentation." Facility manager from ARCF also found the usefulness of commissioning document "The function performance test; these are used. I referred to it often because it refers to some of the tests that we have done, I can go back to see and learn how the system works, to validate how the system works. For instance, these pumps are supposed to come on this level and another level, turn it on, I had a question about whether it has been tested, I can go to that functional performance testing and say that is exactly what I have been tested, this is what the result is. It is more validation for me. I have not used much other

information very often." Commission documents are mostly useful as a type of information history record.

To summarize, the information contents included in eO&M are identified useful/very useful/useful as history record either to facility personnel or related entities in the life cycle of the facility.

### 4.3.2 Facility Equipment Asset Data (FM data)

Three parts of information content of facility equipment were collected for ARCF project. The first part is general information including contact information from the general contractor, sub-contractor, and manufacturers. The second part is space information such as room number, room name, floor number, ceiling height and associated floor plans that are provided by the architect. The third part is detailed equipment information including a list of equipment and its related properties. Table 7 is a list of equipment properties from ARCF project asset data collection.

**Table 7 Equipment properties**

| **Properties** | **Example** |
|---|---|
| Title | AC-1 |
| Asset group | UW00000 |
| asset location | B000 |
| Manufacturer | Dri-Steem |
| Installer | MacDonald-Miller |
| Model | DK-00 |
| Serial | 0 |
| Warranty | 1 |

| | |
|---|---|
| Description | AHU5 HUMIDIFIER CONDENSATE AFTERCOOLER |
| Life Expectancy | 20 |
| Original cost | 1000 |
| O&M files | aaaaa |
| Cx files | bbbbb |
| Attribute | Year Built/Vessel Type/Recommended Coolant/Nation Board etc. |

To decide what information should be included in the equipment list, a consultant that was hired by the University of Washington met with many different shops and identified the type of equipment that they tracked and what information that they needed to perform work efficiently. The consultant provided a specific example of how do they identify the information need, for instance "on a pump, you want model number, serial number, but specifically you also want to see the pressure, the flow rate, and hose power, and a number of specific things for the pump and work through one asset group at a time with individual trades and disciplines, to focus on each trade and their asset group. We knocked that out and worked on to help hold a meeting with different trade in each asset group. So that was really where that came from regarding equipment standard and based on our experience doing it elsewhere and implement those in the project."

In ARCF project, the equipment list and their properties have not been completely uploaded into AiM system. Facility staff has not been able to use those properties. The researcher took the list of equipment and the attribute in excel format and presented them to facility operator to ask on the usefulness of those properties based on the same standard as in listed 4.3.1 eO&M content section. For each level of usefulness, not useful means interviewee identify that they have not used that information and they do not think anyone else will need the information in the future; not very useful means interviewee identify that they have not used that information and they think someone/themselves might need to access that information but not very often (less than one time per year); useful means interviewee identifies that they have used that information and the

frequency that they need to access the information is less than one time per month but more than one time per year.; very useful means interviewee identify that they used the information more than one time per month; useful as history record means interviewee identifies that they have not used that information but they believe they information is useful to keep as history record and some potential party might need to access the information in the future.

Table 8 shows the summary of the usefulness of equipment asset attribute content based on the interpretation of interview that was collected from facility staff in ARCF.

**Table 8 Summary of usefulness of equipment attribute based on interpretation of the interview from facility staff in ARCF**

| Equipment Description | Attribute | Usefulness |
|---|---|---|
| **Humidifier Condensate Aftercooler** | Year-Built | Not very useful |
| | Vessel Type | Not very useful |
| | Recommended Coolant | Useful |
| | National Board | Not very useful |
| | Max Temp | Useful |
| | Fluid Volume | Not very useful |
| | Exchange Type | Not very useful |
| | Dry Weight | Not very useful |
| | Direct Mix | Not very useful |
| | Capacity | Not very useful |
| **Split System Air Conditioner** | Volt/PH/HZ | Not very useful |
| | Serves | Not very useful |
| | Forge Transformer Room | Not very useful |
| | Refrigerant Type | Useful |
| | Lubrication | Useful |
| | Location | Useful |
| | Foege | Not very useful |
| | Filter | Useful |
| | Compressor Type | Not very useful |
| | Compressor Oil Type | Not very useful |
| | Certification | Not very useful |
| | Capacity | Not very useful |
| | Appliance Type | Not very useful |
| **Air Separators** | Year-Built | Not very useful |

| | | |
|---|---|---|
| | Vessel Type | Not very useful |
| | Use | Not very useful |
| | National Board | Not very useful |
| | Field ID | Not very useful |
| **Control, Supply Air Valve** | Type | Not very useful |
| | Size | Not very useful |
| **Control Damper** | Parent DDC Panel Name | Not very useful because it rarely breaks |
| | BAS Address | Not very useful |
| **Condensate Return Unit** | Type | Not very useful |
| | Suction Size | Not very useful |
| | Serves | Not very useful |
| | Max Temp | Not very useful |
| | Max Pressure | Not very useful |
| | Feet head | Not very useful |
| | Discharge Size | Not very useful |
| | Capacity | Not very useful |
| | Bearings | Useful (need to know the type of bearings and the size of bearings) |
| **Clean Steam Generator** | Internal Control | Not very useful |
| | Capacity | Not very useful |
| **Exhaust Fan** | Type | Not very useful |
| | Size | Not very useful |
| | Shives | Useful |
| | Serves | Not very useful |
| | Nominal Pressure Drop | Not very useful |
| | Efficient Rating | Not very useful |
| | Drive Line | Not very useful |
| | Belt Type | Useful |
| | Bearings | Useful |
| | Air flow - maximum | Not very useful |
| **Elevator** | Power Supply | Not very useful |
| | Electrical Panel Name | Not very useful |
| **Control, Exhaust Valve** | Type | Not very useful |
| | Size | Not very useful |
| **Fan coil Unit** | Type of fan drive | Not very useful |
| | Total Capacity | Not very useful |
| | Static Pressure in "inches" | Not very useful |

| | | |
|---|---|---|
| | Sensible Capacity | Not very useful |
| | Leaving Water Temp | Not very useful |
| | Leaving Air Temp | Not very useful |
| | Filter Type | Useful (need to know the dimension) |
| | Fan Type | Not very useful |
| | Fan Motor hp | Not very useful |
| | Exit Static Pressure | Not very useful |
| | Entering Water Temp | Not very useful |
| | Entering Air Temp | Not very useful |
| | Cooling Coil Delta | Not very useful |
| | Chilled Water Flow | Not very useful |
| | Capacity | Not very useful |
| **Humidifier Panel** | Water Requirement | Not very useful |
| | Saturation Efficiency Curve Air Pressure Drop Curve | Not very useful |
| | Nominal Moisture Gain | Not very useful |
| | Capacity | Not very useful |
| **HW Coil Circ Pump** | Type | Not very useful |
| | Suction Size | Not very useful |
| | Serves | Not very useful |
| | HW Coil Circ | Not very useful |
| | Max Temp | Not very useful |
| | Max Pressure | Not very useful |
| | Feet head | Not very useful |
| | Discharge Size | Not very useful |
| | Capacity | Not very useful |
| | Bearings | Useful (need to know the type of bearings and the size of bearings) |
| **Heat Exchanger** | Year-Built | Not very useful |
| | Vessel Type | Not very useful |
| | Max Temp | Useful |
| | Fluid Volume | Not very useful |
| | Exchange Type | Not very useful |
| | Dry Weight | Not very useful |
| **Dock Lift** | Power Supply | Not very useful |
| | Electrical Panel Name | Not very useful |
| **Panel Board** | Power Supply | Not very useful |

| | | |
|---|---|---|
| | Main Bus Current | Not very useful |
| | Electrical Panel Name | Not very useful |
| | Capacity | Not very useful |
| | Aic Rating | Not very useful |
| **Steam Pressure Reducing Valves** | Valve Size | Not very useful |
| | Outlet Pressure | Not very useful |
| | Minimum Capacity | Not very useful |
| | Inlet Pressure | Not very useful |
| **Reverse Osmosis System** | Water Filter Type | Useful |
| | Site Number | Not very useful |
| | Pressure Drop | Not very useful |

Many equipment Attributes were not very useful to facility operator for maintenance and operational purpose in ARCF as shown in Table 5. When facility operator was shown the attribute information for humidifier condensate aftercooler, he stated that "I do not think I will need to know year built, vessel type, it is a little bit more than what I want. This looks like specs…" Also, he mentioned that some specific attributes might be helpful. For example, when he was shown the attribute of split air system air-conditioned, he pointed out that "Lubrication type is very good information to know as well as location and refrigeration type." However, a lot of times, manufacturer model number and serial number provided enough information for them. He said "For example, when we go through air separator, all it is that if air goes through something, the air spins and take all the humidity out of the air and drives the air, it is a metal cone. That stuff, how often you are gonna replace it, even when I replace it, I will use mostly manufacturer model number and serial number, that kind of staff…" The information need is less than what is provided.

The information need is depended on the equipment type considering of how often the equipment will break and how they are going to fix it and if there is moving part for maintenance. "...if we look at aftercooler, it is a little heat exchange, it has a couple of pipes in it. It is hot steam; you want to cool it so you can pump it, it doesn't in the pump. There is gonna be some cool water to go through it. It is all it is, no moving parts, the maintenance on it just to make sure it is not leaking and looks ok, not rusting. If you go down to supply air valves, these valves do not break. It operates, and it limits how long air will go through the hole. The only time that it is gonna break is a motor actuator; it moves back and forth, that will break. So for valves, it is good information if you order

a replacement, but valves have a 40-year life expectancy. For motors, it has to be replaced periodically. So, we need to know what type of motor actuator it is." For some equipment like a clean steam generator, elevator, the facility operator mentioned that would not fix it by himself "...I do not touch the elevators. That is life safety thing, the elevator shop will touch it and we will not. Kone (elevator company) will do it in five years. Then we asked him if Kone might need to know that information, he said: "Probably not, they will probably need to go and look at it." As for clean steam generator, he said: "Basically if something goes wrong with the generator, I will call the vendor." Most of the equipment does not need the level of detail of information provided because the information usage frequency is low.

Facility operator stated that the attribute that would help them is consumable parts such as a belt, filter or bearings. When they were asked about how often could those parts be replaced and what information he needed, he further explained "...for example, for the exhaust fan, we do a quarterly maintenance check on it. We may have to replace the belts once a year, belts are consumable. For me, it is good to know the size and type of the belts and bearings. So if we have to replace it, we can order it before we go there and it saves time...For bearings, from my experience, probably 5-10 years it will go bad, bearing is a consumable part, but it lasts pretty long time before you need to replace it...." Another example is fan coil unit. The table gives the type of filter, but facility operator also needs to know the dimension. "...I am looking at filter type. Merv 8 tells me what the quality of the filter is, but we need to know the size. The Merv rating is how much staff it takes out of the air. So you can go anywhere from Merv 5 to Merv 1. Merv 15 is very high filtration. We need to know the dimensions, 24*24*2, and they are based on how wide, how tall and how thick it is...The filter is consumable when it gets dirty; you replace it. The most thing that we are going to replace is a filter. That has to be replaced when you have too much dirt on it and start to go bad, because I have seen people that do not replace filter for a long period of time, the filter stops working, it keeps plugged, and fan keeps running, pushing air out, it creates vacuum inside the box, it is humid out and it is cool enough inside there, you start to fill a box [of] water and fan stops, the filter is generally the only thing that you end up replacing." For filters, how often it will break depends on the equipment and environments. For example, the facility staff said "on the air handling unit, there are two filters. There is pre-filter which gonna go bad more quickly, and then there are bigger filters that will not go bad as quickly, but it is also more expensive and harder to change. It depends on how things are, for example, as far as what air quality is outside. For example,

last summer, we have the fires and smoke in the air. They have put a lot of debris on the air handling unit...” Therefore, the most important attribute information required by facility operators is the type and dimension of the consumable part of the equipment.

### 4.3.3 Geometric Information

Technically, it is possible to link the BIM model with asset data. In ARCF project, there was no strong evidence to show the need for linking asset data with BIM model. The BIM manager from Broaddus & Associations stated that “That was one of the things that we talked about early on in ARCF. That is a vision for being able to link the model with asset data, as we try to get the vision more focus on from UW. There was not a strong component for people to say that we really want to see those models and we really want to see what is going on in the field to support our work order management, our preventive maintenance management and no one is clear on they want that, we really question how valuable it is.” Instead of linking BIM model with asset data, ARCF project settles on a simplified version. The BIM manager explained it “what they team was doing is that they took 3D coordination model, that was from Skanska, the contractor, they set up viewpoint...It was not for every piece of equipment, but the equipment that is prioritized is that it was covered by items above ceilings or in the wall, something that someone could not walk after the field and see it. Those are the things that have a model to understand what is going on above the ceiling and wall, that is where the team did that work.” When facility staff in ARCF were asked about what they need regarding geometric information, he stated that “Generally I am looking for which valve that I need to isolate, that kind of stuff, or where is that in the building. It is more how to isolate things and where it is connected to. Or what can I do to reset the breaker? I will go through the drawings; the electrical drawings are helping me as far as not sure where I will go. It will show you what panel it is on, what breaker, that kind of staff. I use it as far as where I can find staff.” To conclude, 3D information is not in priority need for UW facility operation and maintenance.

## 4.4 Pathway of Information Deliverables (Single Source of Truth)

Information follows two pathways in the ARCF project. All the documents are embedded in eO&M and asset data is saved in AiM. Compared to traditional pathways where shared database,

email, Ftp site, CD/paper handover existed at the same time, the two-pathway information management system has dramatically improved the work efficiency.

Traditional information delivery method was not efficient partially because it creates multiple pathways for the end user. As Masters (2011) pointed out in his thesis, historically technicians in UW were not able to retrieve training videos efficiently; those training videos were traditionally stored in the physical record as CD in the engineering library. Even though in some facility areas, one person managed a book of CDs for one facility zone, once that person has left, no one knew the right pathways to access it. In the ARCF project, all the training videos were kept in electronic files and saved in mp4 format. A standardized format for long-term storage and easy to access for everyone who needs it are the two main considerations. The creator of eO&M explained that "Recording format changes dramatically during the mid-1990s, so at that time, it was video set and then we started to get CDs. Then we will put electronics files on CDs and then DVDs. Then we start to have hard drives. But the media keeps changing. Sometimes you cannot even play those old set because most users do not have video equipment back then. So, what we said is ok, we will take those videos, we will keep them as electronic files, and we will have the contractor to put them all in mp4 format so that almost anything can play mp4 video files. Again it is standardized video playback format. It is very generic, and it should be around for quite a while, again, it will not be here forever, but even it is, it will probably have software that allows you to transform to a newer format." As mentioned in the content section, training videos have frequently been used by facility staff in the ARCF project. They can easily access and play those videos on their computer.

Some other information pathway still exists that could lead to information use inefficiency. In the traditional UW facility information management model, Master (2011) pointed out in his thesis "We print out a piece of paper, hand it to the technician who goes out and writes all the details on the work order. [They] then turn it back to the leads. In our shop the leads [enter] that information and close out the work order." Information format flows from digital to paper and then digital again. In the ARCF model, this additional pathway layer of information still exists. In the observational study, the researcher observed how technician performed work order in ARCF. The lead still printed out a paper copy for the technician to go out and the technician came back with the paper copy and then inputted updated information into CMMS system. The lead told the researcher that "For my tech that is gonna do the maintenance he works better on the paper copy,

so I print him off the work order phase...” There will be a transition time before facility personnel build familiarity to the technology and take digital tools into the field.

Even though two pathway information management system was useful, the need for creating a pathway between CMMS system and documentation system (eO&M) was frequently mentioned both by facility staff on campus and staff on the ARCF projects. The facility manager in the ARCF project commented that “That will be ideal if eO&M can be linked to AiM. That was one of the gaps right now that we have to access two platforms, we go to AiM to get the preventive maintenance work order, the task list, generate frequency, but if we need specific information for manufacture, we have to go to eO&M.” Asset manager at the University of Washington said that “So I think ideally, as you link asset information into the system, you would already put a link from asset to that library. So that if you are in the field, you gonna do some maintenance on it, you have questions about it, you could click on the asset itself, pull up O&M manual, read through and find the information you are looking for, for example, drawings. But that has to be linked together. Currently, I do not think our environment exists 100%.” There was consideration of putting documentation into CMMS system for ARCF project. However, the facility staff’s ability to manage those data become a major concern. The consultant of eO&M explained it “Traditionally it has been extremely difficult for facility people to take information into CMMS, because of that, there was not much confidence that they could manage all of those eO&M files because that is a much more difficult process. So even though the system has the ability to do that, we look at the process, we basically come to a conclusion that they have enough problems with just very basic of using the software I think it is too much for the owner to also to manage the eO&M within the software. Also, I think it is got input into the system, it gets swallowed up, you do not have visibility anymore, it is kind of under control of facility people, but there are a lot of people who need to see that information. Engineers, architects, for instance, to do remodel, they do not have direct access to those files, so there is not a process for them to do that right now.” Therefore, it is possible to integrate O&M document with asset data and that will help facility mangers’ work more efficiently. However, it is important to consider the process of how to manage the information before locking the information into CMMS system.

Single Source of Truth (SSOT) is a concept that is used in information systems design and theory. The idea is that information models and associated data schema has to be structured in a way that every data element is stored exactly once to make sure that everyone in the organization uses the

same data when making business decisions. Any possible linkages to the data element are by reference only. SSOT system provides authentic, relevant and referable data. In most organizations, SSOT implementation is rarely possible because they usually have multiple information systems. In current UW information management environment, a central location to store data has not established for facility information management. The combination of eO&M documentation management and CMMS asset management is an intercept step before the central location is available on campus. eO&M is hosted on UW CPO Bluebeam server which is locally on the campus. It is only available to the people who can log into the server. To make the link between eO&M and CMMS system possible in the future when there is central location on campus to save all the asset data and documents, BIM manager from Broaddus & Associations coordinate with consultant from Wilson Jones Commissioning will identify what documentation goes to what equipment asset and reference the name of the eO&M documentation with FM asset data. Digitized documentation deliverables (eO&M) makes the process of establishing the single source of truth process on campus faster and easier to implement. One reason is that it is much easier to keep the electronic document in central location compared to the paper document. For a big campus like UW, if the paper document is saved in a central location, facility staff must physically go to the library to check the record.

To summarize, the need of creating central location to insure authentic, relevant and referable data is identified. To implement single source of truth, facility owner might choose technologies such as Master data management (MDM).

## 4.5 Timing of Information Deliverables

Facility staff in the ARCF project did benefit from faster document turnover time. Facility maintenance data final deliverables for the project were required to be provided to the owner within two (2) weeks of the substantial completion date. Operation and Maintenance (O&M) documentation draft was required to be submitted within two (2) weeks before the substantial completion date, and final submittal was required to be submitted within two (2) weeks before the final payment request.

In the case study presented by Masters (2011), the time between substantial completion and final receipt of those documents ranged from 10-13.5 months. Traditionally, UW used a centralized

database (Innovator) with a web-based retrieval portal (FS-DOS) to access archived project documents such as O&M manuals and drawings. One of the issues that he mentioned was that it took a substantial amount of time to turn documents over at the end of the project physically, it also took time to import them into the database system. In the ARCF project, because eO&M was hosted on UW CPO Bluebeam server, facility staff did not have to wait until eO&M was complete and engineering record department uploaded the information to their database to get access to it. Even though eO&M interface may have had some issues with the hyperlinks, facility staff in the ARCF project could look up information through folders in eO&M.

At the time of this research, software interoperability problems caused a delay in transforming the FM information into AiM system during handover phase. Facility staff has not been able to make full use of the asset data profiles that are collected by the consultant even though the project has been delivered a year. When the asset manager was asked about why asset data did not upload into AiM, he explained that "The tool that our IT folks have been using to enter the information into the system using AiM is an outside tool and the tool and AiM, they do not play nice with one and another. AiM and most CMMS system at this point, almost like ad hoc, every six months, you have to hit update. However, the outside tool does not update because they are not in the same schedule. Then you run into potential cliches that would not gonna work with each other."

In the future, software compatibility should be communicated and tested with the project team and included in the data requirement specification in the beginning of the project.

## 4.6 Facility Maintenance Information Management

In the ARCF project, facilities maintenance did not have a plan for the maintenance of asset data and eO&M documentation in maintenance and operation stages at the time of the study. When asked about what the method was planned to use to maintain those documents, the facility manager in the ARCF project stated that "This is the gap that we need to close. The question is who is going to maintain those documents… in traditional FM model, we do maintenance only. We do not get involved in maintaining documents..." There is a lack of agreement on the maintenance and operation model in management level because of the limitation of the budget. He said "The operation and maintenance model was defined and put together by a team, now it is time to

implement, they originally implement that maintaining document is part of my work, but now my boss says, wait a minute, we did not know that you have to do that. I think it is just the money thing. They only allocated this amount of money. It is just everyone needs to get into the room and figure out what to do…. right now, there is a list of things that already have been changed, and they need to be uploaded in eO&M" When he is asked about if he has documented those changes, he said "They are documented in AiM right now. I do not have a separate document that I maintain. The way I can find though is that I can go to AiM query work orders that are construction work orders because that means it was a change. Then drill into that work order, and I can see what was done. But I am not maintaining separate sheet or anything like that. It is in someone's list on what is the best way to do that. Part of challenges for me are I was not expecting there are so many changes that we have been made already." Over the time, eO&M will lose value due to lack of updates.

Managing electronic documents was challenging. Electronic documents handover not only consisted of the basic format such as pdf. and doc, but also rtv., nwd., dwg, etc. Engineers and contractors created the original documents using professional software such as AutoCAD, Revit, Naviswork, etc. and then converted and printed them out in a pdf format. However, most of University facility staff did not have capabilities to operate AutoCAD, Revit or Naviswork. Hiring a full time/part-time drafter to update those AutoCAD and Revit drawings would add to additional costs. Besides the multiple formats of documents, as-built drawings and specification and final project record set create makes it problematic to update information. In the facility FM data specification, which sets of documents should reflect ongoing facility change was undefined. If the university chooses a compromise way to change pdf documents instead of rtv., nwd., dwg etc. file, other documents might lose value over time.

Information overlaps existed between facility asset data and eO&M documentations that creates the complexity of information management. For example, facility asset data includes information such as manufacturer, model number, serial number, warranty, description, life expectancy, and attribute. Some of the information existed in eO&M as well. In current UW campus management structure, maintenance asset manager was responsible for gathering asset data, develop maintenance plan and generate a work order for the whole university. He had to rely on the facility staff to provide facility asset change information. When he was asked to explain the process, he said "So we do not [have] formalize process established yet. This is what I envision. That is job

plans specify [the] specific task, and the guy disagrees with it, or they have [the] wrong piece of equipment asset information, if there is any correction that they need to notify me and we need to receive the information and make the necessary adjustment, you know, we can have a conversation about they disagree with. [For example] the steps that something needs to be done or [a] particular task that doesn't need to be done at all. They think it is waste of their time and effort. We can have [a] conversation about it and whether or not it is needed." However, he was not responsible for managing documents such as specifications and drawings. It was possible that eventually the University has someone to be in charge of managing eO&M documentation or facility staff in ARCF decides to manage document by themselves. But information management inefficiency or waste will be generated because different people have to maintain the same type of information in the different database system. It may also lead to inconsistency of the information.

Lack of connections between ARCF facility staff and other parts of campus were identified in the study. For example, facility manager mentioned that "it will be nice to have vendor contact information in AiM. For instance, if you need to do preventive maintenance on a fan, we have belt size and belt fan, it will be helpful if we have contact information for where I can get them from, for instance, company, email…" However, he and facility trade staff were not aware that there were issues with uploading information into AiM and some of the asset profile and attributes were still missing. Facility staff were excited about being able to provide input on making facility maintenance and operation plan. The control technician stated that "We have a sequence of air handling changes for the air handler because when they build the building, they do not account for operations, we have a new procedure that they are actually making changes on the air handling unit and I am actually in the process of going over that, so that we can get the change right. For the actual sequence of operations on the air handler, I am providing input on that procedure. So that it is more of what we want than what we have…" Therefore, the involvement of downstream participants might be an effective way to drive better information management.

To summarize, at the time of research, UW facility infrastructure could not provide good support to help effectively manage digital information deliverable.

# Chapter 5: Industry Information Exchange Standard Analysis

## Introduction:

The objective of this Chapter is to analyze the connection between national standard and industry implementation. This Chapter starts with introducing two versions of UW information deliverable specification and current National BIM standard and BuildingSmart Alliance project. Then this Chapter compares UW Standard with National Standard in terms of format & structure, content, pathway, facility maintenance and operation. Each of it is carried in detail in the following section.

## 5.1 UW FM Information Deliverable Specification Development

UW started to implement COBie in the project at 2011 to address the need of transferring paper based management into digital management to improve facility operation process. The first version of UW Information Deliverable Speciation was published in Jan 2014 based on COBie 2 standard. The second version was published in 2017 after taking the lesson of implementing first version of specification in ARCF project. The first version was developed for ARCF project; however, UW decided to use the second version for final deliverable requirement in ARCF. The second version of information deliverable standard specification was also used as UW standard to implement in other UW campus ongoing or the following projects.

The first version of information deliverable specification had three section 1) Strategy & Objective 2) BIM for FM Execution Pan 3) FM Data Criteria. Of three sections, FM data criteria section was a specification and guide to understand how project information should be organized and delivered over to UW. In this version, COBie version 2 formatted data was a project deliverable to support UW CMMS. COBie 2 consisted of sixteen (16) separate “tabs” of Excel data worksheets as shown in the figure 5.

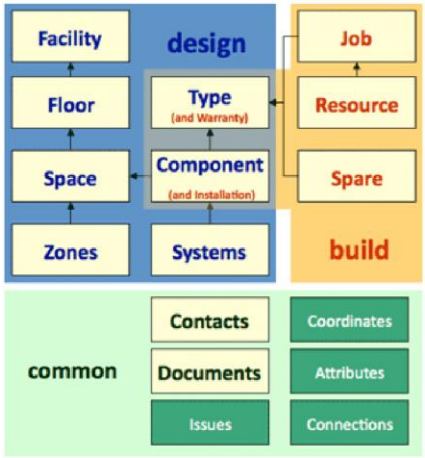


**Figure 5 COBie 2 (Construction-Operations Building Information Exchange (COBie), 2016)**

Each tabbed worksheet had a series of column fields (A,B,C etc) like excel spreadsheet. For example, contact tab includes personnel contacts such as architects, engineers, product manufacturers, warranty guarantors, spare parts providers, prime contractors/subcontractors, project management staff, commissioning agents, test and balance engineers, construction materials testing companies, other testing agencies, utility service provides, owner's space management agent, owner's facility management agent, owner's CMMS management agent etc. Under contact tab, columns were organized as shown in Figure 6. The information under each worksheet needed to be filled in different stages of the project life cycle.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Email | CreatedBy | CreatedOn | Category | Company | Phone | ExternalSystem | ExternalObject | ExternalIdentifier | Department | OrganizationCode | GivenName | FamilyName | Street | PostalBox | Town | StateRegion | PostalCode | Country |
| 2 | bill.east@u | bill.east@u | 2012-10-30 | 34-55 14 11 | Engineer R | 217.352-65 | n/a | n/a | n/a | n/a | n/a | Bill | East | 2902 Newn | PO Box 900 | Champaign | IL | 61826 | USA |
| 3 | danielle.r.l | danielle.r.l | 2011-09-14 | 34-55 14 11 | USACE | 217-373-34 | Autodesk R | IfcPersonA | n/a | n/a | n/a | Danielle | Love | 2902 Newn | PO Box 900 | Champaign | IL | 61826 | USA |
| 4 | mariangeli | mariangeli | 2011-09-14 | 34-55 14 11 | USACE | 217-352-65 | Autodesk R | IfcPersonA | n/a | n/a | n/a | Mariangeli | Carrasquill | 2902 Newn | PO Box 900 | Champaign | IL | 61827 | USA |
| 5 | james.d.mc | mariangeli | 2011-09-14 | 34-55 14 11 | USACE | 217-352-65 | Autodesk R | IfcPersonA | n/a | n/a | n/a | James | McAulley | 2902 Newn | PO Box 900 | Champaign | IL | 61827 | USA |
| 6 | info@cole | danielle.r.l | 2011-09-14 | 34-31 21: D | Cole-Parme | 800-323-43 | n/a | n/a | n/a | sales | n/a | n/a | n/a | 625 East Bu | n/a | Vernon Hill | IL | 60061 | USA |
| 7 | contact@s | danielle.r.l | 2010-03-15 | 34-31 11: N | Securall | 888-326-78 | n/a | n/a | n/a | Sales | Securall | n/a | n/a | 5122 N. Sta | n/a | LaPorte | IN | 46350 | USA |
| 8 | Marketing | danielle.r.l | 2011-09-14 | 34-31 11: N | Philips Day | 800-234-18 | n/a | n/a | n/a | sales | n/a | n/a | n/a | 776 South | n/a | Tupelo | MS | 38804 | USA |
| 9 | dependabl | danielle.r.l | 2010-03-15 | 34-31 11: N | Tubelite In | 800-866-22 | n/a | n/a | n/a | Sales | Tubelite In | n/a | n/a | 3056 Walke | n/a | Walker | MI | 49544 | USA |
| 10 | fibrdor@fil | danielle.r.l | 2010-03-15 | 34-31 11: N | FIB-R-DOR | 800-342-73 | n/a | n/a | n/a | Sales | Fibrdor | n/a | n/a | n/a | PO Box 132 | Maumelle | AR | 72113 | USA |

**Figure 6 Contact tab example (Construction-Operations Building Information Exchange (COBie), 2016)**

The final handover deliverables in the first version included 1) project team compliance and conformance to the FM Data requirements 2) COBie Version 2.24 file with all documents in one folder 3) Record Set/As-built models 4) Facilities Model with saved viewpoints of all COBie components per the FM Data requirement.

The second version of information deliverable requirement specification includes two parts FM data and eO&M. Chapter 4 described the structure, format, content of the deliverable.

The main difference between two version was that in the first version, FM data and relate documents submit in COBie format and the second version is a simpler version that FM data is required to submit in a single excel sheet format and documentations is organized in the format of eO&M.

## 5.2 National Standard & BuildingSMART Alliance Project Development

The first version of NBIMS-US is published in 2007, it provided a general guideline of developing open standard. The first consensus based-BIM standard for the United States was published in 2012 as NBIMS-US Version 2. The latest version of NBIMS-US was published in 2015. Apart from National BIM standards, there are several "ie" information exchange projects developed by the BuildingSMART alliance to support the development, adoption and management of standards. This study selected the projects referenced in NBIMS-US V3 that had the potential to influence facility operation and maintenance stage. The goal and timeline of national standards along with goal status and timeline of related BuildingSmart Alliance are listed below.

**NBIMS-US Version 1-Part 1:Overview, Principles and Methodologies (V1P1) (Dec, 2007)**

The first edition of NBIMS-US Version 1 - Part 1 (V1P1) is released in December 2007, its primary purpose was to establish the approach for developing open BIM standards. (Institute Releases First-ever Consensus-based BIM Standard for the United States, 2018)

**NBIMS-US Version 2 (May, 2012)**

The National BIM Standard-United States (NBIMS-US) Version 2 covers the full life cycle of buildings; it included the process from planning, design, and construction to operations and sustainment. (Institute Releases First-ever Consensus-based BIM Standard for the United States, 2018)

**NBIMS-US Version 3 (2015)**

NBIMS-US Version 3 provided the structure and framework for a collaborative process and the ethics of trust between the professionals (Institute Releases First-ever Consensus-based BIM Standard for the United States, 2018)

**National BIM Guide for Owners (2017)**

The Guide provides building owners with a documented process and procedure for their design teams to follow to produce a standard set of BIM documents during the design and construction of the facility, and for maintenance and operations of the facility upon handoff. Establishing the criteria, specifications, and expectations in the design and construction process will help owners capture the full value of investing in BIM while providing a uniform approach for institutional and commercial building owners to achieve consistent BIM requirements for their facilities. (National BIM Guide for Owners - National Institute of Building Sciences, 2017)

**Construction Operations Building information exchange (COBie) (2005-present)**

Timeline: COBie was first started in 2005 through the first two grants provided through the National Aeronautics and Space Administration and the White House Office of Science and Technology Policy. COBie developed from an initial idea to an industry recognized standard implemented in commercial software across the globe

Status: as information exchange standard listed in NBIMS-US V3

Goal: identifies the content of the information that must be captured and exchanged at each phase of the project to reduce the waste that is generated with the current paper process

(NIBS (National Institute of Building Sciences) (2015))

**Specifiers' Properties information exchange (SPie) (2007-present)**

Timelines: The project began at 2007, it is still under development.

Status: The current stage of the project was expanding and finalizing SPie equipment specification property definitions and extending with maintenance properties.

Goal: provide an open standard format for manufacture to export product data

(NIBS (National Institute of Building Sciences) (2015))

**Operations' Properties information exchange (OPie) (2011-2012) - cancelled**

Timeline: The project was initiated in 2011, and no further information was provided after 2012

Status: Cancelled

Goal: identify properties that needed by facility operator and maintenance technicians

(NIBS (National Institute of Building Sciences) (2015))

**Life-cycle information exchange project (LCie) (2010-present)**

Timeline: first proposed in East 2010, LCie is the basis for the process models found in NBIMS-US V3, an additional NBIMS-US V3 defining the product supply chain, developed from LCie is expected to be submitted.

Status: Under development, in NBIM-US V3

Goal: support Chief information/Technology PLM-based effort to facilitate systems integration and associated change management

(NIBS (National Institute of Building Sciences) (2015))

**Heating, Ventilating, and Air Conditioning information exchange (HVACie) (2011-2013)**

Timeline: project began in January 2011 and submitted to NBIM-US V3 at September 2013

Status: submission of NBIM-US V3 Ballot in September 2013

Goal: provide an open-standard format for modeling thermal transmission fluid, heat transfer equipment, and distribution system

(NIBS (National Institute of Building Sciences) (2015))

**Electrical System information exchange (SPARKie) (2010-2013)**

Timeline: project began in April 2010

Status: submission of NIBS (National Institute of Building Sciences) (2015) Ballot

Goal: provide an open-standard format for the components, assemblies and connections of a facility that distribute and use electricity

(NIBS (National Institute of Building Sciences) (2015))

**Water System information exchange (WSie) (2010-2013)**

Timeline: Project began in April 2010

Status: submission of NIBS (National Institute of Building Sciences) (2015) Ballot

Goal: provide an open standard format for the components, assemblies, and system of a facility that distribute and remove water

(NIBS (National Institute of Building Sciences) (2015))

**Building Automation Management information exchange (BAMie) (2011-unknown)**

Timeline: The draft was internally released in Dec 2011, draft MVD was posted in March 2013

Status: unknown

Goal: provide levels of detail that enable workflow automation of the entire system during its life-cycle from early stages of proposal, layout, and shop drawing creation to mobilization, installation, red-lines and as-built documentation

(NIBS (National Institute of Building Sciences) (2015))

UW specification is developed to fit organization's facility operation management requirement. Chapter 4 have analyzed some challenges still exist in terms of using information deliverables that developed from UW information deliverable specification version 2. Since the version 2 does not adopt industry standard, the following section mainly focuses on if NBIMS-US V3, National BIM Guide for Owners and related BuildingSmart Alliance projects could help address some of the challenges for owners.

## 5.3 Format & Structure of Information Deliverables

### 5.3.1 Construction Operation Building Information Exchange (COBie) Format vs. Spreadsheet Format (XLSX, XSL or CSV) for Delivering FM Data

UW decided to use single page excel spreadsheet rather than COBie industry standard format as UW information deliverable specification for the following reasons. The first was software support. The facilities data integrator who worked for ARCF explained the situation "The nice thing about the industry standard is that there is [a] common language that how we can interface information

and share information, that interoperability to support it from platform to platform, you know different provides and software. That can work on the construction side. But in the operational side, they did not have the module [in AiM] to be able to import the data into COBie standard…AiM does support COBie format, but the university did not purchase the module. They did not want to investment in that product… I think it was [a] decent amount to purchase that module to make that works. It did not address a number of important factors that they thought import module is supposed to address. For example, flexibility and be able to customize how you bring the data in. They were gonna lose lots of control on how they want to bring the data in, and they want it to look at. I think they just did a review and said you know this were gonna bring our information in, but we cannot customize [it], it was not a great value." Also, he mentioned that importing data into AiM was much simpler "AiM now has a better platform for doing importing, and it is [a] much simpler process and customizable, and there is a lot better support for it…" Another challenge of using COBie format was the implementation. "One of the challenges was COBie format itself. It is hard to understand. So, when we were communicating to the team, contractor, subcontractors and even design professionals, that is not their world and that is not how they organize information. A lot of team members were not familiar with it and had never done it before and it seems very complicated for them. So, we have to push back there, the big obstacle is [the] education of it. On here, here is what we are doing it and here is why we are doing it in this way and try to coach them because when we look at the big picture, it seems very complicated for folks that have never done it before especially using the COBie format. The challenger for us was to help the team to look at small goals one step a time, focus on this item and get them in, and then focus on next one. That is our effort, and that is who we address that challenge." Comparing capturing information in COBie 2 format with single page excel spreadsheet format with owner self-defined data structure, the need for exchanging FM data into AiM in ARCF could be addressed in either way. However, from the perspective of industry implementation, the additional cost of purchasing COBie and locking information down into one format are were obstacles for UW implementing COBie format. In addition, the ease of use in the construction process limits the use of COBie as well.

COBie format has potential opportunities to eliminate non-value-added operations. According to NBIMS-US V3(2015), the possible savings from using COBie format were classified in the following areas: 1) VALIDATION savings from being able to check the space and equipment

data's completeness programmatically and if conforming standards and requirements. For example, owner's requirement data would be able to be transferred directly from owner to the Architect or Planner's system using COBie-formatted data instead of relying on design professionals to re-enter the owner's space requirements into the system. 2) COPYING savings from using electronic documents and data as the project record and the elimination of paper documents. Most of the activities in project life cycle that were related to data exchange would have savings from elimination of paper documents. 3) HANDLING savings from handling transmittal and automated logging of project documents using managed project collaboration and management system. 4) SEARCHING savings from capable of electronically comparing product data to product specifications. These savings would come from having standard product template data through the ongoing development of Life-Cycle information exchange for Equipment Assets and Specifiers' Properties information exchange (SPie) projects. 5) REFORMATTING savings from managing assets by adopting a single, open standard data format. 6) RECREATION savings from using standard, structured data format for moving data in the life cycle of the project, eliminating the need for data re-entry.

From owner's perspective, the important savings come from using coping, searching, reformatting and recreation. In current environment, if the owner adopts COBie format, owner could only benefit from using electronic documents and data as the project record and recreation. As mentioned above, UW still needed to purchase the COBie module to achieve recreation benefit. Search saving cannot be achieved because SPie project was still under development and the adoption of manufactures were limited. Reformatting savings could not be achieved because UW used its own data format. Therefore, from cost perspective, owner did not have much incentive to adopt COBie in UW case.

### 5.3.2 National BIM Guide for Owners - National Institute of Building Sciences. (2017) vs. eO&M for Digital Documentation Format Archiving

For UW information delivery specification, the electronic document was mentioned to be provided in pdf format. As mentioned in Chapter 4, PDF format as ad hoc standard format assure data longevity. In Section 3.3 of National BIM Guide for Owners - National Institute of Building Sciences (2017), it identified standards and requirement for graphical output or paper printing. It

defines all approved submittals, and other documents that required in traditional paper-based formats should provide with Portable Document Format (PDF) format or other open electronic document format. PDFs should comply with the following ISO Standards: ISO 19005-3 (2012)[4]; ISO 32000-1(2008)[5] and for the construction documents, it should follow the Guideline for Construction PDF Documents. (Construction PDF Coalition, 2018) The format that are maintained by an official standards development organization such as ISO was formal standard format. Compared to pdf format, formal standards are developed through a consensus process that considered the information requirements of multiple organizations. Formal standard is more flexible and useful compared to ad hoc format. Standard formats are recommended if data will be archived for an extended period. (Fallon et al., 2006) Therefor, it is recommended to adopt standard format as defined in National BIM Guide for Owners - National Institute of Building Sciences (2017), for UW projects.

### 5.3.3 [Life-Cycle information exchange for Equipment Assets and Specifier's Properties information exchange (SPie)] vs. [UW FM Data Standard and eO&M] for Handling Facility Asset Information

One of the issues that was identified in the case study is that data searchability in the documents needs to be improved. Both observational study and interview show that facility operator needed a better way to search information.

BuildingSmart tried to address the problem of data searching for the AEC industry through Specifiers' Properties information exchange (SPie) project to replace traditional manufacture cut sheets. The initiative of SPie project was to establish a set of open, structured and standard templates for manufacturers to export data into those templates for information to be consumed by different shareholders during the life cycle of the project. The benefit of SPie for facility management that was identified by Building Smart Alliance as that facility operator could benefit from getting correct manufacturer warranty information, preventive maintenance information and get manufacturer parts number when they need. They can look across manufacturers for the

[4] ISO 19005-3 (2012): Document Management-Electronic document file format for long-term preservation-Part 3: Use of ISO 32000-1 with support for embedded files (PDF/A-3)

[5] ISO 32000-1 (2008): Document Management-Portable document format-Part 1: PDF 1.7.

originally installed product to find if there are new products that are more efficient. The project started in 2007. However, at the time of the study, the willingness of manufacture participate was still barrier for the industry use. (BuildingSMART Alliance Specifiers' Properties Information Exchange (SPie) Project - National Institute of Building Sciences, 2017)

In the current practice of the university environment, the facility operator directly contacted manufacturers for the complex equipment maintenance for example elevator (made by Kone) that was mentioned in the content section. Lots of businesses in the industry are relationship based. It is not clear how much efficiency and willingness will create for facility operator to look across manufactures for finding a better product. Therefore, instead of relying on standardizing product data, a good user interface and better search engine might be enough to solve the problem.

### 5.3.4 [National CAD Standard V3] vs. [UW eO&M] for File Naming Convention

In the case study section, the consultant that managed eO&M was struggling with file naming and UW did not have standard file naming convention at the time of the study. There is a gap between traditional information deliverable naming convention and digital information deliverable naming convention.

National BIM Guide for Owners - National Institute of Building Sciences Section 3.4 (2017) provides a reference to file and folder naming convention. It mentions that National CAD Standard (NCS) provides a proposed naming convention for files. Incorporating NCS in UW Standard Naming Convention might help UW to adopt industry standard more effectively in the future.

### 5.3.5 [OmniClass Construction Classification System (OmniClass)] vs. [UW FM Data Standard] for Information Classification

UW used its own information hierarch and naming convention to manage asset data. In the UW FM Data Specification Version 1, equipment asset data was organized based on UW asset group definition, and each group was mapped to Uniformat, Master Format, and Omni-Class as shown in Table 9. In the version 2 of UW FM Data Specification, classification mapping was no longer provided. Instead, the equipment was classified as a group or serialized as shown in Table 10.

**Table 9: UW FM Data Specification (first version) Information Classification (Equipment Asset Group Matrix Example) (Reference: UW FM Data Requirement for O&M Standard Specification)**

| UW Asset Group "Type-Category" | Asset Group Description | Classification | Comments | Attributes |
|---|---|---|---|---|
| UWxxxxxxx | ACCESS PANELS | Uniformat | | Capacity |
| | | D07010.10 | | Installed capacity |
| | | Master Format | | Power supply |
| | | 28 13 00 | | Remote power booster |
| | | Omni-Class | | Remote battery backup |
| | | 23-29 13 00 | | |

**Table 10: UW FM Data Specification (second version) Information Classification (Equipment Asset Group Matrix Example) (reference: UW FM Data Requirement for O&M Standard Specification)**

| Code (Note 1) | Asset Group (Note 1) | Comments | Type (Note 2) | System |
|---|---|---|---|---|
| UWxxxxxxx | ACCESS PANELS | One per bldg. | GROUP/SERIALIZED | ARCHITECTURAL/BUILDING/ELEC |

Note 1: Equipment Group Matrix is organized by "Asset Group". The first column is the abbreviated name for the "Asset Group Code". The table is organized by "System"

Note 2: "Serialized" Assets are assets that tracked individually by piece of equipment

"Group" are assets that will be handled as a group and not tracked individually (for example: window, light etc.

NBIMS-US V3 (2015) outlines that common information classification should reference OmniClass Table. Projects, in addition, SPie/Opie/Lcie/HVACie etc. also references OmniClass for information classification. OmniClass is a means of organizing and retrieving information that

specifically designed for the construction industry. The design intendtion of OmniClass is to provide a way of organizing, sorting, and retrieving information and deriving relational computer applications. The basis of its table is drawn from other extant systems in use, for example, MasterFormat for work results, UniFormat for elements and EPIC (Electronic Product Information Cooperation) for products. OmniClass consists of 15 hierarchical tables for representing different classified construction information throughout the full project lifecycle. (NBIMS-US V3, 2015) Table 23 Products in Omniclass is to identify product classes without regard to their application. The product is defined as component or assemblies of components that are permanently incorporating into construction entities. (OmniClass, 2010) Table 7 shows an example of how OmniClass Table 23 organize products information.

**Table 11 OmniClass Transition Matrix Example (OmniClass, 2010)**

| **2010-06-24 OmniClass Number** | **2010-06-24 OmniClass Title** | **Synonym** | **Definition** |
|---|---|---|---|
| 23-29 13 00 | Security Access Controls | | Equipment used to protect the occupants and the facility through access control |

As mentioned earlier in this Chapter, the latest version of UW FM Data Specification no longer uses COBie format data structure. However, it might still worth considering mapping UW asset group to OmniClass. With the development of technology and US Industry Standard, if UW decides to fully adopt industry standard in the process in the future, having an industry standardized information classification in the data management system will smooth that process. It might address the need for information sorting, organization, and retrieval in the future.

### 5.3.6 [NBIMS-US V3 (2015)] vs. [eO&M] for Standardized Document Structure

Even though eO&M has enabled the owner to successfully realize information exchange from paper-based documentation deliverable to electronic-based documentation deliverable. To fully enable integrated system to exchange document and asset data, the owner need to organize documents in a standardized way.

There are a significant number of documents coming from design, construction and commissioning stage. In ARCF, as discussed in the case study section, the content of documents was captured based on the UW research group's research (Anderson et al, 2012) and the experience of the consultant. In the content of information deliverable section Table 3, the documentation structure of eO&M was introduced. It was organized based on the content of documentation: project general information, O&M product and system data (submittal and O&M), as-built drawings and specifications by contractor, final project record set by A/E consultants, warranties, training commissioning.

NBIMS-US V3 provides a list of the corresponding traditional contracted deliverable for each the business processes identified in the NBIMS-US COBie standard and identifies current document-based deliverables that can be replaced, in-all or in-part by the information exchange standard. Submittal document, final design document, and turnover O&M document were submitted as part of eO&M deliverables, and how final design document, submittal information, and the turnover package could be captured and recorded using COBie is discussed below to compare information exchange standard defined in NBIMS-US V3 with current industry implementation.

**Table 12 Traditional document list for preparing and organizing design final document, submittal document and turnover package document are identified in NBIMS-US V3(2015). (Green highlights are contents included in eO&M)**

| | | |
|---|---|---|
| **Finalize Design- Design Final Document List** | Information Content | Basis of Design Narrative; Design Final Drawings; Energy Analysis; Life Cycle Cost Analysis; Cost Estimate; Geotechnical Report; Calculations; Environments Report; Project Information Form; Quality Control Data; Color Documentation Binder; Code Compliance Certification; Specifications; Submittal Register |
| | Contracted Exchange/Deliverable | Design Final; Product Type Candidate |

| | | |
|---|---|---|
| **Develop Pre-Construction Plan Document List** | Information Content | Equipment Lists; Certificates of Insurance; Surety Bonds; List of Proposed Subcontractors; List of Proposed Producers; Construction Progress Schedule; Network Analysis Schedule; Submittal Register; Schedule of Prices; Health and Safety Plans; Work Plan; Quality Control Plan; Environmental Protection Plan |
| | Contracted Exchange/Deliverable | Pre-Construction Plan |
| **Prepare Submittal Information - Product Type Selection Document List** | Information Content | Product Data; Samples; Design Data; Test Reports; Certificates; Manufacturer's Instructions; Manufacturer's Field Reports; Operation and Maintenance Data |
| | Contracted Exchange/Deliverable | Product Type Selection |
| **Prepare Submittal Information - System Layout Document List** | Information Content | Shop Drawings |
| | Contracted Exchange/Deliverable | System Layout |
| **Identify Discrepancies Document List** | Information Content | Request for Information |

| | | |
|---|---|---|
| | Contracted Exchange/Deliverable | Inquiry Issue (RFI) |
| **Organize Submittal Information Document List** | Information Content | Pre-Construction Plan; Product Type Selection; System Layout (Refer to the information content for each of these individual items for a complete list of included information) |
| | Contracted Exchange/Deliverable | Submittal Package |
| **Closeout Document List** | Information Content: | Operations and Maintenance Manuals; Record of Designated Equipment; Record Specifications; Record (As-Buit) Drawings; Final Approved Shop Drawings |
| | Contracted Exchange/Deliverable | Turnover Package |

The first set of information from eO&M is project general information such as brief project description, contact information for the owner, major contractors, subcontractors, and vendors. COBie captures the lists of companies and person name needing access to the job site through COBie.Contacts and the list are updated from COBie.Contacts as the project proceeds.

Final conformed submittal and operation and maintenance data (O&M data) are an important part of eO&M. Submittal documents are generated and organized through the process of preparing submittal information, organizing information and performing submittal review. According to NBIMS-US V3 (2015), the majority of information related to submittal and O&M documents such as product data, design data, test reports, certificates, manufacturers' instructions, manufacturers' field reports can be linked to COBie data sets through the COBie.Document entity. The information related to product data is vision to be provided in a data-oriented format directly from product manufacturers using discrete COBie data exchanges either through SpreadsheetML or COBieLite versions as the development of SPie and LCie project. Specific content and format specifications to support such direct information exchange are defined in those projects. This kind of exchange is not common practice today. The preparation and transmission of submittals are not in the scope of COBie. An example data structure is defined in LCie project for the exchange of such information. In addition to submittal stage, operation and maintenance manuals are part of

final handover package in the closeout stage. When product manufacturers begin to provide product data in SPie format, it is expected that they will provide their O&M manuals in COBie format.

In eO&M, the information that comes from design stage is final updated record set design drawings, final updated record specification, and final design calculation. According to NBIMS-US V3 (2015) COBie, information related to the requirements for various products found in COBie.Type can be used to create outline specifications for the project from the properties identified in the COBie model. However, such applications currently are not widely used. Information related to drawings and calculations are outside the scope of the COBie specification. It mentions that drawing files contain a level of geometric details are not suit for COBie inclusion.

As-Built Drawings and Specification by Contractor Section in eO&M include as-built drawings, as-built specification, RFI, ASI and BIM files. NBIMS-US V3 (2015) specified paper copies of final record copies of the as-built drawings complete set of contract documents with all modifications, and shop drawings could be provided in PDF format and linked through the COBie.Document tab.

For the commissioning stage, equipment start-up and performance reports could be linked to COBie data. COBie.Component.WarrantyStartDate can be used to document the start-up or energization and date for a given piece of equipment in COBie. Other information such as report may be linked to the specific COBie.Component through the COBie.Document entity. NBIMS-US V3 mentions that for the information not conducive to capturing COBie format maybe captured in PDF files and directly linked to the associated Zone, System or Component.

From the previous comparison, it can conclude that for the information deliverable content that captured in eO&M, COBie provides a general information exchange standard for that information. However, it is not practical today to get information such as product data and operation and maintenance data from manufactures through COBie format or SPie format. Most of the document information is captured PDF files and linked to the associated Zone, System or Component in COBie. Such solution is like ARCF project handover deliverable solution that references equipment, and space name to associated documents files information, for example, submittal, commissioning and warranty documents. Therefore, using COBie format to capture document does not provide owner much benefit to the owner in current practice.

## 5.4 Content of Information Deliverables

### 5.4.1 [Operator's Properties information exchange (OPie) & Specifiers Properties Information Exchange (SPie)] vs. [UW FM Data Specification (Version 1) & UW FM Data Specification (Version 2)] for identifying equipment attribute

In current practice, the University hires a consultant to identify the equipment attributes through interviewing with facility staff on campus. The first version of UW FM Data Standard provided very detailed equipment attribute that UW would collect for maintenance and operation. In the second version, the equipment attributes that were collected are the type and size of belts and filters.

The national standard project has not successfully collected the general equipment properties (also called attributes) for meeting facility operation and maintenance's requirement. OPie was initiated to identify properties needed by facility operators and maintenance technicians beyond those properties identified by the SPie project in 2011. Survey forms based on information used by U.S. Army Installation Command personnel working on military installations was sent out, created and distributed to the National Institute of Building Sciences, Facility Maintenance and Operations Committee for review. A limited number of responses (three partial response) were received. This project was closed due to lack of industry interest. Dr. East and members of the Norwegian government have conversations about the possibilities of validating information gleaned from U.S. Army sources using the information being collected on operators' properties in Norway. However, no further information is available at the time of National BIM Standard Version 3 was published. (NIBS, 2015)

I participated the development of SPie project. The current stage of the project was to expand and finalizing SPie equipment specification property definitions and to extend with maintenance properties. Product specific attribute for product template was based off Unified Facilities Guide Specifications (UFGS) and COBie Guide.

Table 13 shows a comparison of chiller attribute that is defined in SPie technical Report and UW FM Data Specification Version 2. Table 14 shows a comparison of air handling unit attributes that were defined in UW FM Data Specification Version 1 and Version 2. The second version only requires the attributes of consumable parts of the equipment such as filters and belts that match the interview result from case study section.

**Table 13 Comparison of chiller attribute defined in Specifiers Properties information exchange (SPie) (2013), UW FM Data Specification Version 1 and Version 2. (Green highlights are same/similar attributes)**

| | Equipment Attribute from Specifiers Properties information exchange (SPie) technical report (2013) | Equipment Attribute - UW FM Data Specification Version 1 | Equipment Attribute - UW FM Data Specification Version 2 |
|---|---|---|---|
| **Chillers** | Current | Vessel Type | Filter 1 |
| | Voltage | Year Built | Filter 2 |
| | Frequency | National Board (NB) # | |
| | Power | Field ID | |
| | Capacity | Use | |
| | Water Flow | Safety Value (SV) Setting | |
| | Ambient Drop | Power supply | |
| | Entering Water Temperature | Electrical supply | |
| | Leaving Water Temperature | Electrical panel name | |
| | Motor Controller | Capacity | |
| | Unloading Steps | Chiller Cooling Capacity | |
| | Chiller Media | Chilled Water Inlet/Outlet temp | |
| | Chiller Type | Chilled Water Flow Rate | |
| | Refrigerant Type | Chilled Water Pressure Drop | |
| | Energy Efficiency Ratio (EER) | Cooling Water Inlet/Outlet temp | |
| | Integrated Part-Load Value (IPLV) | Cooling Water Flow Rate | |
| | Heat Reclaim | Colling Water Pressure Drop | |
| | Sustainability | Refrigerant Type | |
| | System Description Chiller Type | Type- Air Cooled, Water Cooled | |
| | Component | | |

**Table 14 Comparison of air handling unit attribute defined in UW FM Data Specification Version 1 and Version 2.**

| | Equipment Attribute - UW FM Data Specification Version 1 | Equipment Attribute - UW FM Data Specification Version 2 |
|---|---|---|
| **AIR HANDLING UNIT** | FIELD ID | FILTER 1 |
| | SERVES | FILTER 2 |
| | BELT | BELT 1 |
| | BEARINGS | BELT 2 |
| | SHIVES | |
| | TYPE | |
| | SIZE | |
| | power supply | |
| | electrical panel name | |
| | capacity | |
| | air filter type | |
| | return fan capacity | |
| | supply fan capacity | |
| | fan ext pressure drop | |
| | chilled water rate | |
| | coil flow | |
| | coil capacity | |
| | coil pressure drop | |
| | entering air temp db/wb | |
| | leaving air temp db/wb | |
| | entering water temp | |
| | leaving water temp | |
| | interlocked with other fans | |

The comparison shows that there are some overlapping attributes between SPie technical report and UW FM Data Specification and they both have detailed attribute requirement. The case study interview result shows that the equipment attributes that would satisfy facility operator's information requirements are the type and size of the consumable parts of the equipment. Similarly, UW FM Data Specification version 2 specifies that the equipment attributes that are required to capture are filters and belts. Therefore, the data need for consumable parts size and dimension is fit for most of university project in UW.

## 5.5 Pathway of Information Deliverables

### 5.5.1 [NBIMS-US V3] vs. [eO&M for Electronic Documentation Deliverables and UW FM data Deliverable Standard]

The information followed two different pathways in ARCF and the need for combining two pathways into one was identified in the previous section. FM asset data and eO&M are cross-referenced. Name of electronic files match what is referenced in the appropriate fields for document name. COBie is to capture the construction handover package. All the contents of the turnover package are either included or referenced within the COBie data structure. (NBIMS-US V3 Section 4.2.4, 2015)

However, no matter it is using simplified combination of FM asset data and eO&M information delivery method or COBie delivery method, the solution of addressing the muti-pathway problem for the university is to have a central location to save the data.

## 5.6 Facility Maintenance Information Management

The case study has identified that the most significant challenge for current information delivery model in the ARCF project was information change management in operation and maintenance stage. COBie addresses the problems of construction handover deliverables, currently, but there are no open standard to support information exchange in the operation stage of a facility. NBIMS-US V3 (2015) identifies three business cases if BuildingSMART alliance project considers developing an open standard to exchange the information related to update COBie data during the operations and maintenance phase of a project. First is service call which does not change information but only uses the information provided. The second is work order that is also mentioned by facility manager in ARCF case study. Replacing one piece of equipment with another does not change the location of the equipment but only the attributes such as manufacturer, model, serial number and attribute data change. NBIM-US V3 does not mention how work order will affect the management of documentary deliverables. The third case is facility renovation in which case COBie data that is being removed from an underlying database can be flagged and the new COBie data provided. (NBIMS-US V3 Section 4.2.9.3.5)

# Chapter 6: Discussion, Conclusion, and Recommendations for Further Research

## 6.1 Discussion & Conclusion

To successfully implement BIM for FM practices, owners need to clearly define information requirement. This research examined a real-world digital information deliverable on a university research building project, to identify the usefulness of the deliverable in terms of format, structure, content, pathway, timing and facility maintenance infrastructure for facility maintenance and operations, to determine the gap between current national standard and industry implementation.

Over the course of the investigation presented in this thesis, the usefulness of digital information deliverable practices includes following: 1) Improved information retrieval: creating a documentation handover interface was useful to help facility personnel to retrieve information more efficiently; smart asset naming was useful for facility personnel to retrieve information 2) Better-quality information content relevancy: The eO&M content of warranty claim instructions and high-quality videos were identified as very useful for practitioners in this case (used the information more than one time per month 3) information content completeness: Thabet et al (2016) mentions FM staff were not aware of construction submittals. The content of eO&M presented in case study was identified to be able to be referenced in the project life-cycle by different stakeholders and help facility personnel reference additional information 3) Information content accuracy: previous research identified that one of the issues of traditional information deliverable is almost 50% of asset information was missing due to having to manually search for the data and the inability to find it in the limited time (Thabet et al., 2016). The digital information deliverable process presented in this research collects the asset data throughout the construction process, delimited the need of collecting asset data after construction 4) Information flexibility: Delivering FM data and eO&M separately was identified as an intercept for the university to implement before they have central location to save the data 5) digital information delivery method was helpful to realize fast turnover time.

The main lessons learned from using digital information deliverable presented in Chapter 5 includes the following: 1) identifying and specifying appropriate format and structure of digital information deliverable requirement for facility maintenance and operation are important; When

specifying the format and structure of information deliverable requirement, the owner needs to consider how to manage and update data after turnover and facility maintenance infrastructure availability; appropriate software compatibility should be taken into consideration to avoid delay. 2) When specifying the content of information deliverable, facility owner needs to consider the granularity of the data, the frequency of information use and the user of the information. In ARCF case and other UW projects, the most useful attribute of asset data was the type and dimension of the consumable part for facility operation and maintenance, and this may only apply to projects with similar attributes. 3) To integrate data between FM data and handover documentation, the owner needs to create a central location to ensure authentic, relevant and referable data. 4) Information deliverable should avoid information overlapping for information management efficiency.

The key findings of comparing UW information deliverable specification and National Standard include 1) National BIM Standard V3 and National BIM Guide for Owners provide guidelines including standard electronic document format, file naming convention, and information classification standard Omniclass; 2) COBie format is not very easy to implement in current industry practice and does not provide enough cost savings to owner to adopt the standard in current practice; 3) The value of SPie project heavily rely on industry's participation; 4) Using COBie format to capture document does not provide owner much benefit because COBie format or SPie format is still not very practical today; 5) It may not be practical to provide standard equipment attribute because owner has a varieties of requirements; 6) There is no open standard to support information exchange in the operation stage of the facility.

Some of the above findings have also been suggested by previous research. These practices include the followings: 1) Fallon et al. (2006) proposed to consider information priority, information type, retention type, the software application for downstream, need of sharing with the external organization and update frequency. 2) Mayo & Issa (2015) mentioned that owners' misconception of the importance of the data format could lead to errors in FM programs and operations 3) Parsanezhad et al. (2013) stated that COBie format is challenging to implement because COBie information field has mismatch with organizational business goal and lack of incentives for manufacturers to provide product information in COBie-compatible format.

The lesson learned from using digital information deliverable and the key findings of comparing UW information deliverable specification and the national standard is the unique contribution of the study and are widely generalizable to a variety of projects. Some of the details in identifying the usefulness of digital information deliverable practices may only apply to project with similar attributes.

## 6.2 Recommendations for Practitioners

Future work will consider provide a matrix of information need requirement identification to guide facility owner to identify information needs and develop information deliverable specification.

First, information can be categorized based on owner's facility management structure and available guidance, one example is as shown in figure one which is developed by Wang et al. (2013).

For information content, except asking what data do you need and when do you need the data for each type of information, following questions are recommended to add in the matrix: 1) what is the information priority? 2) what is the frequency of using the information?

For information format and structure, the following questions are recommended in the matrix: 1) what is available forms and format for each type of data? (structured and proprietary; structured and standard; unstructured and proprietary; unstructured and standard) 2) Based on the content of information, decides the type information (static[6] or dynamic[7]) and the frequency of information update 3) based on information content and priority, decides retention period of the information (essential-must be retained, legally mandatory-retention period must be explicitly defined, phase specific-the use phase must be specified, transitory-data that is not required to be included in the deliverable)[8] 4) What is software compatibility? 5) Data standard should be reviewed for adoptions.

[6] Static information: information creation has been completed, it will never be updated (Fallon et al. (2006))
[7] Dynamic information: information should be updated to reflect changes (Fallon et al. (2006))
[8] Essential means that information is required for reliable facility operation and safety, unaccepted risk would be created without the information. Legally Mandatory means that data are not expected to be used in regular basis but to be achieved for a specific period for legal purpose. Phase specific means that data is useful for specific period but not for long-term operation. Transitory means data is not required to be referenced in any subsequent life cycle (Fallon et al., 2006)

For information management infrastructure, the owner needs to consider the possibilities of the single source of truth. Finally, facility information requirement should consider meeting facility owner's current goal and future goal.

## 6.3 Future Research

Currently, owners determine the data needed for the FM task by interviewing internal facility staff in practice. As more and more owners are adopting digital information exchange process, an information sharing platform could be built by an organization like Building Smart Alliance for the owner to share their identified asset data and properties that are fit for each FM task in each building type. This research uses the qualitative method to measure the usefulness of information. Further research is suggested to use quantitative measurement to determine the usefulness of information in terms of quality, relevance, completeness, and timeliness during the life cycle of facility operation.

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# Appendix A- Observational Study Sheet

| Job Shadowing Sheet (ARCF) | | |
|---|---|---|
| Date: | | |
| Shawdowing Hour | | |
| Observational Person Name and Title | | |
| Work Order Type | Corrective Maintenance ☐ | |
| | Preventive Maintenance - Asset Based ☐ | |
| | Preventive Maintenance - Building Based ☐ | |
| Asset Name | | |
| Procedure 1: Get a picture of the work order | | |
| Procedure 2: Information need to perform the work order | | |
| Describe the detail of used information | | |
| Geometric Information ☐ | Non-Geometric information ☐ | |
| | Yes | No |
| In AiM or not | | |
| In eO&M or not | | |
| If need to ask facility manager: | | |
| if need do a site work | | |
| if need to collect more information (if yes, go to next section, include search eO&M) | | |
| Other Note: | | |
| Procedure 3: Missing Information collecting process (include eO&M) | | |
| Missing information Detail 1 | | |
| Activiity (site work, look up drawings etc) that is related to collect missing information and ask why perform that kind of activity will help | | |
| How much time it takes to perform the activity | | |
| The level of development if it is a geometric information and the them to describe the detail information that they are looking for | | |
| Is that an attribute/documentation/people knoweldge if it is non geometric information and ask them to provide detail | | |
| Other Note: | | |
| The decision making process based on the information | | |

| | |
|---|---|
| Missing information Detail 2 | |
| Activiity that is related to collect missing information | |
| How much time it takes to perform the activity | |
| The level of development if it is a geometric information | |
| Is that an attribute/documentation/people knoweldge if it is non geometric information | |
| The decision making process based on the information | |
| Other Note: | |
| Procedure 4: The use of the information | |
| How information is ditrbuted to facility operator to perform the work | |
| Other Note: | |
| Procedure 5:Information Update | |
| How new gathered information is updated in asset management system | |
| How feedback information is updated in the management system | |
| Other Note: | |