Value Proposition of COBie at University of Washington

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Abstract

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Building Information Modeling (BIM), has been practiced for several years by designers and contractors in design and construction phases. After receiving a positive feedback of the BIM in industry, owners are now interested in getting the benefits of the BIM in operations and maintenance. The information value produced during each phases of the project drops in phase transfer during the building lifecycle, and this drop has the highest value in transition from construction to operations and maintenance (O&M). BIM can capture the O&M information produced during the phases of pre-design, design, and construction, and transfer it to the operations and maintenance phase.

Construction Operations Building Information Exchange (COBie) was developed by the US Army Corps of Engineers as a method of delivering O&M information and project specific data in a standardized format. COBie can be extracted from BIM, and be imported to Computerized Maintenance Management System (CMMS) of the owner where the maintenance work orders are managed.

The value of COBie for Facility Management is determined in two phases of turn over, and operations and maintenance. The value of COBie at University of Washington in turn over phase was investigated previously, and this research study focuses mainly on the value of COBie in operations and maintenance. Interviews with Facility Services (FS) employees were conducted to understand the work order work flows, and how COBie can impact it. The challenges FS employees are facing performing the work orders are related to two categories of sources and

processes, and research study has investigated how COBie can address these challenges and help the work order process.

Based on the interview result analysis, since COBie can provide comprehensive O&M data from the first day of operations with high accuracy, it can considerably ease the work order process. But FS employees are also reliant on other sources and documents like as-build plans and O&M manuals to get information to perform work orders. COBie is not enough on its own to provide all the information needed for Facility Management, but based on the COBie standard and the data provided in each project, FS employees can be less reliant on other sources than COBie.

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Dedication

I would like to dedicate my thesis to

my beloved parents.

Acknowledgements

This thesis represents not only my research results, but also a big change in my life as a geotechnical engineer who decided to pursue master's degree in Construction Engineering, while being on her track of PhD studies. I would like to express my deepest gratitude to my advisor, Dr. Carrie Dossick, for her excellent guidance, caring, and patience, helping me through this big change to learn the fundamentals and technology, and providing a very active and friendly environment to do my research. My special appreciation goes to Jeffrey Angeley, the Senior Project Manager at Capital Projects Office, who hosted me as an intern and walked me step by step through the construction management practices in the industry. I would like to thank my other committee member, Dr. Amy Kim, for her guidance and support throughout the course of this research.

My sincere appreciation goes out to Steve Babinec, and Cesar Escobar who helped me a lot in this research project. A special thanks to Chris Monson for his help and guidance in COBie project. I am greatly thankful to employees at Facility Services who kindly collaborated in interview process, and shared their experience and knowledge with the research team. I would like to thank Capital Projects Office, and Built Environment department for giving me the opportunity to work in F2 COBie project. Special thanks to faculty members and staff of both departments of Construction Management, and Civil Engineering for their dedication and support. My enormous appreciation goes to my mother and friends for being supportive all the time.

Acronyms

3D …………………………………	Three dimension
BIM ………………………………	Building Information Modeling
CAD ………………………………	Computer Aided Design
CEO ……………………………....	Campus Engineering and Operations
CM ………………………………..	Corrective Maintenance
CMMS ……………………………	Computerized Maintenance Management System
CPO ………………………………	Capital Projects Office
EPA ……………………………….	Environmental Protection Agency
FEMP ……………………………..	Federal Energy Management Program
FM ………………………………...	Facility Management
FMC ………………………………	Facility Maintenance and Construction
FS …………………………………	Facility Services
IFMA ……………………………..	International Facility Management Associations
NBIMS ……………………………	National Building Information Modeling Standards
NIST ………………………………	National Institute of Standards and Technology
NIBS ……………………………...	National Institute of Building Sciences
NRC ………………………………	National Research Council
O&M ……………………………..	Operations and Maintenance
PM ………………………………..	Preventive Maintenance
ROI ……………………………….	Return On Investment
UW ……………………………….	University of Washington
WO ……………………………….	Work Order

Chapter 1: Introduction

A study by National Institute of Standards and Technology (NIST) showed that approximately $10.6 billion of the total annual $15.8 billion lack of interoperability costs in the U.S. capital facility projects in 2002 is born by the owners. Eighty five percent of the interoperability problem cost on owner's side is related to the operations and maintenance (O&M) which is due to the poorly transfer of O&M information from the other stakeholders like designers and contractors to the owner, and poorly maintained information by the owner. The information value produced during each phase of the project drops in phase transfer during the building lifecycle, and this drop has the highest value in transition from construction to operations and maintenance phase. For preventing the inefficiency costs of interoperability, it is crucial to collect the O&M information produced during the phases of pre-design, design, and construction, and transfer it to the operations and maintenance phase.

Building Information Modeling (BIM), is a technology tool which can capture the information produced in different phases of the building, and as a result, reduce the interoperability costs, and increase operational and maintenance efficiency. BIM has been practiced for several years by designers and contractors in design and construction phases. After receiving a positive feedback of the BIM in industry, now the focus is also on the benefits of the BIM in operations and maintenance. Multiple studies have been done on the value of BIM for Facility Management which proves a considerable return on investment and savings in operations and maintenance. COBie was developed by the US Army Corps of Engineers as a method of delivering O&M information and project specific data in a standardized format. The best practice of COBie is when it starts from the pre-design stage, and collects all the information produced in different phases of the facility life cycle.

University of Washington (UW) is one of the oldest Universities on the west coast founded in 1861. UW owns over 500 building with more than 20 million gross square footage of space. Based on the NIST study, the annual interoperability cost for UW can be quantified $4.6 million, where about $3.9 million would be related to maintenance and operations. In 2011, Construction Owners Association of America (COAA) initiated a case study project with the aim of implementing COBie on construction projects of large institutions and measuring the achieved results. Being a large institution, Capital Projects Office (CPO), UW's internal construction management department, and UW Facility Services (FS) jointly, decided to try the implementation of COBie at UW with collaboration of Dr. Carrie Dossick, the faculty member of the Built Environment department.

UW's first COBie pilot was Dempsey Hall. The decision of COBie implementation on Dempsey Hall was made during the construction phase, and as a result, COBie was not implemented completely. Two research studies were conducted on Dempsey Hall. One of the studies focused on understanding the obstacles of information exchange in current process, and the work flow change in COBie method. Other study had focused on the analysis of time spent for information exchange in paper-based and COBie format. Studies showed that, in current process for new constructions, usually there is no effort for collecting asset data, and creating asset profiles in Computerized Maintenance Management System (CMMS) of UW, AiM. Only some important assets which usually have mandatory or regulatory Preventive Maintenance (PM) are created in AiM in the early stages of the occupation, and the rest of the assets might be entered in AiM system if there is a Corrective Maintenance (CM) work order. In COBie process, design and construction teams have the responsibility of the O&M data collection, and are able to provide the information from the first day of operation in COBie format. This is while in current process, shops has the responsibility of data collection, and the process starts after the turn over phase, and might take 1 to 2 years to capture only a part of the data COBie can provide.

COBie Pilot II was the establishment of COBie standtards based on UW specific needs. COBie Pilot III is the implementation of COBie on ARCF project, and rebaselining of William Foege Building. The aim is to prepare a guideline for COBie process for future projects.

The value of COBie for Facility Management is determined in two phases of turn over, and operations and maintenance. This study focuses more on the effects of COBie in operations and maintenance phase, while the previous studies had mostly focused on the COBie impact in turn over phase. Chapter 2 reviews the previous studies of operations and maintenance, and the value of BIM and COBie for the owners. Chapter 3 introduces COBie project at the University of Washington. Chapter 4 is about the methodology and data collection of the current research. This study follows the case study method, and interview is the tool for data collection. Chapter 5 includes description of the work order work flow for both Preventive and Corrective Maintenance work orders at UW. Chapter 6 talks about the challenges of facility maintenance FS employees are facing which are divided into two categories of sources, and processes. Chapter 7 analyzes how COBie can help the facility management, and Chapter 8 is the discussion and conclusion.

Chapter 2: Literature Review

2.1- Facility Management

International Facility Management Associations (IFMA) defines Facility Management (FM) as "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology." IFMA identified eleven core competencies of facility management of 1) communication, 2) emergency preparedness and business continuity, 3) environmental stewardship and sustainability, 4) finance and business, 5) human factors, 6) leadership and strategy, 7) operations and maintenance, 8) project management, 9) quality, 10) real estate and property management, and 11) technology. (www.ifma.org) This study will mostly focus on the operations and maintenance, and technology core components.

The Federal Energy Management Program (FEMP) defines Operations and maintenance as "the decisions and actions regarding the control and upkeep of property and equipment. These are inclusive, but not limited to, the following: 1) actions focused on scheduling, procedures, and work/systems control and optimization; and 2) performance of routine, preventive, predictive, scheduled and unscheduled actions aimed at preventing equipment failure or decline with the goal of increasing efficiency, reliability, and safety." (Sullivan et al., 2004)

A building has four phases in its lifecycle: 1) Plan and design, 2) Construction and commission, 3) Operations, maintenance, and renewal / revitalization, 4) Decommission and disposal. As seen in figure 1, among the four phases of the lifecycle of a building, the operations, maintenance and renewal phase has the longest duration. The first two phases of design and construction takes about 2 to 5 years which is typically 30 to 40 percent of the total cost of the lifecycle. This is while 60 to 70 percent of the remaining cost occurs in third phase of operations and maintenance. Owners usually focus on the cost of the first two phases, and fail considering the total cost of ownership which is mostly related to the third phase. (Ghallahar et al., 2004; NRC, 1998)

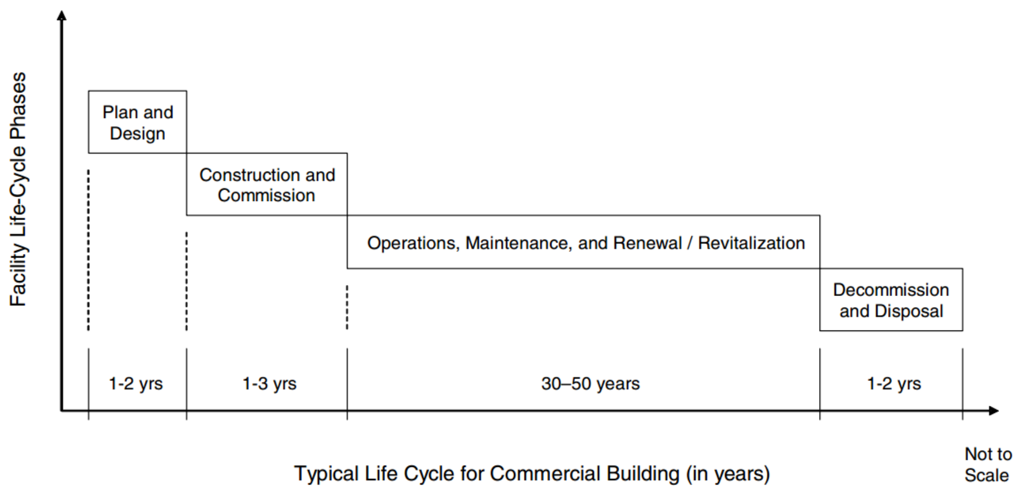


Figure 1 Typical Life Cycle of a Commercial Building (Ghallahar et al., 2004)

As seen in figure 2, building performance goes down because of its age, the use it receives, or functional adaption to new uses. The performance can decline at an optimized rate if the building is maintained properly. For having an optimum building performance, facility maintenance is very crucial during the building service lifetime. (Ghallahar et al., 2004; NRC, 1998)

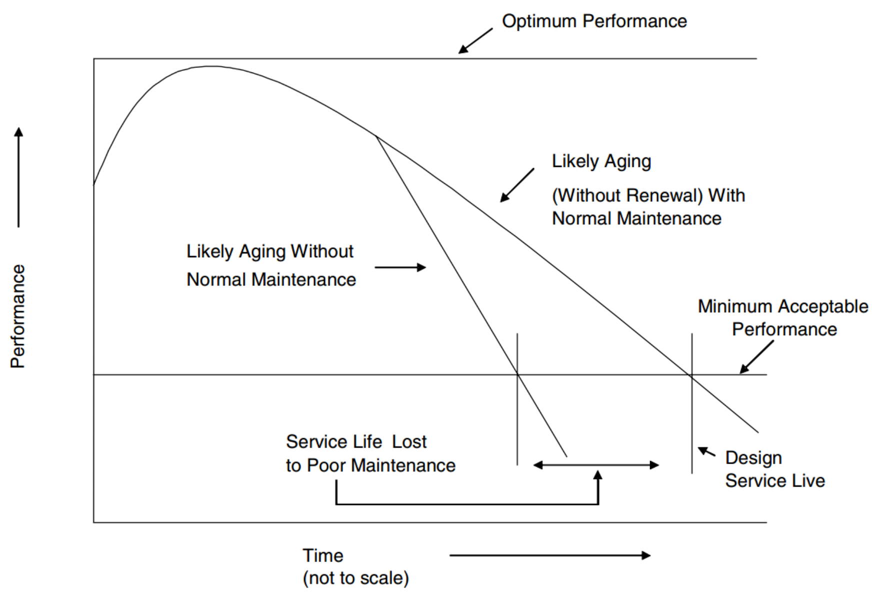


Figure 2 Maintenance Effect on Facility Performance (Ghallahar et al., 2004)

2.2- Interoperability Problems

The National Institute of Standards and Technology (NIST) had defined the "Interoperability" as "the ability to manage and communicate electronic product and project data between collaborating firms' and within individual companies' design, construction, maintenance, and business process systems." (Gallagher et al., 2004)

NIST had commissioned a study to identify and estimate the efficiency losses in the U.S. capital facilities industry due to inadequate interoperability among computer-aided design, engineering, and software systems. The capital facilities industry is changing by use of technology tool like computer-aided drafting technologies, 3D model technologies, and a host of internet and standards based design and project collaboration technologies. This study had focused on design, engineering, facility management and business processes software systems, and redundant paper records management in all facility life cycle phases. For this purpose, 105 interviews were conducted with stakeholder groups of architects, engineers, general contractors, special fabrication and suppliers, owners and operators, software vendors, and research consortia representing 70 organizations. (Gallagher et al., 2004)

Based on interview and survey results, $15.8 billion annual interoperability costs were quantified for the U.S. capital facilities supply chain in 2002 where the majority of these costs were born by owners and operators. Owners and operators bore approximately $10.6 billion which is about 68% of the total estimated interoperability cost. Study showed that 85% of the interoperability costs on owners and operators side are incurred during operations and maintenance phase which is approximately $9 billion. The rest cost occurs in design and construction phases of building construction of the owner. (Gallagher et al., 2004)

NIST describes the reason for interoperability problems in operations and maintenance phase as "Over the years, owners and operators receive and maintain information in a variety of different media: preferred electronic file formats, miscellaneous file formats, and paper information. This information does not always adequately reflect the true configuration of facilities either because as-built information was poorly communicated or because information was poorly maintained over the years. The net result is that owners and operators suffer significant efficiency losses each year.

Efficiency losses mostly impact facilities management and operations and maintenance staff. The single largest impact is on information verification and validation, or the time spent ensuring that the information accurately represents what is set in place.” (Gallagher et al., 2004)

The annual cost of interoperability born by owner is equal to $0.23 per square foot. Considering University of Washington as a large institute with three campuses and having over 20 million gross square footage, the annual cost of interoperability born by UW can be quantified as $4.6 million. Based on NIST research, 85% of this cost is occurring in operations and maintenance which equals to $3.9 million of annual interoperability cost.

2.3- BIM

National Building Information Model Standards (NBIMS) defines Building Information Modeling (BIM) as “a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder.” (NBIMS, 2008)

As mentioned before, based on the NIST study, about 15% of the interoperability cost is born by owners in capital facilities industry in design and construction phases. BIM is one of great technology tools for reducing this cost. Benefits of BIM in design stage is 1) Earlier and more accurate visualizations of a design, 2) Automatic low-level corrections when changes are made to design, 3) Generation of accurate and consistent 2D drawings at any stage of design, 4) Earlier collaboration of multiple design disciplines, 5) Easy verification of consistency to the design intent, 6) Extraction of cost estimates during design, 7) Improvement of energy efficiency and sustainability. (Eastman et al, 2008) The 3D visualization helps architects during design, and any change they make reflects to other parts of the project. Mechanical, electrical and plumping systems can be visualized, and by doing clash detection, model can be modified much easier in comparison with traditional approach.

During construction, contractors build the facility much easier with BIM, specially in complex buildings. Benefits of BIM for construction and fabrication are: 1) Using design model as basis for fabricated components, 2) Quick reaction to design changes, 3) Discovering design errors before construction, 4) Synchronization of design and construction planning, 5) Better implementation of lean techniques, 6) Synchronization of procurement with design and construction. (Eastmen et al, 2008)

During design and construction phases, BIM can contribute a lot to facility management. It can be seen in facilities, where the equipment is in an unsafe location, or there is lack of accessibility to do the work order on it. In traditional design practice, usually owner's O&M group are not involved. This is while in design stage with use of 3D visualization of BIM and including avatars, clearances to maintain critical equipment can be insured, and location of the equipment can be specified with collaboration of O&M group. (Foster, 2011) Figure 3, shows how using BIM and avatar can help design for maintenance. Picture on bottom left shows a maintenance friendly area while the picture on right shows a case where it is not maintenance friendly.

Figure 3 Design for Maintenance (Foster, 2010)

BIM also helps facility management in turn over phase. Tremendous amount of information generates during different phases of a project lifecycle. As seen in figure 4, by the end of each phases of planning, design, and construction there is drop of information value, meaning all the information is not transferring to the next phase. The highest information value drop is related to the change phase of construction to operation where the handovers are handed to facility managers for facility maintenance. BIM is a technology tool which can record the information through all the phases, and be used in the operation lifecycle.

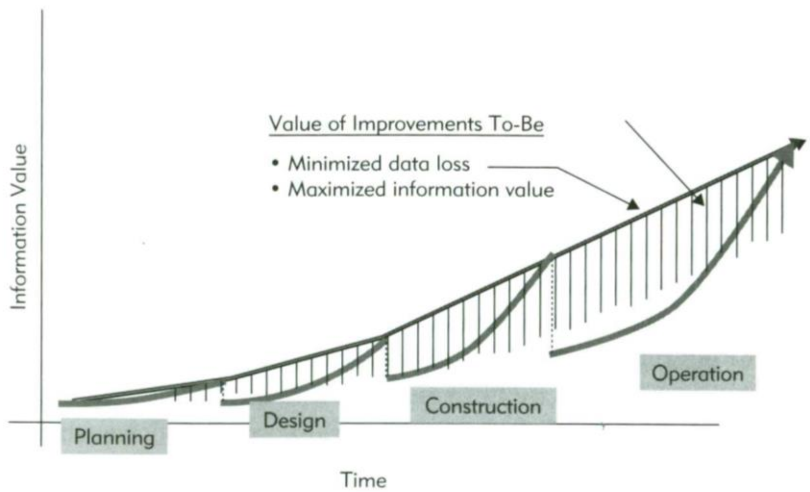


Figure 4 Information Value Drop during Building Life Cycle Phases (Smith & Tardif, 2009)

BIM can capture the information produced through different phases of the project lifecycle. With integration of BIM and Facility management process, owner can get the benefits of it in turn over and operations and maintenance phase, and reduce the interoperability cost. Figure 5, shows an asset attributes in BIM, and the delivery of BIM for FM in each phase of the lifecycle.

Teicholz lists the benefits of BIM for FM in his BIM for Facility Management book as:

- Improving workforce efficiency because of the availability of better information when it is needed rather than requiring FM staff to spend time looking up information on drawings, equipment documents, and other paper records
- Reducing cost of utilities because of improved maintenance data that support better preventive maintenance planning and procedures.

- Reduction in equipment failures that cause emergency repairs, and impact tenants.
- Improved inventory management of parts and suppliers and better track of asset and equipment histories.
- Longer equipment lives supported by more extensive use of preventive maintenance rather than corrective maintenance.

(Teicholz, 2013)

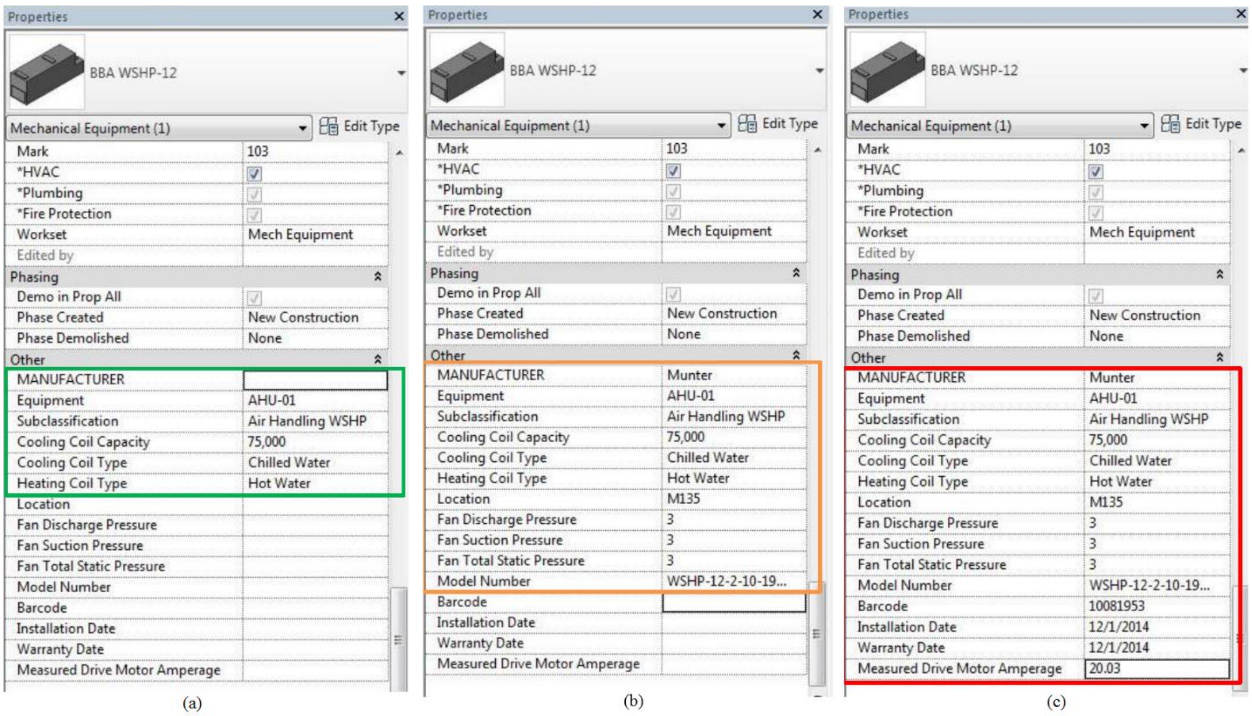


Figure 5, BIM for FM Delivery: a) Design phase, b) Construction phase, c) Turn Over (Source: Dubler, 2014)

There are several approaches for using BIM in facility management in operations and maintenance phase. One of the options is to use COBie, the open source standard supported by buildingSMART alliance. This approach does not require integration with BIM. COBie captures information without the graphical data. It can be imported to the CMMS system of the owner. (Teicholz, 2013) COBie will be discussed more in next section.

Another approach is to have links between BIM modeling system and FM support system to create two-way links between two systems. An integrated option will be to use CMMS system with a

BIM modeling system using the BIM application programming interface (API). This approach provides the integration of both systems where graphical data is in BIM, and FM data is entered into COBie and/or directly in CMMS system. (Teicholz, 2013)

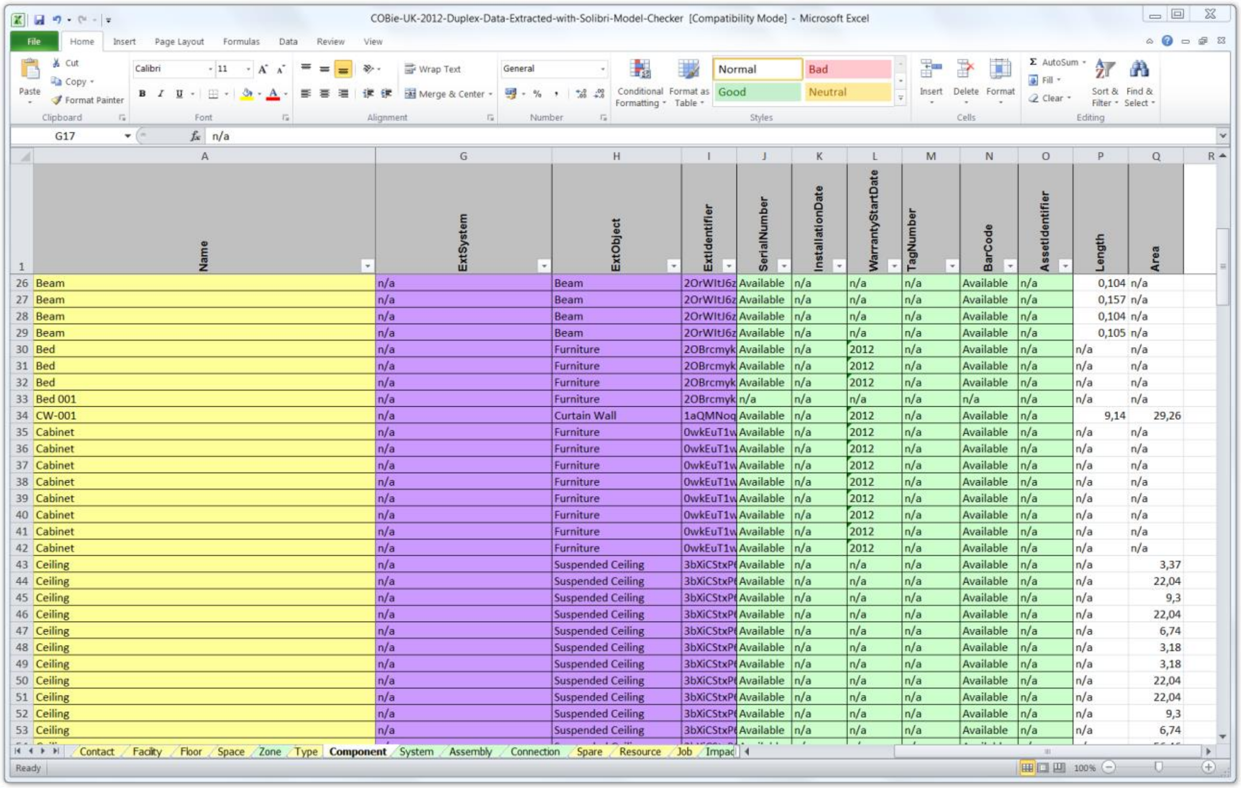
2.4- COBie

The Construction Operations Building information exchange (COBie) format is defiend as “the international standard for the exchange of information about managed facility assets. COBie does not add new requirements to contracts; it simply changes the format of existing deliverables from paper documents and proprietary formats, to an open, international standard format” (East et al. 2012)

COBie was developed by the US Army Corps of Engineers as a method of delivering O&Ms and project specific data in a standardized format. As mentioned before, information value drops when the project transfers to a new phase during its lifecycle. That’s why the best practice of COBie is when it starts from the pre-design stage, and collects all the information produced in different phases. COBie data is stored through the stages of 1) Early design, 2) Construction documents design, 3) Construction quality control, 4) Product installation, and 5) System commissioning. (East et al., 2012)

Most of current information exchange practices are paper-based. COBie eliminates the information exchange effort done on owner’s Facility Manager side after receiving the handovers by the contractor. It simply provides the project and asset information usually in a spreadsheet format. Figure 6, shows an example of a COBie spreadsheet which is coded by color based on requirements. COBie spreadsheet has multiple worksheets which needs to be filled in different stages of the project lifecycle.

In the early design stage, physical spaces are determined based on the owner’s special requirement. Information of “Facility”, “Site”, and “Project” worksheets can be entered into the COBie spreadsheet. Some physical information like room numbers in the physical space are known and as a result, “Floor”, “Space”, and “Zone” worksheets can be completed in early design stage. In construction documents design stage, the components and systems of the building has been determined and asset types are known. Worksheets of “Component”, and “System” can be partially filled out. Since there is no installation and equipment warranty information, some parts of these worksheets needs to be entered later. (East et al., 2012)



	Name	ExtSystem	ExtObject	ExtIdentifier	SerialNumber	InstallationDate	WarrantyStartDate	TagNumber	BarCode	AssetIdentifier	Length	Area
26	Beam	n/a	Beam	2OrWltJ6z	Available	n/a	n/a	n/a	Available	n/a	0,104	n/a
27	Beam	n/a	Beam	2OrWltJ6z	Available	n/a	n/a	n/a	Available	n/a	0,157	n/a
28	Beam	n/a	Beam	2OrWltJ6z	Available	n/a	n/a	n/a	Available	n/a	0,104	n/a
29	Beam	n/a	Beam	2OrWltJ6z	Available	n/a	n/a	n/a	Available	n/a	0,105	n/a
30	Bed	n/a	Furniture	2OBrcmyk	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
31	Bed	n/a	Furniture	2OBrcmyk	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
32	Bed	n/a	Furniture	2OBrcmyk	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
33	Bed 001	n/a	Furniture	2OBrcmyk	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
34	CW-001	n/a	Curtain Wall	1aQMNoq	Available	n/a	2012	n/a	Available	n/a	9,14	29,26
35	Cabinet	n/a	Furniture	OwkEuT1w	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
36	Cabinet	n/a	Furniture	OwkEuT1w	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
37	Cabinet	n/a	Furniture	OwkEuT1w	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
38	Cabinet	n/a	Furniture	OwkEuT1w	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
39	Cabinet	n/a	Furniture	OwkEuT1w	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
40	Cabinet	n/a	Furniture	OwkEuT1w	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
41	Cabinet	n/a	Furniture	OwkEuT1w	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
42	Cabinet	n/a	Furniture	OwkEuT1w	Available	n/a	2012	n/a	Available	n/a	n/a	n/a
43	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	3,37
44	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	22,04
45	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	9,3
46	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	22,04
47	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	6,74
48	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	3,18
49	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	3,18
50	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	22,04
51	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	22,04
52	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	9,3
53	Ceiling	n/a	Suspended Ceiling	3bXiCStxP	Available	n/a	n/a	n/a	Available	n/a	n/a	6,74

Figure 6 A COBie Spreadsheet Example (Source: solibri)

In contractor quality control stage, construction team need to provide the submittals consisting product manufacturer data sheets, shop drawings, and physical sample, and get the approval from the design team. In this stage, manufacturer and asset model is already known for the contractor and can be inserted into COBie file. After getting the approval, general contractor installs the assets in the building. In the product installation stage, information of warranty, installation date, and serial number are all available and are added to the COBie file.

In the last stage, the operational information is available and worksheets of “Job”, “Resources”, and “Spare” are filled. These work sheets include some instruction like the Preventive Maintenance and safety, required materials and training, and replacement parts. Other worksheets like “Attribute”, and “Connection” which has been filling out during different stages are completely done by reaching this stage. There is an option for adding information in worksheets of "Assembly", "Connection", and "Impact", which provides the components and their logical connection, and also the economic, environmental, and social impacts in different stages respectively. The information can help with the shutdown in maintenance.

Figure 7, shows the worksheets and the phases information needs to be collected and entered to the COBie spreadsheet.

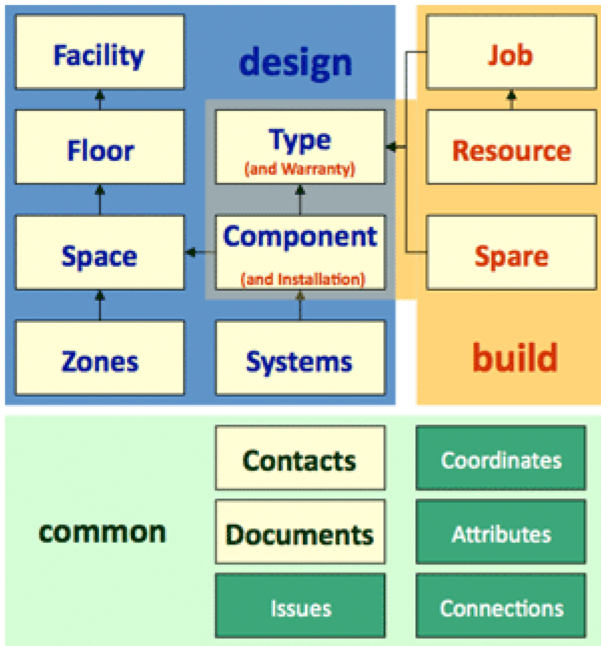


Figure 7 COBie Worksheets and their related phase (BuildingSMART alliance)

2.5- BIM for FM saving

Implementation of BIM in a project, and setting it with the O&M information is not free. Owners are interested in knowing if the initial cost in design and construction phase worth getting benefit of the BIM for FM during its operation and maintenance phase. Return in Investment (ROI) is one of the topics researchers are focused on. Based on the data provided by International Facility Management Association (IFMA) in 2009 about cost of operation and maintenance, Teicholz had estimated an ROI of 64% equals to payback period of 1.5 years. (Teicholz, 2013). Recently, a study by Construction Owners Association of America (COAA) Texas division estimates 2.5 times more ROI in turn over phase, and 10% more efficiency in O&M phase by using BIM for FM. (Parnel et al., 2014)

2.5.1- Penn State University

Penn State University is planning to reduce 45 minutes per each work order by implementation of BIM for FM. They had considered the annual work orders of 2009-2010, and by projecting 10% of the savings spent on research, inaccurate information, and interoperability problems, they came up with the $2.2 million annual savings. Table 1, shows the amount of PM and CM work orders, the average time for each, and how the projected money savings was calculated. (Kasprzak & Dubler, 2012)

Table 1 Cost Savings for Completed Work Orders at Penn State University (Kasprzak & Dubler, 2012)

FY 2009/2010 WCC Work Orders				Projected Savings	
Type	Amount	Time (hrs)	Average Wage	Time (min)*	Monetary
Preventative Maintenance	109,000	1.5	$50.00/hr	45	$817,500
Corrective and Emergency Maintenance	55,000	5	$50.00/hr	45	$1,375,000
Total	164,000	438,000	N/A	45	$2,200,000
*Projections are based on a 10% savings spent on research; inaccurate information, or other interoperability issues.					

For this purpose, Penn State University requires use of BIM in all new constructions, and any renovation project having value of more than $5 million. They also require other projects which the project manager categorize them as appropriate to have BIM with asset data required for O&M. Penn State had established the BIM Project Execution Planning Guide in 2009, and all the projects use the same guideline. (Kasprzak & Dubler, 2012) They involve in the project from the early stages, check the clearance space for the equipment, and set rules for the construction. With having BIM, they save $300,000 annually in turn over phase, and were able to increase 4% of the PM work orders. (Dubler, 2014)

2.5.2- University of New Mexico

University of New Mexico did a survey about the use of BIM for Facility Management in 2010. Survey has initial set of questions for understanding the facility characteristics of the participants. The next set of question were aiming to explore the current operations and maintenance practices, rating of current accessibility to O&M information, and accuracy of as-built drawings, and to assess the familiarity of operations personnel with BIM. Then participants were asked to watch a short video of "View of the Future for FM". The video shows an example work order for a suspected leaky pump in a mechanical room, and describes how BIM can help looking up for information of the pump. In this video, the work order is connected to the BIM model, and with the 3D visualization, personnel can select the pump, and get the manual. Manual contains icons related to O&M manual, parts list, access to asset management system, building control system, access to laser scan, panel schedule, and specs. (Forns-Samso, 2010)

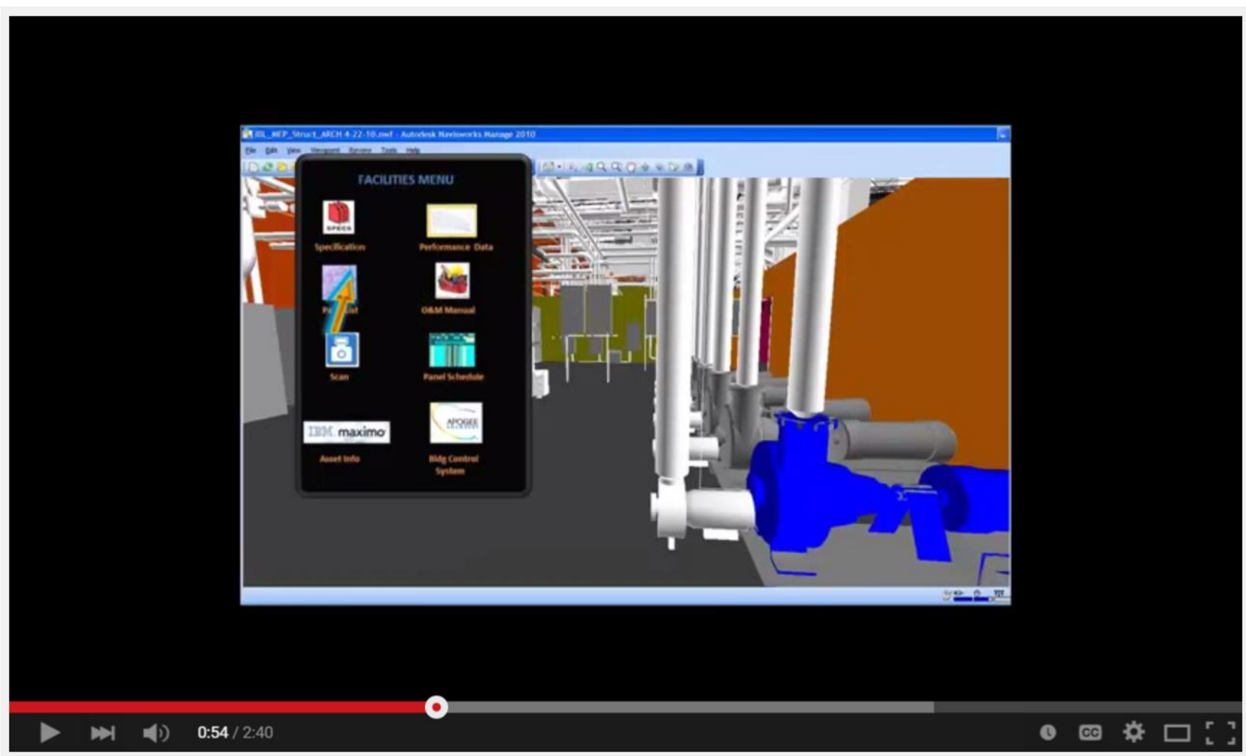


Figure 8 Video Caption of "View of the Future for FM" (https://www.youtube.com/watch?v=nHGhH9g4_gg)

Among the 125 participants of the survey, 99% of the responders were in the U.S. The majority of the respondents, about 63%, were working in facilities as campus with multiple buildings, with 30% representing educational buildings. The majority of the participants, 34%, were in facilities with size of over 5 million square foot, and 21% of them were in facilities having area between 1 to 5 million square foot. (Forns-Samso, 2010)

Some of the question of the survey were developed to address the interoperability problem. Majority of the respondents had average satisfaction with the access to O&M information; meaning most information is available but not in one place. Most of the participants also had average level of accuracy in as-built drawings; meaning most information is correct but incomplete. (Figure 9)

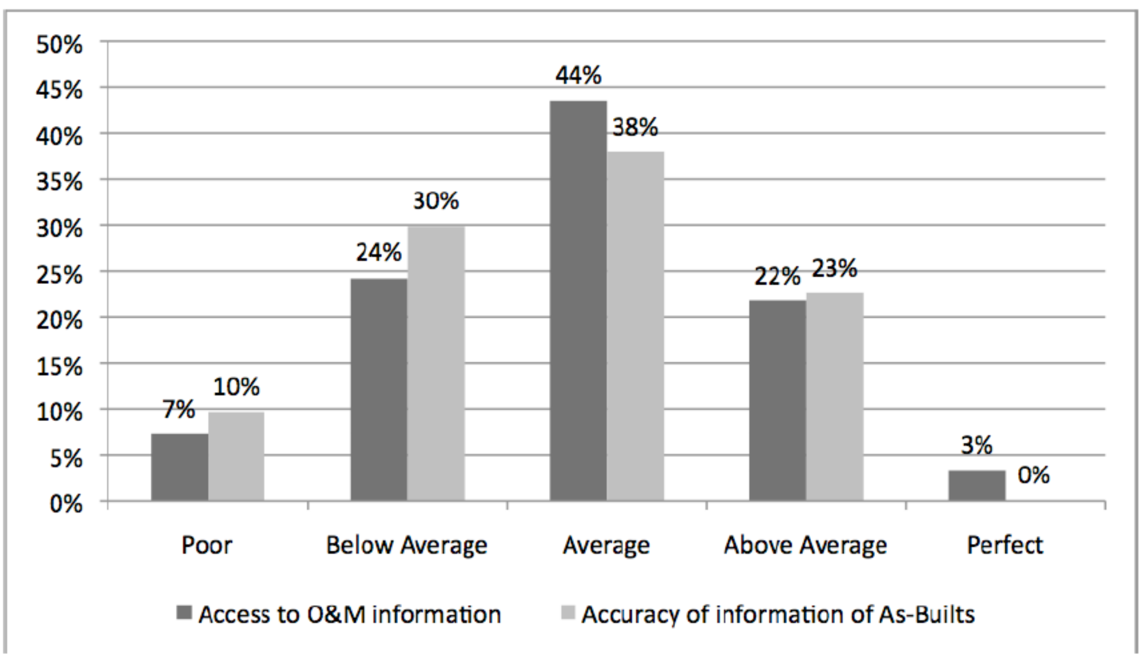


Figure 9 Respondents rating of accessibility to O&M information and accuracy of information of as-built drawings (Forns-Samso, 2010)

The main aim of the study was to assess the value of BIM for Facility Management. Survey had analyzed the level of the familiarity of the participants with BIM concept. As seen in figure 10, 38% were familiar with the concept, 36% were involved in BIM. The rest were either unfamiliar or having vaguely understanding of the concepts. (Forns-Samso, 2010)

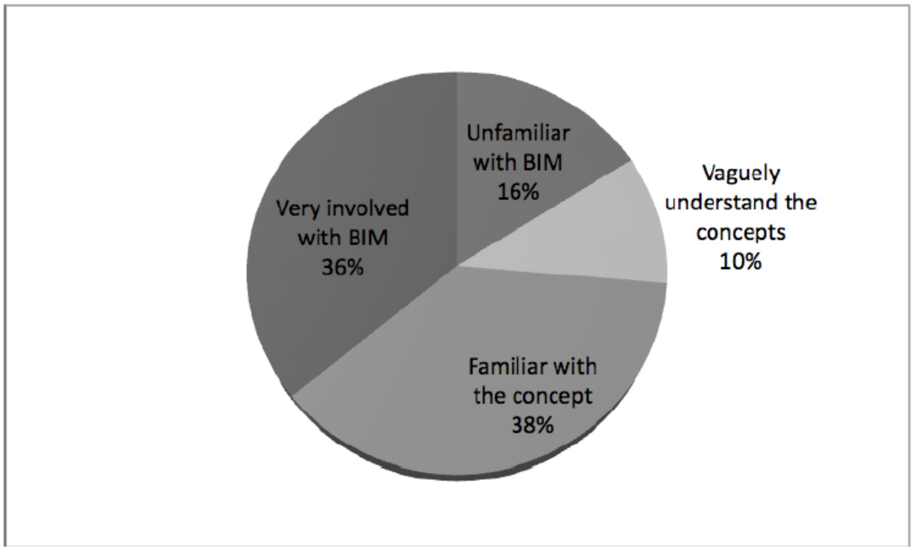


Figure 10 Respondents Understanding BIM Concept UNM (Forns-Samso, 2010)

After watching the video of "View of the Future for FM", participants were asked to estimate what percentage of time they could save on their work order process, if they could access O&M information using BIM. The majority of respondents didn't know the answer. Among the rest of the responses, 34% chose the range of 21% to 40%, and 32% chose the range of 11% to 20%, which means a considerable amount of time can be saved using BIM, and having access to the sources to do the work order.

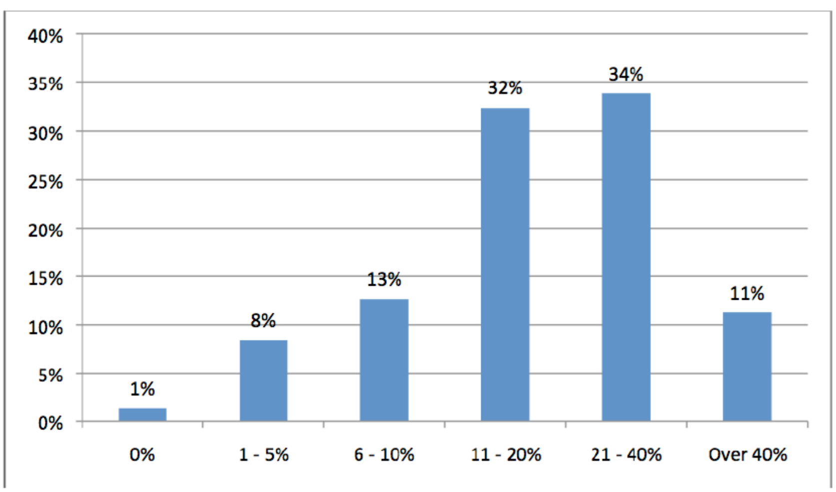


Figure 11 Percentage of Time Saving in work order process work flow (Forns-Samso, 2010)

2.5.3- Sandia National Laboratories

Sandia National Labs had developed an in-house survey called “straw man” for use of BIM for FM. They had used the video of “View the Future for FM” which was explained in previous section for estimating the amount of time they can save using BIM. Based on this survey, they could save up to 2 hours per work order. With performing 24,000 work orders per year and the average wage salary of $50 per hour, they could save up to $2.4 million per year. (Foster, 2010).

2.5.4- Texas A&M

Texas A&M Health Science Center has nine campus location in Texas. TAM HSC at Bryan was the first campus which used BIM/COBie for FM process in Texas Health Science Center. This project had three phases of construction as phase1, implementation of COBie as phase 2, and implementation of CMMS system populated with data for FM use as phase 3. Broaddus & Associates was hired by Texas A&M University System Facilities Planning & Construction as program manager, COBie integrator, and was responsible for implementing COBie for the TAM HSC facility turn over. (Teicholz, 2013)

Broaddus & Associates in collaboration of FUSS TAM HSC conducted a case study about the projected time saving of handling work orders using COBie dataset and BIM. For this purpose, interviews with FUSS staff was conducted and a typical work order process in a form of a flowchart was formulated. The flowcharts were sent to facility managers working on different campuses in the TAM HSC and recorded their responses regarding the time saving due to use of COBie and BIM. Responders were asked to mark the activities in the work order process impacted by using COBie and BIM. (Jawadekar, 2012)

Figure 12, shows the work order flowchart formulated based on the interview results, and the activities impacted by COBie and BIM highlighted in blue color. Finding O&M data, review of O&M data, finding warranty, visiting equipment, retrieving additional data in field, and returning to shop were the activities impacted by use of BIM and COBie.

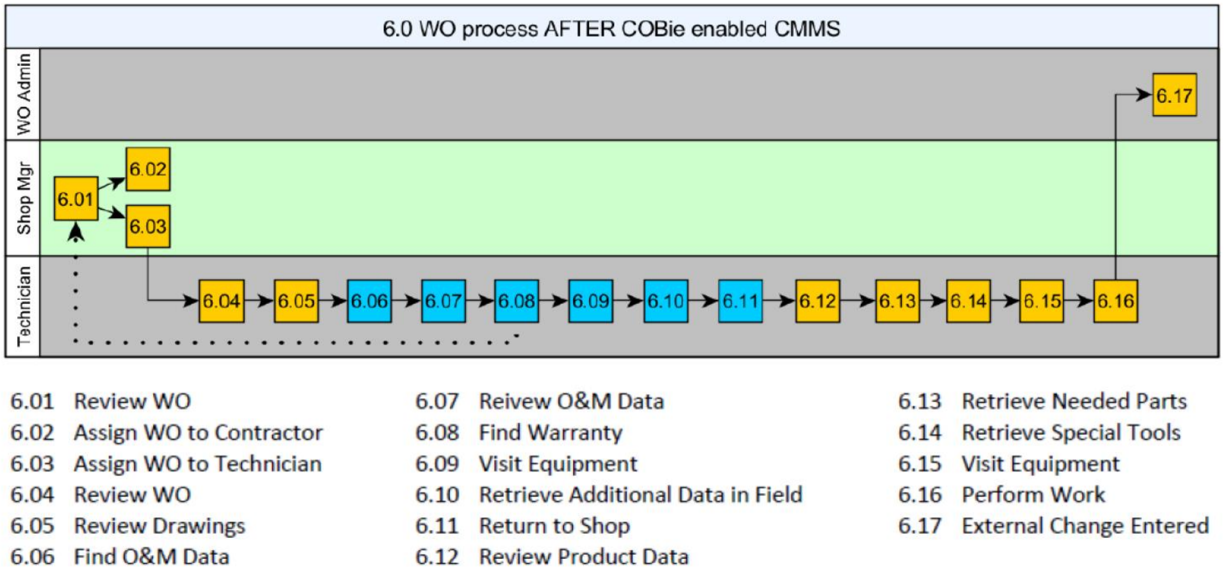


Figure 12 Work Order Process After COBie Enabled CMMS (Jawadekar, 2012)

Based on the result, on average, 8.7% of time was estimated to be saved per work order using COBie dataset and BIM. (Table 2)

Table 2 Time Spent on Work Order Process Before and After COBie Enabled CMMS (Griffith & Cervenka, 2011)

	Dallas	Bryan	McAllen	Average	Details:
Total Time per WO (Min)	115.5	129.3	146.3	130.3	Average time before COBie (from interviews)
Total Time per WO (Min)	109.0	117.1	130.1	118.8	Average time after COBie (from interviews)
Total Time per WO (Min)	6.5	12.1	16.1	11.6	Average savings per WO realized by COBie data (from interviews)
SAVING per WO (MH)	0.11	0.20	0.27	0.19	Average hour savings per WO realized by use of COBie data (from interview)
TIME SAVINGS (%)	5.6%	9.4%	11.0%	8.7%	WO time savings diveded by total time per WO
Technician Count	16.00	5.00	1.00	n/a	Amount of campus technicians available for WO's
Available Hours/YR	24000	7500	1500	n/a	Technician count multiplied by actual FTE (1,500 MH)
Expected WO's/YR	13210	3842	692	n/a	Available MH's divided by total time per WO
Expected MH Savings/YR	1429	775	186	n/a	Expected WO's/YR mulitplied by MH savings per WO

The final purpose of the FM departments on projects of three campuses of Bryan, San Antonio, and Round Rock is to upload preventive maintenance schedules in the computerized maintenance management system (CMMS) used, and integrate it with the COBie database. They applied the lessons they learnt from the Brayan case study to other projects. (Jawadekar, 2012) The Bryan project was used as the prototype for the methods to be used on future TAM HSC projects. (Teicholz, 2013)

Chapter 3: COBie at University of Washington

3.1- Introduction

University of Washington is one of the oldest Universities on the west coast founded in 1861. UW owns over 500 buildings with more than 20 million gross square footage of space. Based on the NIST study, the annual interoperability cost for UW can be quantified $4.6 million, where about $3.9 million would be related to maintenance and operations. This indicates how much facility management efficiency is important for University of Washington.

The Facility Services department (FS) is the UW's internal facility management department providing a wide range of services like maintenance and alterations, engineering services, and records management of facility documents. FS is a part of UW Finance & Facilities. The Capital Projects Office (CPO) is the UW's internal construction management department having a role as the owner's representative for coordinating the delivery of a facility between architects, engineers, contractors, and commissioning agents. CPO is a part of UW Planning and Management (PM), and work with process partners like FS to provide service to University clients. At the end of a new construction, CPO gives the O&M documents and plans to FS.

In 2011, Construction Owners Association of America (COAA) initiated a case study project with the aim of implementing COBie on construction projects of large institutions and measuring the achieved results. Being a large institution, CPO and FS jointly, decided to try the implementation of COBie at UW with collaboration of Dr. Dossick, the faculty member at Built Environment department. COBie project at UW has three pilots of 1) Dempsey Hall project, 2) COBie standard establishment, and 3) COBie implementation on ARCF project, and rebaselining of Foege Building.

3.2- Pilot I: Dempsey Hall

Dempsey Hall is a $41.8 million classroom and administration building with 65,000 gross square feet for the UW Foster School of Business. The dean's office, MBA and undergraduate offices, the Arthur W. Buerk Center for Entrepreneurship, MBA and undergraduate career centers as well as classrooms and an executive forum are located in this building. (foster.washington.edu)

Figure 13 Dempsey Hall at University of Washington, Seattle Campus (foster.washington.edu)

. The decision of COBie implementation on Dempsey Hall was made when the building was under construction. COBie implementation was paid to the general contractor of this project, Sellen Constructions Company, as a change order. Since the design documents and contracts were already completed, COBie was not implemented completely, and the research focus was mainly on examining COBie data sets for a limited number of specific building assemblies and processes. Submitted COBie spreadsheet by contracted was then imported into CMMS system of UW, AiM.

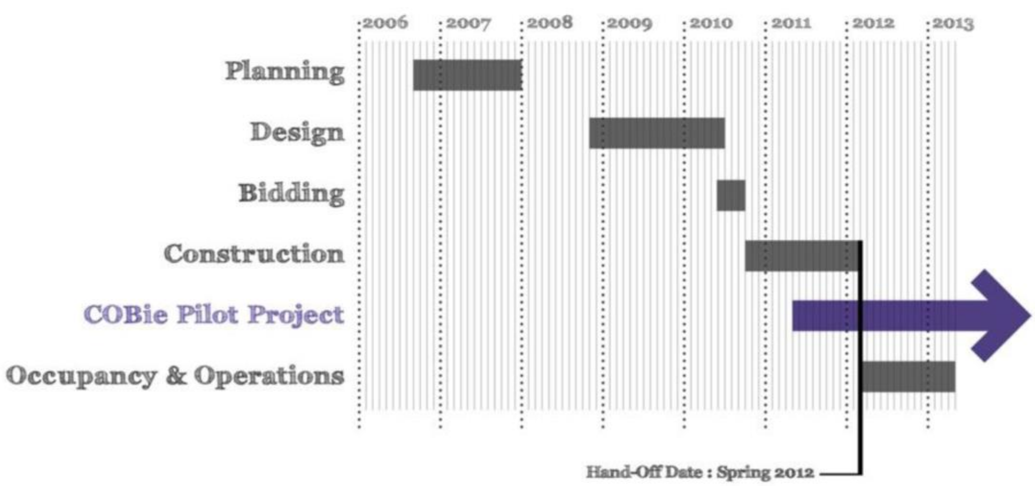


Figure 14 COBie Pilot I Schedule

3.2.1- Information Exchange Work Flow

A research on the obstacles of information exchange between CPO and FS was done during the COBie Pilot I. The research had focused on the work flow of the current process of information exchange, and how it is compared to the COBie work flow. Figure 37, shows the current information exchange workflow, and figure 38 shows the COBie work flow. In current information exchange process, the responsibility of O&M data collection is on FS side, and in COBie format the work is done on design and construction team side. COBie provides the asset data from the first day of operation, this is while the information exchange process, starts after FS receives the handovers from CPO. (Marsters, 2011)

There is a time lag between the end of construction and receiving handovers by FS due to the administration processes. When handovers were in paper-based format, this time lag was about 1 to 2 years. Recently, handovers proided my designers and contractors are in digital format, and the time lag takes about a few months. The time lag of the Cedar Apartments project in 2011, was 130 days. FS do not have information of the new construction within this time lag. (Marsters, 2011)

3.2.2- Analysis of Time Being Spent on Information Exchange

The COBie data sets for Dempsey Hall were selected based on the interviews with key UW staff involved in the construction of Dempsey Hall, and staff members in CPO and FS. The list was containing the main Mechanical, Electrical, and Plumping (MEP) equipment which had 8 categories, 33 asset groups, and total of 1111 assets in the COBie spreadsheet. Table 3 shows the asset categories, and asset types prepared for Dempsey Hall. (Aghazarian, 2012)

A research was done about the comparative analysis of construction operation information exchange via paper-based systems and COBie Format for Dempsey Hall. In this case study, the time spent for retrieving data and entering it into AiM both manually, and using COBie was investigated. (Aghazarian, 2012)

Table 3 Asset Groups in Dempsey Hall (Aghazarian, 2012)

Category	Asset Group	Category	Asset Group
Mechanical Equipment	A/C, Server Room, Air Cooled	Pipe Accessories	Ball Valve
	Fire Dampers		Butterfly Valve
	Fire Extinguisher		Globe Valve
	VAV Box	Doors	Interior Doors
	Exhaust Fan		Fire Doors
	Convector		Elevator Doors
	Air Handling Unit		Exterior Doors
	Gravity Intake	Lighting Fixtures	Emergency Lights
	Roof Vent	Furniture	Toilet Partitions
	Unit Heater, Steam		
Electrical Equipment	Transformer	Plumbing Fixtures	Drinking Fountains/Coolers
	Panel Board		Drains (Wastes)
	Switch, Interrupt, High Voltage, Fused Air		Service Sinks
	Variable Frequency Drive		Sinks/Lavatories
Fire Alarm Devices	Smoke Detectors		Water Closets
	Fire Alarm System		Urinals
	Fire Extinguisher		Siphonic Drains

It was the first time the general contractor, implemented COBie on a project. Total of 387 hours spent on COBie process was reported by Sellen Construction Company, and about 60% of the total amount of time was spent on learning curve. Asset types' geometry and properties are represented in Revit model in the form of family. Most parameters of the assets are pre-defined in Revit, but in Dempsey Hall project some of them did not exist in the software by default, and general contractor needed to create those families in Revit. From the 387 hours of COBie implementation by general contractor, 140 hours was spent on creating Revit families, and setting the Revit model. Parameter value entry had taken them 110 hours. They had spent 53 hours on meetings, and 20 hours on site-visits for data validation. (Aghazarian, 2012)

For calculating the time spent in paper-based method, two different cases were assumed. First case was when the data is collected asset by asset, and then entered to AiM manually. The other case was to collect the data of asset related to the same asset group in a spreadsheet first, then insert the spread sheet into AiM, and manually change the attributes, like room number, and serial number. The results were compared to the hours spent for COBie process by the general contractor. (Aghazarian, 2012)

Estimated amount of time being spent on retrieving data from different sources like O&M manuals and site visits was determined based on the interview results. Table 4 shows the sources of O&M manuals, as-built drawing, and site visit used for retrieval of asset data in paper-based format. Minimum of 15 minutes for the ideal case, and maximum of an hour for non-ideal case was considered. (Aghazarian, 2012)

Table 4 Retrieval of Asset Data in Paper-Based process (Aghazarian, 2012)

Attributes	Site Visit	O&M Manual	As-Builts
Asset Description	✓	✓	
Asset Type	✓	✓	
Asset Group	✓	✓	
AIM Status	✓	✓	
AiM Region	✓	If Recorded	✓
AiM Facility	✓	If Recorded	✓
Room: FACROOM	✓	If Recorded	✓
Manufacturer	✓	✓	
Model	✓	✓	
Serial Number	✓	✓	
Install Date		If Recorded	
Serves	(only if the asset is serving the room in which it is installed)		
Belts		If Recorded	
Type		If Recorded	
Size		If Recorded	
OmniClass Number		If Recorded	
OmniClass Title		If Recorded	
Supplier		If Recorded	
Supplier Address		If Recorded	
Supplier Phone #		If Recorded	

(Method of Retrival: Site Visit, O&M Manual, As-Builts)

The researcher has tried to learn how to use AiM, and then calculated the approximate time being spent on entering the data into AiM system. It had taken the researcher about an hour for entering 5 assets into AiM which is equal to approximately 12 minutes per asset. In second case which is called the efficient method of data entry, the time being spent for manually changing the attributes of each asset was estimated as one minute. (Aghazarian, 2012)

Interview results revealed that shop leads do not collect all the asset data, and in reality they will attend to collect 17 asset groups out of 33 provided by COBie in Demsey Hall. As a result, only 62% of the asset data will be actually gathered in paper-based method. The result of time analysis was adjusted to learning curve, and was calculated for all the asset, and for 62% of assets approved by shop leads. Figure 15 graphically shows the calculated estimation of time needed for retrieving and entering data into AiM in paper-based format and COBie method.

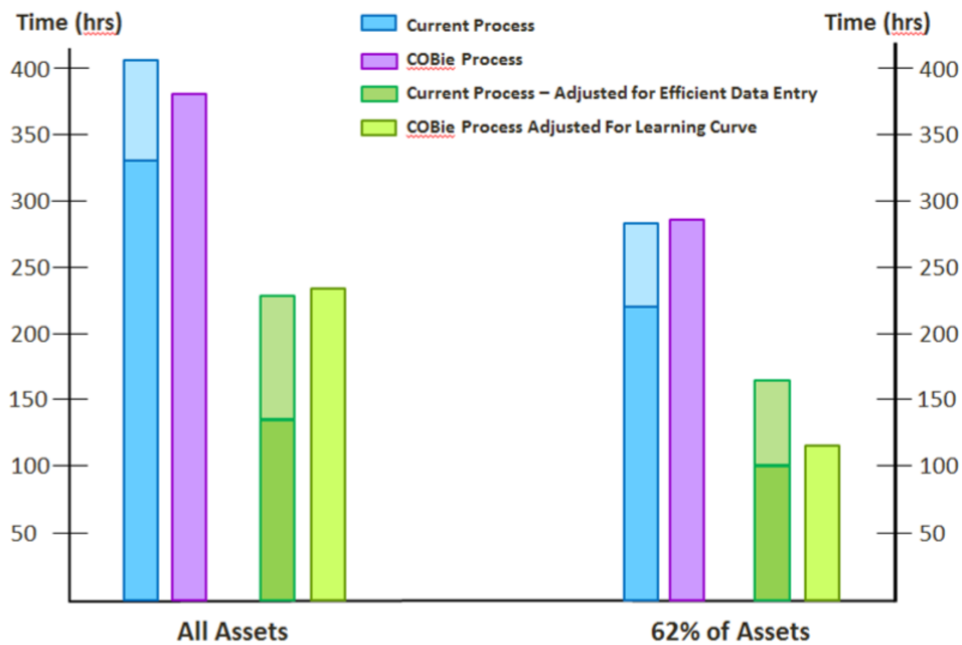


Figure 15 Comparitive Diagrams of Time Spent in Current and COBie method (Aghazarian, 2012)

Research results for Dempsey Hall case study showed that the differences between two methods were not considerably high, but gathering all those data manually usually takes one to two years after the building is occupied. This is while the COBie method provides the data from the first day of occupation. Additionally, errors occur in paper-based method since the collected information is written by hand, and there might be error in data retrieval and misread of the data by the person entering data into AiM. Figure 16 shows the comparison of current, and COBie method during facility life.

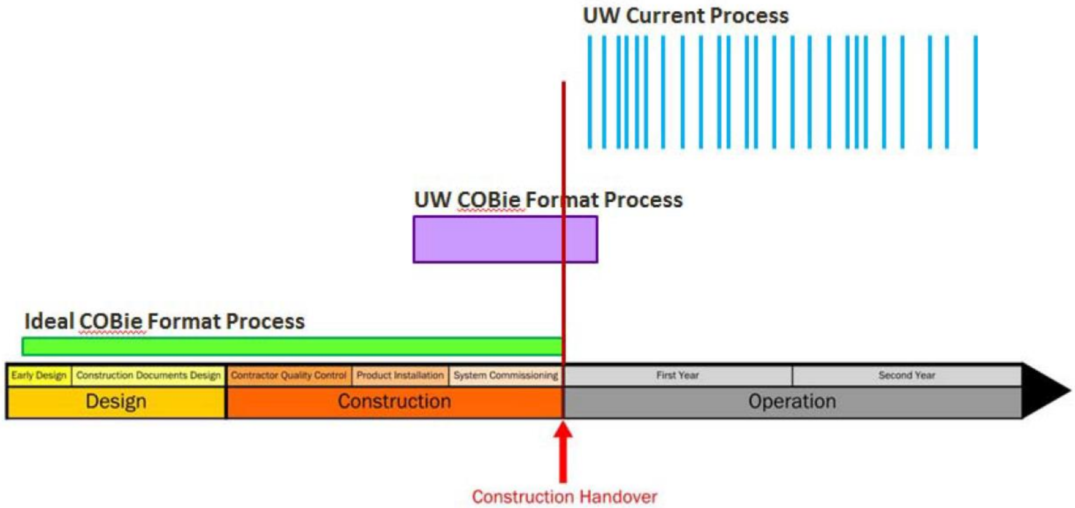


Figure 16 Time Span of Construction Handover Process (Aghazarian, 2012)

3.3- Pilot II: COBie Standards

COBie was not implemented completely on Dempsey Hall due to the phase the decision of implementation was made, and assets in Dempsey Hall project were selected based on the interviews with FS employee since there was no COBie standard. UW decided to stablish its own COBie standard with getting consulting from Broaddus & Associations.

With the collaboration of the FS staff, UW COBie standrads was stablished addressing the owner's requirements and needs. Total of 193 asset groups with type of attributes and information was specified.

3.4- Pilot III: ARCF and Foege Building Projects

UW Magnuson Health Science Building is the world's largest single university building with 5.74 million gross square footage. COBie Pilot III started in 2014 with two projects of implementing COBie on a new construction, and rebaselining of an existing building. The aim is to prepare COBie and BIM process guideline for UW to develop 3D model and make COBie data for critical buildings in the health science zone area. COBie implementation on Animal Research and Care Facility (ARCF), and rebaselining of Foege Building built in 2010 are the COBie Pilot III projects.

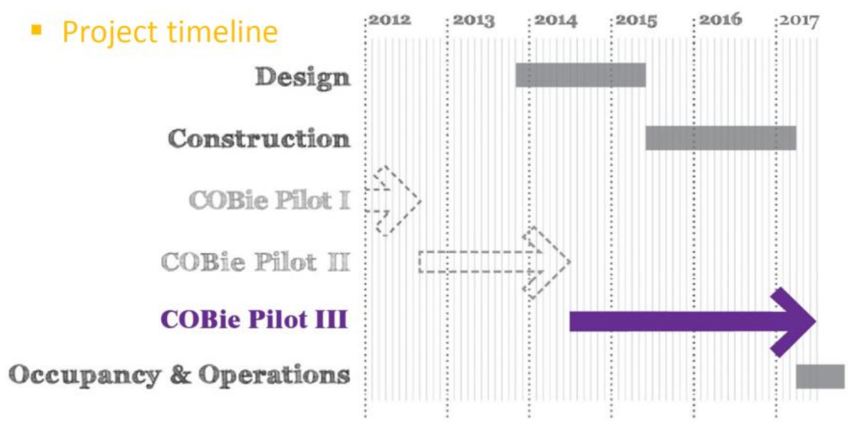


Figure 17 COBie Pilot II and III Schedule

3.4.1- William Foege Building Rebaselining

Foege Building is a $150 million building with 265,000square foot gross area which includes offices, research laboratories, and support facilities for department of bioengineering. COBie research team under the supervision of Dr. Carrie Dossick, is making the BIM model for this building, and aiming to extract COBie from the model. This is the first time a building is being rebaselined at UW.

As an existing building, BIM model does not need to have a high level of detail, since it will not be used for construction. In this stage, COBie team is working on stablishing a standard for level of details for each of the asset components in UW COBie standard.

Figure 18 Foege Hall at University of Washington, Seattle Campus

3.4.2- ARCF Project

University of Washington has a need for a new animal research building to continue its medical research. The new building will allow the University to increase the size of its research program and allow more investigators to pursue new scientific and medical advances which benefit both human and animal populations. Animal Research and Care Facility (ARCF) is an underground vivarium research facility with budget of $125 million. ZGF is representing the design team, SKANSKA is the general contractor, and Broaddus & Associations has the Facility Data Integrator (FDI) role in the project.

ARCF is the first project COBie will be implemented completely starting from design phase. Project has the Design-Build method of delivery, and it is in construction phase now. This building has a complex mechanical, electrical and plumping (MEP) system. Since this building will be a habitat for animals, facility management is very crucial. For this purpose, the Facility Services department need to have the asset data, and O&M information from the first day of occupation. For this purpose, CPO has decided to have the COBie specification in the ARCF contract. The decision for implementation of COBie on ARCF was made after the bidding process. As a result the cost of COBie will be charged as a change order by both design and construction teams.

Figure 19 ARCF Underground Project at University of Washington, Seattle Campus (Courtesy of ZGF)

Broaddus & Associations is responsible for overviewing the BIM execution plan for FM, determining the asset matrix, helping both design and construction teams through COBie process, and checking the accuracy of the COBie spreadsheet. Since there are some new types of equipment in this building which are not included in UW COBie standrads, additional project specific asset groups need to be defined. Design team was collaborating with the Broaddus & Associations for identifying the new asset groups. FDI is in the process of aggregating the asset type matrix to pass it to Skanska for construction phase.

Chapter 4: Methodology and Data collection

4.1- COBie Pilot III

COBie research team started working on pilot III in 2014. Pilot III is focusing on two aspects; implementation of COBie on new construction in ARCF project, and rebaselining of Foege Building built in 2010. Details of this pilot is provided in chapter 3. Two graduate student interns were hired by Facility & Finance department for "F2 COBie" project to work on pilot III. Jeffrey Angeley, the Senior Project Manager at CPO, and Cesar Escobar, the GIS/GPS specialist at CEO hosted the interns. Dr. Carrie Dossick, the faculty member of Construction Management department at UW is supervising the interns in COBie project. The researcher, Bita Astaneh Asl, is working in ARCF project as COBie Specialist, and Lokesh Masania is the BIM Specialist working on Foege Building rebaselining. Pilot III aims to identify the challenges of COBie implementation both on new construction and rebaselining, and provide a guideline for future projects to support facility management at UW. Once COBie is turned over to FS and imported into AiM system, the benefits of COBie in operations and maintenance can also be studied.

4.2- Research Question

The COBie specification was not included in the project specification upon bidding. As a result, design and construction teams were asked by CPO to implement COBie on the project as a change order. Due to the few projects COBie in implemented on in United States, industry is not very familiar with COBie. Multiple meetings about COBie was held with design and construction teams before they accept the change order. COBie team was involved in the COBie meetings with ZGF, Skanska, Broaddus & Associates, CPO, and FS. One of the questions which was asked a lot was: "Why does ARCF project need COBie?"

As discussed in the literature review, several studies was done on the value of BIM and COBie for Facility Management. University of Washington had investigated the value of COBie in turn over phase, but there was still a need to study the value of COBie in operations and maintenance phase. While addressing the question of the COBie need for ARCF, the research team came up with the research question of:

"How can COBie help facility management at University of Washington?"

With combination of the value of COBie in turn over phase based on the previous studies, and its value in operations and maintenance phase, the value proposition of COBie at UW could be determined. Furthermore, since the aim is to continue implementing COBie on other buildings at UW, there is a need to identify the priority of the buildings which need COBie to be implemented on. The research could provide information to understand: "When is COBie needed?".

4.3- Methodology

COBie studies had started in 2011 in United States, and there are a few projects which COBie is implemented on. Each owner has its own unique turn over and operation and maintenance process which differs from others. Due to the insufficient number of previous COBie studies, and the unique process each owner has, the case study is one of the best methodologies to be followed.

Previous studies in other institutes has mostly focused on the value of BIM or BIM and COBie together for FM, in which visualization and geometric component of BIM, and the easiness of access to O&M documents and plans are also considered. This is while, UW had concentrated solely on the value of COBie for FM, since BIM model has not been used for facility maintenance at UW. This study follows the case study method for determining the value proposition of COBie at UW.

4.4- Data collection and Analysis

For understanding how COBie can help the facility maintenance, interview was the best approach for data collection. All the interviews were planned to be face to face and since the research was related to human subjects, research proposal was sent to International Review Board (IRB) for approval. University of Washington Human Subjects Division (HSD) had determined that the research qualifies for exempt status in accordance with the federal regulation under 45 CFR 46.101/ 21 CFR 56.104, and researcher got her certificate in Human Subjects division training to be qualified to participate as interviewer. Research process was divided into three steps, and in each of the steps multiple interviews were conducted. Based on the interview analysis, interview tools were prepared and interviewees were selected. In the next section each of the stages are discussed.

4.4.1- Stage 1

Facility Services consists of 7 different departments of Building Services (BSD), Campus Engineering and Operations (CEO), Emergency Management (EM), Facility Maintenance and Construction (FMC), Facilities Employee Services (FES), Finance and Business Services (FABS), Strategic Planning and Continuous Improvement (SPCI), and Transportation Services (TS). Research started with identifying the departments at FS which are directly impacted by COBie data, and could get the benefit of it for facility management. For this purpose, research team started having some informal interviews with FS employees to understand which departments are working mainly with AiM system and using the asset data to perform maintenance work orders. Based on the interview result, two departments of Campus Engineering and Operations (CEO), and Facility Maintenance and Operations (FMC) are using the asset data for facility management.

4.4.2- Stage 2

After identifying the key departments, research team decided to conduct interviews to understand the work flow of the facility maintenance work orders done by both departments. For this purpose, the interview tool was prepared as seen in Appendix A. Three CEO engineers, two shop leads, and two managers of FMC were interviewed in this stage. The result of the interviews were analyzed, work flow was mapped, and the parts which could impacted by COBie was identified. Chapter 5 provides the facility maintenance work flow in details.

While the focus was mostly on understanding the facility maintenance work flow, interviewees were also asked to talk about the challenges they are facing performing their job. Based on the analysis of the interview results regarding the challenges FS employee are facing in stage 2, research team decided to focus more on shops, their challenges of performing the work orders, and understanding how COBie can help them, in stage 3.

By the end of stage 2, research team had two meetings with the UW IT team who are working on the business case for a library of facility-related asset information. UW IT and COBie team had some goals in common which was a great motivation for sharing the research results by both teams, and UW IT team supported the plan of stage 3 of the research study.

4.4.3- Stage 3

Facility Maintenance and Construction is divided into four geographic zones of Northeast, Southwest, Central, and Health Science. FS also have a Campus Grounds division, and their manager participated in interview in stage 2. Facility Maintenance work orders are handled by shops, and each zone has its own shops. Each shop has a lead, and a team of technicians. A group of shops are managed by a supervisor, and the zone manager leads the supervisors and all the shops in the zone. There are different types of shops of machinery mechanical, sheet metal trades, electrical, plumping, refrigeration, and carpentry at FMC. Elevator, high voltage, HVAC, and signal shops, and utility shutdown sections are at CEO department.

An interview tool was prepared for the stage 3 as seen in Appendix A. Interview tool had multiple purposes of identifying the main sources available for shops, the challenges of using them, challenges of performing the work orders, and how COBie can help them in this process. Among the 21 shop leads in FMC department, interviews with 10 shop leads were conducted. Three CEO engineers, two FMC managers, and one supervisor were also interviewed in this stage. In this series of interviews three zones out of four zones were covered, and interviewees were from trade shop disciplines of machinery mechanical & sheet metal trades, electrical, plumping, refrigeration, and carpentry. Table 5, shows the list of interviewees. Chapter 6 provides the challenges shops are facing doing the facility maintenance.

Based on the results of stage 2, and stage 3 parts of the work flow impacted by COBie, and the key activities done in current process which can be removed with COBie process were determined. This led to having an approximation of the time being saved in COBie format. The criteria for prioritizing new and existing buildings were specified based on the interview results. The value of COBie in operations and maintenance phase is written in chapter 7.

By having the value of COBie in turn over phase from previous studies, and results of this study about value of COBie in maintenance and operations, value proposition of is concluded in chapter

8. The current challenges are discussed, and some suggestions are provided. This study has opened up some future studies which is discussed in the same chapter.

Table 5 Interviewee Profile

Interviewees	
Shop Leads	10
Supervisoe	1
FMC Manager	2
CEO Engineers	3
Total	16

Chapter 5: Facility Maintenance Work Flow

5.1- Facility Services Departments

Facility Services at University of Washington have the mission of learning, adapting, and innovating to preserve physical assets and deliver best services. Their vision is to be a world-class organization to provide exceptional service anywhere and anytime. In order to provide good service they are divided into seven different departments:

1. **Building Services:** Building Services delivers custodial services to the UW campus for providing clean and sanitary environments for students, faculty, staff, and visitors and manages the recycling and solid waste management program.

2. **Campus Engineering & Operations (CEO):** Campus Engineering provides professional engineering support for the design, construction, operation and maintenance of all University facilities. Campus Operations maintains and operates critical building systems, and utility shutdown coordination program. It also provides emergency maintenance response service to the Seattle campus community.

3. **Emergency Management (EM)**: UW Emergency Management is responsible for developing and implementing institution-wide programs and projects that promote disaster planning, training, mitigation, response, prevention and recovery for all-hazards.

4. **Facilities Maintenance & Construction (FMC):** Facilities Maintenance and Facilities Construction are responsible for general maintenance, repair, alterations, and renovations of all campus facilities including building interiors, exteriors, and grounds.

5. **Facilities Employee Services (FES)**: Facilities Employee Services is comprised of four strategic business units focused on providing expertise and service to the largest organization on upper campus. Human Resources, payroll, employee safety, and training academy is some of the services they provide.

6. **Finance and Business Services (FABS):** FABS consists of FS Finance which manages and oversees financial resources and provides business expertise to enable Facilities Services to achieve its mission and goals; Moving & Surplus, Stores, and FS Technology Services, which administers information systems in support of Facilities Services' mission.

7. **Strategic Planning and Continuous Improvement (SPCI):** SPCI includes the Office of the Chief of Staff, provides leadership and support to the AVP and all FS Departments regarding strategic planning, communications and marketing, performance measurement and operational excellence. The SPCI team functions as a center for information gathering, education, analysis and reporting for balanced scorecard, and serves to model how making improving the work, is the work.

8. **Transportation Services (TS):** Transportation Services provides innovative and sustainable transportation solutions that facilitate the educational, research, cultural and service missions of the University. TS supports the UW campus with the following: Parking, Transit, Bicycling, Walking, Rideshare, Fleet Services, UW Shuttles, and Transportation Planning & Construction. (www.washington.edu/facilities/)

Based on the different FS department responsibilities and informal interview results, two departments of Facilities Maintenance & Construction (FMC), and Campus Engineering & Operations (CEO) are directly getting benefit from the COBie data for performing facility maintenance. FMC department is responsible for performing the maintenance work orders, and CEO is providing operation and maintenance services assistant to FMC for doing work orders.

5.2- Work orders

All the work orders are managed in CMMS system of UW, AiM. There are 10 different categories of work orders defined in the system. Here is the categories with their definition in AiM:

1. **Assist:** Shutdowns and capital construction assists
2. **Call out:** On call work performed on non-working hours as an exception to regular shift schedule

3. **Corrective:** Work performed in response to a request for maintenance services
4. **Event:** Work associated with an event
5. **Planned:** Scheduled work
6. **Predictive:** Predictive maintenance work performed to predict future problems and target replacement prior to component failure
7. **Preventive Mandatory:** Mandatory preventive maintenance work orders (Inspect and ensure equipment that must be functional for the operation of campus. Shutdown notification required)
8. **Preventive operation:** Operational preventive maintenance work orders (Inspect and ensure equipment required for routine campus operations)
9. **Preventive regulatory:** Regulatory preventive maintenance work orders (Compliance is mandated by a regulatory agency)
10. **Preventive:** Preventive maintenance work orders (All other PM works)

Preventive, preventive mandatory, preventive operation, and preventive regulatory are categorize as PMs, and others are generally categorized as CMs. Each of the work orders are given priority based on their urgency. They are 8 different priorities defined in AiM system for work orders. Priorities start with level of 100 and goes to 800. Lower levels shows the higher urgency. Those priorities with regard to limit of response and correction time are defined in AiM as below:

1. **100 Emergency**: Immediate response threat to life, health, facility or utility. Respond immediately: correct same day
2. **200 Urgent**: Respond within one work day: correct (complete) within two work days unless ordering of materials is required
3. **300 high**: Respond within (1-3 working days); correct within (3-7 working days) unless ordering of materials is required
4. **400 Routine**: Respond within (4-7 working days); correct within (25 working days) unless ordering of materials is required
5. **500 Scheduled**: Response time not applicable, used for project work that is larger in scope and budget and will be scheduled long term
6. **525 Scheduled-BBM**: Response time not applicable, work order will be associated with quarterly building based maintenance schedule

7. **600 Recurring**: Response time not applicable, used for recurring work orders that are ongoing or for inquiries
8. **800 Preventive**: Response time applicable, used for preventive, preventive mandatory, preventive regulatory, preventive operational maintenance work that is planned and completed within 20 working days

5.2.1- Preventive Maintenance Work Order

They are two different types of PM work orders; building based, and asset based. While building based PM is related to maintaining a system of a building; like fire alarm, asset based is related to an asset or equipment itself; like a fan. PMs are done regularly on systems and equipment to keep them running efficiently and prevent unexpected failures.

PM work order needs to be generated in AiM system. Building based work orders are tied up to the property, and asset based work orders are tied up to the asset in AiM. PM work orders can be scheduled for future, and AiM produces automatic PMs based on the schedule and sends it to shops. Here are the steps of PM work order generation:

Shop leads need to gather asset data for asset profile creation in AiM. For this purpose they may have site visit, look in O&M manuals, and review as-built drawing plans. The available sources for shops for data collection will be discussed in next chapter. If the PM is asset based, a serialized asset profile needs to be created in AiM. Then the asset group is chosen based on the type of new asset. Asset data is entered as attributes to the asset profile. Then the information is sent for approval. Previously the PM Manager was doing the asset approval in AiM, But since this position was vacant for several years, FS Technology Services is doing this process now. Recently FS had hired PM management team, and with the change in management system, it is expected that the previous approval process will be followed again.

The status of the asset changes from “Approval” to “Installed” after the administration process, and new asset data profile is created in AiM system (Figure 39). An asset number is given to the new asset in AiM. Figure 20 shows an interior door asset in AiM. The asset profile in AiM shows the asset number (207275), asset group (UW1000005; interior door), manufacturing information, and any preventive maintenance work order defined for it. All the additional attributes can be seen in the attribute tab of the view. If the PM is building based, then the PM work order should be tied to the property profile in AiM. Each property has a number called FACNUM. In figure 20 the FACNUM for Dempsey Hall is 5981.

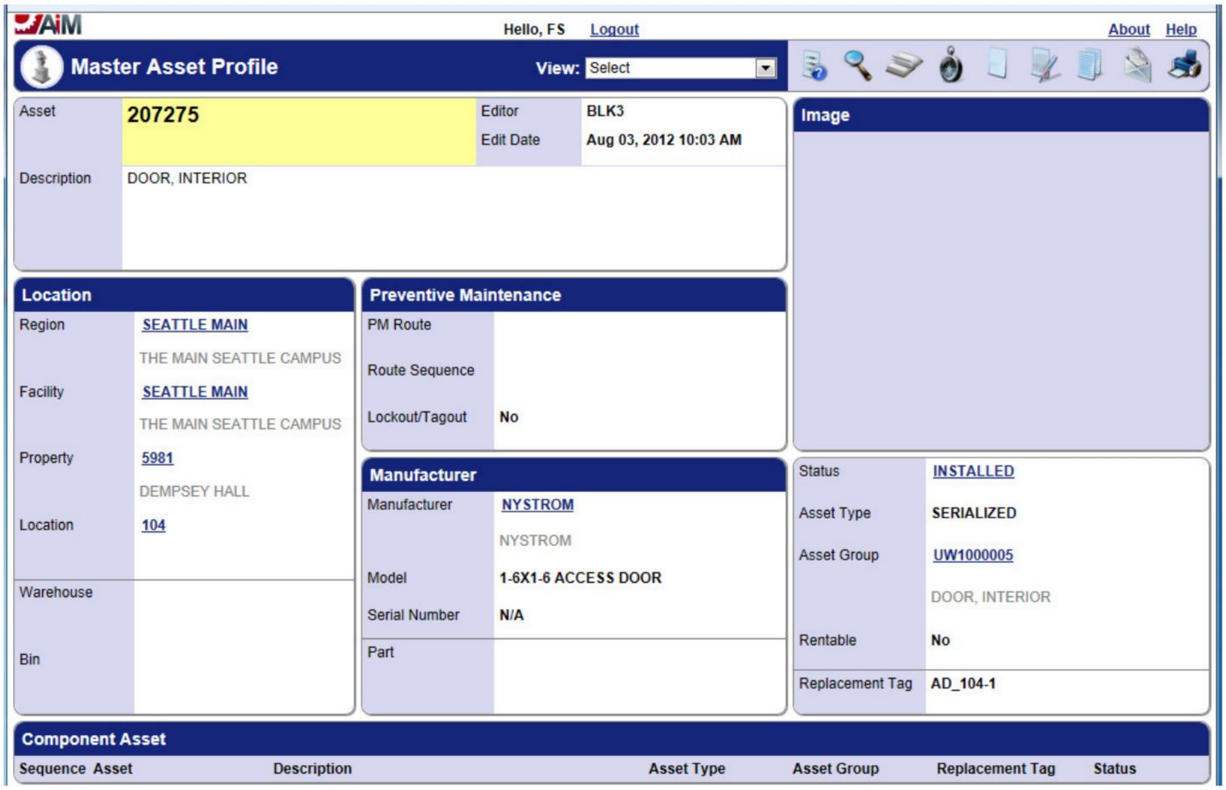


Figure 20 An Installed Asset Profile in AiM System (Source: UW FS Technology Toolbx)

PM Manager is responsible for creating PM work order, but since this position was vacant for a while, shop leads are responsible for creating it. For creating the PM work order, shop leads need to specify the type of the PM work order; asset based (Scheduled) or building based (BBPM Scheduled). Then the description of the PM activity needs to be written. This description is mostly written based on their experience and what is written in the O&M manuals. Then they specify the assigned crew, frequency of work order, and the start date (Figure 40). Figure 21 shows an asset profile with a PM scheduled for it in AiM.

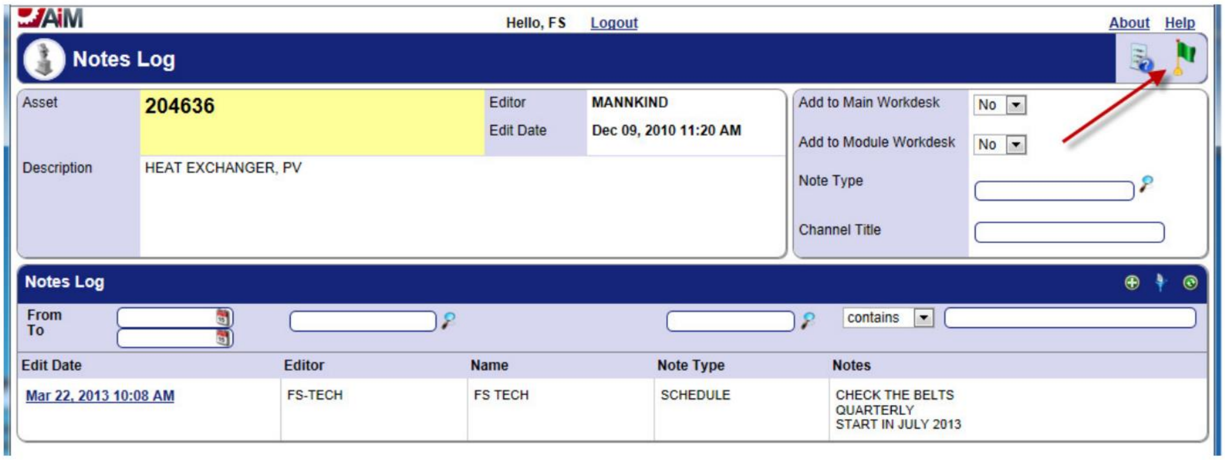


Figure 21 Scheduling a PM Work Order in AiM for an Asset (Source: UW FS Technology Toolbx)

Sometimes for doing the work order shutdown is needed. It usually happens for building based PMs. For doing the shutdown, multiple shops may need to be involved in the process. Campus Engineering is also involved in shutdowns. As a result, a new phase of the work order needs to be created for other shops who involve in the process. Each shop lead or CEO engineer needs to look up for information of the system to understand the impact of the shutdown on occupants to do the PM planning. Shutdown alarm needs to be announced to the occupants two weeks ahead. After the shutdown planning, the work order for other shops are also created, and scheduled.

PM work order is created automatically in AiM based on the schedule, for the origin shop and all other involved shops. Work order pops up in the AiM system of the shop lead. Shop lead is responsible to plan for future, and create 7 days of daily assignments for each of the crew members. If shop lead do not have the labor resources available to do the PM work order, they cancel it, and plan to do it in next cycle.

For doing the PM work order, first the shutdown alarm is announced two weeks ahead to the occupants. The work order status is changed from “Open” to “Active” on the start day. PM is done by shop’s crew and all other involved shop teams. The status of the work order phase changes from “Active” to “Completed” when it is completed. If it reveals that the asset needs repair during the preventive maintenance work order, the status of the WO is changed to complete, and a new corrective work order is created by the shop lead. The corrective work order is explained in next section.

AiM can track the time being spent and the cost for the work order as a total for all phases. After the completion of the work order, the working hours are entered in AiM system by each shop separately for their phase. If the PM is regulatory, a report is prepared for the work order and should be sent to the regulated agencies. Some properties or assets are related to private clients like UW Housing & Food Services (HFS), and those clients are charged for the maintenance services.

5.2.2- Corrective Maintenance Work Orders

Generally CM work order is created when an asset is not functioning well. UW building occupants, or FS employee can go online to UW FS-WORKS webpage and fill out a request for a corrective work order if an equipment is not functioning well in their work place or residential hall. While filling out the request online, they need to provide the requester's information, building name, room number, and the description of the problem. If the requesters are private clients, they can specify the budget number in the request, but it is not mandatory. Figure 22 shows the FS-WORKS online request form.

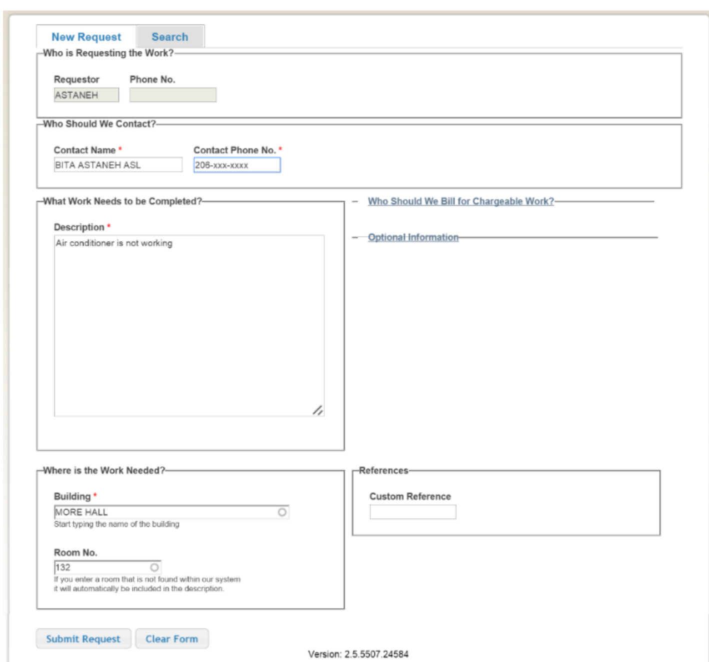


Figure 22 FS-WORKS Online Request Form

The other option is to call the FS Call Center and directly explain the problem. In first option, FS staff, and in second option call center staff are responsible for creating the CM work order based on the provided information. They need to find the zone in which the building is located, and then specify the shop based on the problem description in request. After work order creation they send the CM work order to the responsible shop lead. Sometimes wrong shop is assigned to the work order, and shop leads have to cancel the work order and send email to either the FS or call center staff for correction of CM.

After shop lead receives the work order, they assign a crew for doing the work order, and change the status of the work order from “Open” to “Active”. As explained in previous section, shop lead is responsible to plan for future, and create 7 days of daily assignments for each of the crew members. Crew’s schedule is planned based on the PMs and previous received CMs. shop lead needs to change the schedule of the crew based on the priority of the current received CM. If the assigned priority is not correct, he cancels the work order phase and adds another phase with correct priority information. One of the reasons for changing the priority is when a part needs to be purchased for the equipment, and it will take more time than the priority expectation. For example, work order with the priority of 200, needs to be done within 3 days, but if the replacement part can be delivered to the shop after 4 days, then the priority might be changed to 300.

Work order needs to be linked and tied up to the asset in AiM. If the asset profile is not available in AiM, then the shop lead asks the crew to collect the asset data during their site visit. With the combination of the data gathered from site visit and other sources, new asset is created as described in PM work order section. After the administration process and approval of the asset, the work order can be linked to the asset in AiM to have the track of the maintenance history.

If the asset has warranty, then shop lead call the manufacturer or contractor to repair the equipment. In case the work order needs shutdown or need involvement of another shop to complete the wrok order, shop leads adds phases and sends CM work order to the responsible shops. Those shops also need to look for asset data, and check plans for doing the shutdown. With the collaboration of the shops, the CM is planned and the shutdown alarm is being sent to the occupants two weeks ahead.

For doing the repair, sometimes a part of the asset needs to be replaced. Shop lead is responsible for ordering the parts. UW has some local stores on campus which have typical used parts of the equipment. AiM also handles the material management, and the information of the parts available in stock is provided in AiM. If shop leads do not find their part available in those local stores, they order the parts from manufacturer or other suppliers based on the type of the equipment and part. After the CM is done, shop leads change the status of the work order from “Active” to “Complete” and enters the number of hours spent on the work order and the cost of the parts ordered. (Figures 44,and 45)

Chapter 6: Challenges of facility maintenance

6.1- Type of Challenges

For understanding the challenges shops and CEO engineers are facing while performing the facility maintenance, 10 shop leads, and 3 CEO engineers and a supervisor, and 2 FMC managers were interviewed. Based on the interview results, challenges falls into two categories of source, and process. Next sections will discuss each of the categories separately in detail.

6.2- Sources

All the sources available for shops and CEO engineers were determined. Application, availability, being handy, and challenges of using each of the sources were studied. In next sections, each source is introduced along with their capability and the information type they are providing. Then the challenges of using them is discussed.

6.2.1- CMMS system (AiM)

Facility Services was using the paper format of documents, plans, and was recording the asset data in paper for several years till 1992. Use of mini computers called PDP (Programmed Data Processor) helped FS to develop a PDP based asset management in-house system from 1992 to 1996. In 1996, another in-house system called FMS was developed. FMS was being used till 2001. In 2001, the system changed to FM Enterprise (FME) by MAXIMUS. This CMMS system was then upgraded to a web-based version called FacilityMax (FMax) provided by the same company. In September 2008, the Asset Solutions division of MAXIMUS, was acquired by Trapeze’s parent company, Constellation Software Inc, and they were rebranded to Assetworks and came with AiM, the new CMMS system. In 2009 FS started using AiM which is the current CMMS system.

Interview results revealed that during the system change from FME to AiM in 2009, most of the data was not transferred to AiM. One of the interviewees had an approximation of 2/3 or 3/4 of the assets which remained in the previous system and didn’t transfer to AiM. FME had more information and reports for each asset, but not all the information was transferred to AiM.

While shop leads were expecting to have their asset data back in AiM, they were informed that they are responsible for entering the remaining asset data manually in the system. Considering the daily responsibilities of the shop leads, manually entering the data was an extra duty for them. Different approaches were taken for managing the remaining assets. First the asset data related to regulatory preventive maintenance was entered in the AiM system manually since they were mandatory and the report of the PM needed to be sent to the regulated agencies. Some supervisors asked the shop leads to download and extract the asset data as much as they can, and save them for their records. One of the interviewees had extracted about 7000 assets and their data from FME, and had put them in an excel format. One zone had started entering the asset data gradually within years with getting help from student assistants. At some shops, only a portion of the data was entered manually and they only create new assets in AiM, in case they receive a corrective maintenance related to the asset. One of the interviewees didn’t take action for entering the asset manually after system change.

It should be noted that FME was not a perfect system, and it didn’t contain all the assets. But among those assets, partial information was transferred to AiM. As a result, the new AiM system is containing less asset data. Among the asset data transferred to AiM system, some can be found without having asset number, and they only have FME number which is related to the numbering of the previous system. This adds more confusion for someone who looks for a specific asset in the AiM system.

Assets usually do not have sufficient data or sometimes no data as attributes in AiM. The accuracy of the data is also doubtful. A shop lead was talking about his experience for ordering wrong parts because of incorrect model number and serial number of an asset in the AiM system, and he was preferring to have the crew check the asset data in the field before any part purchase. Other interviewees were also skeptical about the accuracy of the data based on their experience.

AiM also does the material management. The information of the available part in stock of local stores are available in AiM. But shops find those information not helpful, and accurate. They usually send crew to the stores to check the availability.

6.2.2- Campus Engineering Records (FS-DOS)

UW has a centralized database called Innovator in which all the construction handover documents like as-built drawings, commissioning documents, warranty documents, and O&M manuals are kept. Innovator has a web based portal called FS-DOS which allows looking for the documents online. As discussed before, the handover documents were all in paper format. High number of buildings and facilities were resulted in huge number of paper documents. This resulted in the concern of providing space for storing all the documents. The "Lean" project started converting all the paper documents to digital Pdf or Jpeg format. All the paper documents in records department were scanned and uploaded in FS-DOS. Figure 23, shows storage of the high volume of the paper documents on right, and large scanners in Records department on the left. Recently in new projects, construction and design teams are required to submit the handovers in digital format, and there is no need for change in format of the documents.

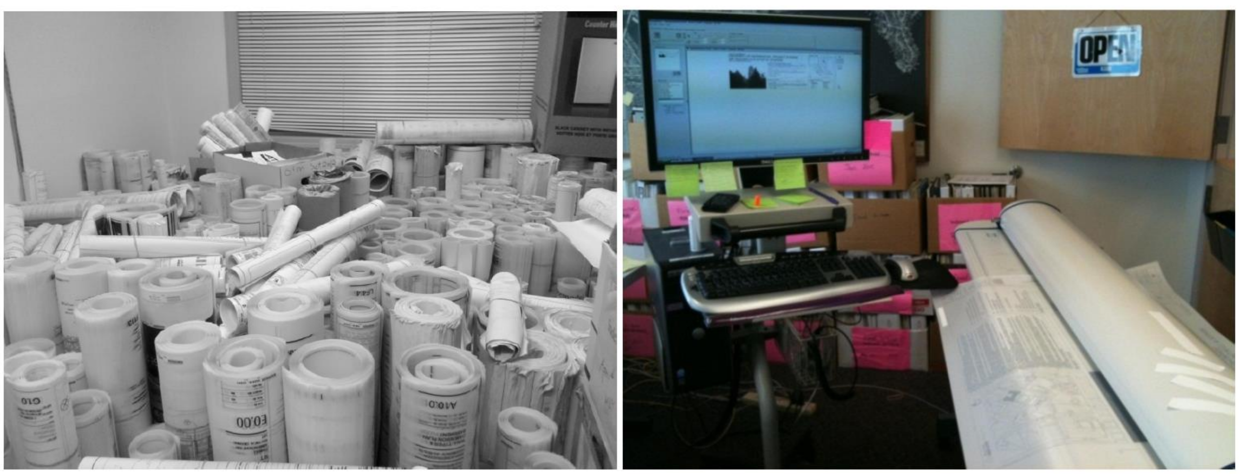


Figure 23 High Volume of Paper Documents, and Scanning Process at CEO Records Department

To look up a document in FS-DOS, a UW NETID which is a unique username for students, staff, and faculty members at UW is needed. As seen in figure 24, documents can be searched with either of facility name, facility number (FACNUM), project number, or document title. The results can be filtered with key words in title, and document type.

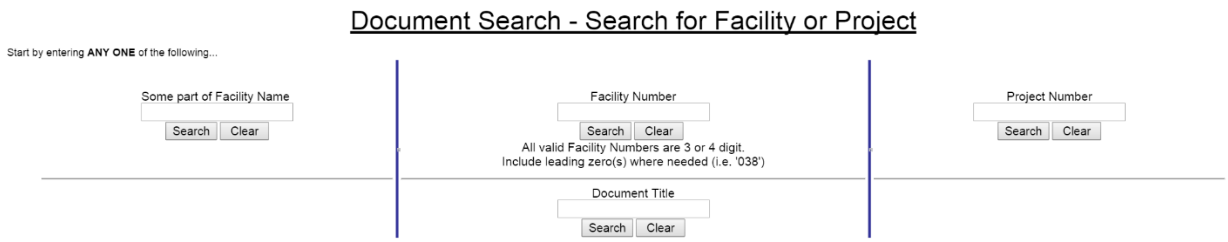


Figure 24 FS-DOS webpage for Document Search

There are 60 different types of document categories defined in FS-DOS, like Architectural drawings, maintenance manuals, permits, and commissioning documents. Staff at Records department of FS are naming and labeling the digital documents, and assign them to the related category in FS-DOS. Sometimes documents are assigned to a wrong category, and files are not named properly. Interviewees were unhappy with the organization of the documents in the FS-DOS. When they open up a category, they find multiple documents without a good reference. They have to go through all the documents one by one, open them up, and see the content. Files also opens in web browser differently. There are some files in pdf format which opens in an external tab in web browser, but there are some figures which need to be downloaded to be opened. One of the interviewees described the problem as: "It is so difficult to find drawings in engineering records. I have to go through hundred drawings, pop them up look at them.. Oops.. it is not the one I am looking at, and then pop another one up..It is not good cross referenced".

Not all the documents are uploaded in the FS-DOS, and some of them are missing. There are also some documents which has label, but there are no documents attached to them. Figure 25, shows a part of the search results for maintenance manual documents at More Hall. As seen in the figure, among the first 11 documents, only 5 of them are available. An important mechanical HVAC O&M instruction document is missing in the system.

Most of the uploaded files are scanned paper documents which are not searchable. O&M manuals usually have hundreds and sometimes thousands of pages, and it is very hard to look for data in a scanned document. As-built plans are also scanned and any change happening to the asset, like replacing an equipment, is not recorded on these files.

Facility# = 140		Search Term = "140"							43 Record(s) Found
Select Record	Building Name	Document Title	Document Type	Project	Year	Size	Status	Sheet#	Document Number
Clear	A-Z Z-A	A-Z Z-A	A-Z Z-A	A-Z Z-A	A-Z Z-A	A-Z Z-A	A-Z Z-A	A-Z Z-A	A-Z Z-A
	ROBERTS HALL	Roberts / More Hall Operating & Maintenance Instructions	Maintenance Manual	np - No Project Number Given	1978	8.5x11	In Vault		082-MM-_4_
	MORE HALL	More Hall: Mechanical And Electrical Maintenance Manual	Maintenance Manual	np - No Project Number Given	1966	8.5x11	In Vault		140-MM-_1_
	MORE HALL	More Hall Alterations - Mechanical And Electrical Instruction Manual.	Maintenance Manual	np - No Project Number Given	1973	8.5x11	In Vault		140-MM-_3_
	MORE HALL	Renovation, Phase II - Supervisory Control System.	Maintenance Manual	np - No Project Number Given	1975	8.5x11	In Vault	MM 140.4	140-MM-_4_
	MORE HALL	Renovation, Phase II - Mechanical.	Maintenance Manual	np - No Project Number Given	1975	8.5x11	In Vault	MM 140.5	140-MM-_5_
	MORE HALL	Renovation To More Hall, Phase 2: Electrical Equipment.	Maintenance Manual	np - No Project Number Given	1975	8.5x11	In Vault		140-MM-_6_
	MORE HALL	Remodeling - Mechanical Equipment.	Maintenance Manual	np - No Project Number Given	1979	8.5x11	In Vault	MM 140.8	140-MM-_8_
	MORE HALL	Mechanical HVAC - Operation and Maintenance Instructions.	Maintenance Manual	np - No Project Number Given	1987	8.5x11	In Vault	MM 140.9	140-MM-_9_
	MORE HALL	More Hall Room # 1 Renovation: Electrical Operation And Maintenance Manual	Maintenance Manual	np - No Project Number Given	1988	8.5x11	In Vault		140-MM-_10_
	MORE HALL	Electrical.	Maintenance Manual	np - No Project Number Given	1989	8.5x11	In Vault	MM 140.11	140-MM-_11_
	MORE HALL	Room #34 Lab Remodel.	Maintenance Manual	np - No Project Number Given	1993	8.5x11	In Vault	MM 140.12	140-MM-_12_

Figure 25 Screenshot of the FS-DOS Results for O&M manuals of More Hall

6.2.3- Submittal exchange

Submittal Exchange is an online document exchange program used at CPO. It is a tool for sharing documents among CPO, design and construction teams. Submittal Exchange contains all the documents of the new construction project from design to construction phases, and final handover submittals. Use of submittal exchange is not open for everyone, but permission can be given to facility services employees upon a request. While handovers takes time to be transmitted from CPO to FS due to the administrative process, submittal exchange provides the opportunity for FS employee to track the construction progress, check the systems and equipment which are going to be used in the new building, and have access to the as-built plans, O&M manuals, warranty documents and other documents they need in submittal exchange by the end of the construction.

6.2.4- Paper Documents

Looking into scanned digital documents in FS-DOS are challenging for shops and most of the time they prefer to look up the information in paper based format. Paper documents are kept in different places in different zones and shops. In one of the zones, there is a room called “print room” where all the paper documents and digital files of the new constructions are kept and employees check the room when they look up for documents, plans, and other sources of information. In another zone, most of the documents are kept in zone manager’s office. There are some old plans that only can be found in campus engineering, and sometimes shops call them to check some information and get help for CEO engineers based on those plans. O&M manuals are usually kept in shop lead’s office, and some of them are kept next to the equipment on site. As a result, sometimes it is very hard to locate the paper documents and plans because of the different locations of storage.

As-built drawings can not be changed in digital format. Shop leads and CEO engineers were used to write the changes of the assets on the plans. So, when a new employee needed to look at plans, they could see the information of the replaced equipment or any change happened. Sometimes the notes on the plans makes it too hard to read. Besides all the challenges, paper documents fades by time, and the quality goes down.

6.2.5- Site Visit

For doing the work order crew need to have the site visit. Having asset data information beforehand is very important for doing the job. For doing PMs, the asset data in available before the work order creation. So, crew have all the information of the asset they are going to do the work on. One of reasons of having the site visit, is the lack of information in AiM system, or not having sufficient asset data. Even when the asset and its data is available in AiM, shop leads ask crew to have a site visit and double check the asset data because of the data inaccuracy in AiM system. For this purpose, crew needs to collect information from nameplate. Nameplate is a tag on each equipment attached by manufacturer including crucial information about asset such as manufacturer, model number, serial number, and operational characteristics. Figure 26 shows a nameplate.

Some shops have a specific form which require crew to fill it up during their site visit, in case the asset information is not available in AiM. Asset data collection by visiting the site is not always feasible. Some assets are not accessible or the nameplate is located on a side of a fixed or heavy asset facing the wall. A shop lead was talking about his experience going on top of an employee’s desk to look up for assets in the ceiling. Those collected information needs to be entered in AiM system. If the asset does not exist in AiM, a new asset needs to be created, and in case the attributes of the asset is missing, asset data needs to be added. Since the forms are handwritten, sometimes wrong information is entered in AiM system.

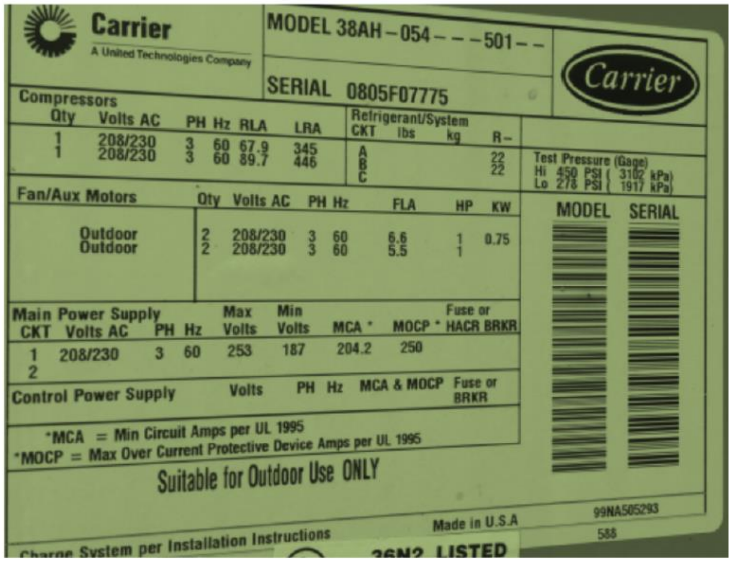


Figure 26 An Example of Nameplate

Besides data collection , there are some other reasons for site visit like understanding the system and where the equipment serves. Mechanical, electrical, and plumping shops are mostly working with 3D systems in the building, and 2D plans usually are not very helpful. They use semi-visible plans and put different floor plans on top of each other for understanding the system. If they do not find them helpful, they go to the site.

6.2.6- Manufacturer

When O&M manuals are not handy, and hard to find either in paper or digital format, shop leads prefer to contact manufacturer directly instead of spending time looking for documents. They need to have the model number and sometimes serial number to get help from manufacturer. They can get the information such as parts which need to be purchased, and trouble-shooting tricks. But it may take 3 to 4 hours to get reply back from the manufacturer and some of them does not exist anymore.

It should be noted that, for old equipment shop leads have to contact the manufacturer since most of the parts of the equipment are discontinued manufacturing or upgraded, and they need to know the new part number to purchase. Some trouble shooting tricks or repair information is not provided in the O&M manuals, and there is a necessity of contacting the manufacturer. Also manufacturers are called in case the equipment is under warranty and needs to be repaired.

6.2.7- Experience

Experience has the main role in what crew or leads are doing at shops. They take care of the equipment and systems for several years, and they are very familiar with how those equipment are functioning and what parts they are made up of. One of the shops leads mentioned that "Over the years, you kind of know your equipment well, so you wouldn't really reference that [asset] information that often.. think about how many cycles we've done of preventive maintenance and we pretty much know all equipment very well."

Experience is also a key factor for maintaining assets in new constructions which are similar to the existing assets in other buildings. If they have worked on those type of assets before, they usually do not need to have information about them. PM work orders are also described mostly based on the experience of the shop leads.

6.2.8- Self Collected

Some shop leads collect the asset data, as-built drawings, O&M manuals, and any other documents from all the sources, and put them in their computer. They prefer to spend time up front and collect the information in a single source to prevent wasting of time looking for information for future work orders. They put lots of time for collecting all the information, but it helps them do their job more efficient.

6.3- Process

Besides the sources which provide information for shops and CEO engineers to do the facility maintenance, there are some process challenges for doing the facility maintenance. Next sections will cover each of the process challenges.

6.3.1- Work Order Process

Based on the interview results, shops in different zones, handle the work orders differently. The work flow of work order may differ from shop to shop, and some steps might be skipped. The research also revealed that any work order can be created and completed in AiM without being tied to the asset in AiM. In next sections CM and PM work order process challenges will be discussed separately.

Corrective Maintenance Work order:

CM work order is created by FS or Call Center staff based on the request of the customer or the FS walk up staff. The work order is nor linked to an asset profile in AiM when it is received by the shop lead. Based on the problem, shop lead needs to identify the asset which will have the repair, and link it to the work order. The interview results revealed that not all the shop leads are linking the work order to the asset profile in AiM, which results in loss of track of asset history.

As discussed before, not all the assets are available in AiM. Since the administration process of asset approval takes some time, for creating a new asset and linking it to the work order, some shop leads keep the status of the work order as “Open”, and create the asset profile and wait until they get the approval. Then they change the status to “Active”, and links it to the work order. Some other shops do it at the end of the work order when it is completed. They complete the work order and change the status of work order to “Complete”, then they create a new asset profile, and wait for approval. After they get the approval, they go back and change the settings of the work order and link the new asset to the work order. Some shops only creates the new asset and do not link it to the completed work order, and some shops do not create the new asset at all. One of the interviewees explains the CM work order challenge: “You wanna work on, and it does not have an asset number, you wanna give it an asset number, but it needs to be worked on.. you can apply for an asset but it sometimes takes 3 to 4 days to get asset number.”

Preventive Maintenance Work Order:

As explained in chapter 5, PM work orders should be linked to the asset profile in AiM. In the PM planning process, the asset profile needs to be created in AiM first, and then the PM is created and tied to it. By giving a schedule, AiM produces automatic PM work orders and sends it to shop leads regularly. Interview results showed some shop leads create the PM work orders manually without linking them to the asset profile. This is mostly happening for assets owned by private client.

The automatic work orders settings does not allow the shop leads to specify some codes like “task”, “option”, and “PCA project” required by some of the private clients like HFS to be specified. As a result, the PM work orders have to be created manually at each period. One of the shop lead interviewees is putting all the PMs in his calendar to be reminded and create the manual work orders which takes his time a lot considering the huge number of PM work orders he does for private clients.

Shop lead needs to assign PM work orders to the crew. Most of the shops are shorthanded, and do not have sufficient labor to do them. Regulatory and mandated PMs are all on the track and the reports are being sent to the regulatory agencies. PMs for assets and systems owned by private clients are also done by the shops. The remaining PMs are mostly canceled due to the lack of labor, and focus is mostly on corrective maintenance since they have higher priority. One of the interviewees mentioned: “All these PMs come up quarterly, so they just keeping going and going, that’s why they get built up.. I do not have so many guys to do so much work.. The PMs are lower priority than repairs”. And another interviewee said: “We should be doing PMs, but we are short-handed.. I apparently did about 4 or 5 PMs during last 3 or 4 years”

When PM work orders are not done regularly, then they change to CM work order and come back to facility services. An interviewee gave a great example: “If you do’t change your car’s oil for three years, then you will stuck on the road and need to go to mechanic”. The number of work orders done within one year in 2014 shows that on average 78% of the work orders are CM, and only 22% are PM as shown in figure 27. Figure 28, represents the comparison of the CM to PM work orders based on the hour sum. As seen in the figure, although campus engineering engineers get only about 10% of the PM work orders, they spend about 50% of the time on them. Based on our interview results, the time is mostly being spent on planning for the PMs.

In the previous system, FME was producing the PM work orders and sending it to shop leads. The assets which were not transferred from FME to AiM, do not have PM work order to be automatically generated. “To get a PM you have to have your assets in AiM, and all of them were taken out”. This also reduces the number of PMs which should be done. After system change in 2009, UW had new construction, but just a portion of the asset profiles are created in AiM.

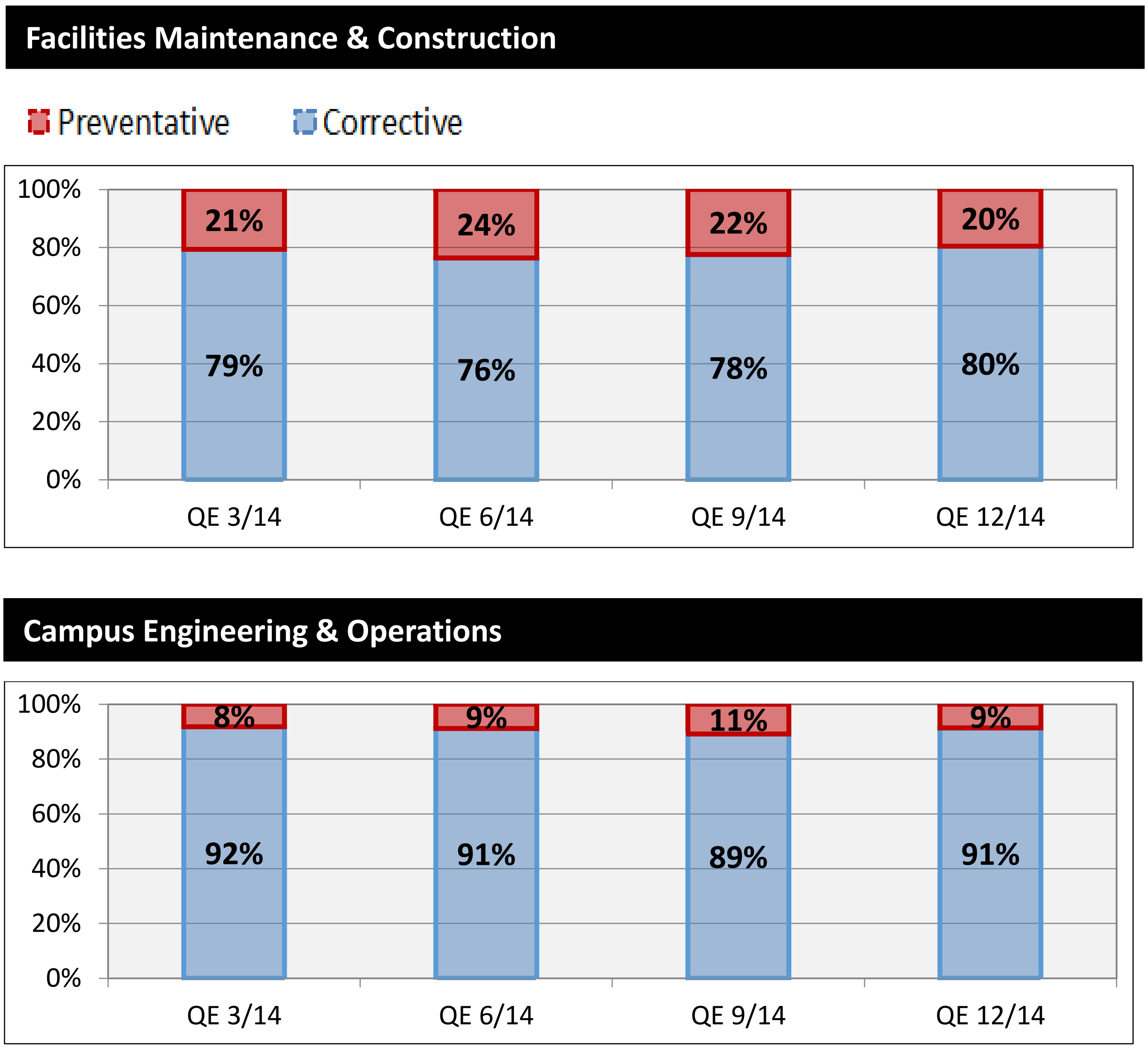


Figure 27 PM vs CM Work Order by WO Count (Courtesy of UW IT)

Shop leads are responsible for the preventive maintenance management of the equipment and systems of the zone they are serving. Previously, the PM Manager was doing this job, but since this position was vacant for a few years, this responsibility is on shop leads' shoulders. They are specifying the tasks to be done, and their frequency based on their experience and anything written in the O&M manuals. This is while, PM management should be done based on life cycle functionality of the equipment. A shop lead expressed his concern about the PM program at UW as "All AiM does is generate a work order for me to go out and look at this piece of equipment.. It may include some information.. It may track cost, materials, but there is no vehicle here for an actual maintenance program.. Like meantime between failure, replacement cost, life cycle, replacement calculations.. We don't have anything like that.. We are in the very basics.. It comes to lead to decide what is important or not"

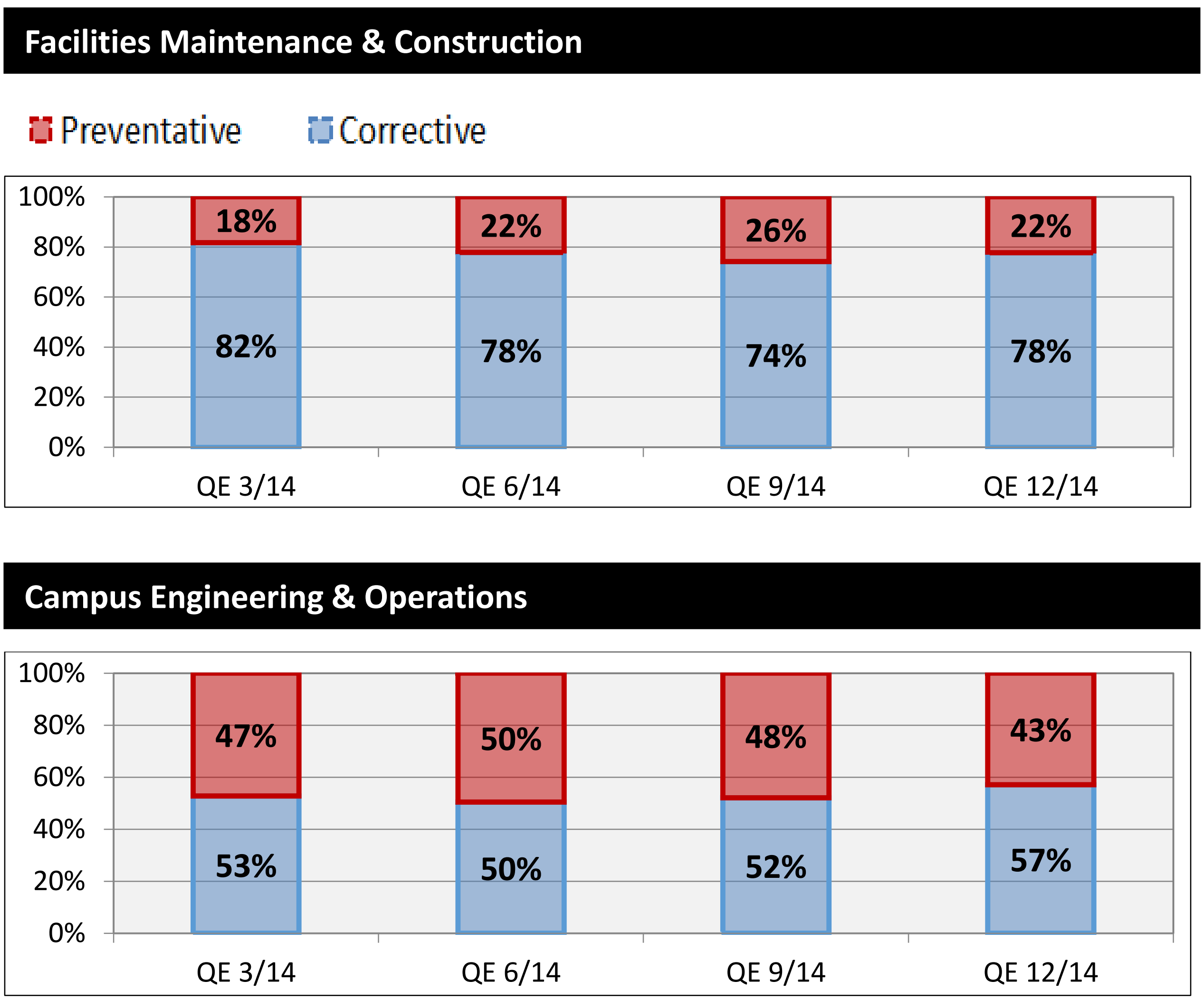


Figure 28 PM vs CM Work Order by Hour Sum (Courtesy of UW IT)

6.3.2- Handover time lag

After the completion of the new construction, CPO hands the handovers to FS. For a long time all the documents were in paper format. Besides the administration process and document approvals, the paper documents needed to be copied and sent to the FS. It was usually taking about 1 to 2 years to receive the handovers by FS. Recently, CPO is requiring the construction and design teams to provide digital format of the documents. The Mercer Hall, was one of the new construction with digital format handovers which took 130 days to be received by FS. During this time lag, FS does not have information about assets in the new building to maintain them.

CEO engineers are involved during design and construction phases of a new construction, and they do the design review. They use submittal exchange, but the interview revealed that shops are not very familiar with this online exchange program. There were only two shop leads among the interviewees who are using the submittal exchange for the new constructions. They are attending the construction meetings for understanding the systems and are gathering all those documents and plans in their own computer for their reference. They were creating new assets and PM work orders as soon as they had the handovers from Submittal Exchange. Other shop leads didn’t have heard about this system, or were not using it. Most of the shop leads are waiting for the handovers to be handed to the shops.

Using submittal exchange might be confusing for the shops, since in contains all the documents from the start of the project. One of the CEO interviewees mentioned that there is an effort for creating a specific space in Submittal Exchange as a tab to store all final submittals there to be much easier for shops to locate the files and use them.

6.3.3- Training

As technology advances and building systems gets more complex, the need for training the employee becomes more important. Facilities were managed in paper-based format for many years. By entering the technology ages, the traditional way of work management has changed, and now shops are mostly relying on two web based systems of AiM and FS-DOS.

AiM system is not user friendly. FS has created the Technology Toolbox webpage providing training pdfs and videos for work, time, material, and asset management in AiM. They also have classes for shop leads and supervisors based on their AiM familiarity level. A few of the interviewees were newly started shop leads with being in the position for less than a year. The interview results showed that those shop leads were not aware of the resources they had to learn AiM and FS-DOS. They had challenge of learning both systems by themselves, or were relying on their colleagues. One of them was calling UW IT team to get help figuring out how to work with AiM.

Most of the shop leads were complaining about the search engine of the FS-DOS and AiM. It revealed that they were not using the systems efficiently, and didn't know how to filter the results to find the document or asset they want much easier. Research team tried their best to provide the sources for learning AiM, and gave some instruction about using FS-DOS and AiM which was appreciated by interviewees.

Since shop leads are mostly trained by trades, they usually do not have computer based skills, and training plays a significant role. In future, more skills might need to be learnt by shops like using CAD files, and BIM models. There is a need for a good training program planned for future, and having a better announcement of the training sources and classes in Facility Services. New employees need to learn how to use the sources, and current employees need to take advanced level training classes to work more efficient.

6.3.4- No Unified Zone

FS is divided into four different zone of Northeast, Central, Southwest, and Health Science. Each zone is performing the facility management separately in different ways. There is no communication between zones, and they are not aware of the management system of each other. One of the interviewees described the relationship between zones as “We are in an island.. We don't know what they are doing [in other zones]”.

There is a need of stablishing a standard for facility managing for all zones at UW. Zones need to have communication and share their experience of success, and learn what they need to do from other's successful actions.

Chapter 7: How COBie Can Help Facility Maintenance Process

7.1- COBie Impact on Work order Process

In chapter 5, the work flow of the work orders both for CM, and PM work orders were explained. In this section the effects of COBie on the work flow will be discussed. Because of the different processes of CM and PM work orders, each of them will be explained in separate section in next paragraphs.

7.1.1- Preventive Maintenance Work Orders

As discussed in chapter 6, the most important phase in PM work order management is planning. Planning phase is where the asset data needs to be collected. Once the asset and PM work order is created in AiM system, there is no need for asset data collection for doing the work order itself. COBie is all about asset data, and as a result, the effect of it can be seen in work flow where the asset data collection is needed.With COBie process, there will be no need for data collection, and no manually creating the asset data in AiM, and no administration process for approval. As seen in figures 39 to 42 in Appendix B, steps affected by COBie are highlighted and the new asset creation process will completely be removed. In case of phase addition, the involved shops or CEO engineers also need to look for information, and may need asset data collection for the systems and assets they are responsible for. During the PM process, if it reveals that the asset needs repair, then a CM work order will be created and the effects of COBie can be seen in CM work order.

7.1.2- Corrective Maintenance Work Orders

Despite PM work order, CM work order is not planned. Shops receive the work order from FS or call center staff, or may create a new work order for a PM which needs to be repaired. In CM work flow, the first impact will be on the asset availability check in AiM system. In a property where the COBie is implemented, all the assets are available in AiM. As a result, shop leads can check the asset information and know the type of equipment they need to fix. In case the asset profile is not available in AiM, the same new asset data creation steps will be impacted as described in previous section. This means, work order might be delayed because of the lack of asset data, so time needs to be spent to look for data, and to create the new asset profile in AiM. Another impact will be linking the work order to asset profile in AiM. When the asset profile is available in AiM, work order can be linked to it with no time lag of administration process.

COBie provides the warranty validation date. If the equipment is under warranty, shop leads can quickly check the date, and ask for the contractor or manufacturer to fix it. This is while in current process warranty documents needs to be checked to figure out if the equipment is under warranty or not. And since the documents are usually hard to locate, COBie will have impact in this process.

7.2- Is COBie enough?

In chapter 6, the challenges of facility maintenance was discussed. COBie is mostly helpful in challenges related to source, since it provides the asset data in AiM, one of the main sources of shops to do the work order. There are some other sources which shops are relying on, and some process challenges which can impact the usefulness of the COBie data. Research study shows that COBie can help easing a part of the facility maintenance process. To get the full benefit, COBie relies on other sources and processes. Next sections cover both challenges of sources and processes and how they can be combined for having more efficient facility management.

7.2.1- Sources

By inserting COBie spreadsheet in AiM system, asset data is available for shops from the first day of operation. The research results shows that asset data is not the only information shops need to have to do the facility maintenance. Besides the asset data, they also need to have O&M manuals, as-built drawings, and other documents like warranty documents to check the additional information which COBie does not provide. Shop leads of mechanical, electrical and plumping need to look at as-built plans to understand the systems they work on. If there is a shutdown needed, the plans help them for understanding the system and the impact of the shutdown on occupants. O&M manuals have information about different parts of the asset, troubleshooting tricks, and functional and operational guidelines. Some COBie information is extracted from O&M manuals, and plans. For example the location and serving zones are extracted from plans, and asset data like type of belt in extracted from O&M manual. Although COBie gathers partial information from all those documents, it does not contain the documents and plans.

Shop leads are looking into two different main sources of AiM and FS-DOS for data collection. Work orders are generated in AiM, but there is no link between the AiM and FS-DOS. Shop leads have challenge of looking in different sources for finding the information they are looking for. The work order management and asset data is in AiM, but the documents are all stored in FS-DOS. Most of the interviewees were suggesting having a combination of both sources, or having a hyperlink between them, since one source is not complete without the other one. As seen in the Figure xxx, research revealed that COBie can add more value to the facility maintenance process in case there is a link between the two sources.

7.2.2- Process

When COBie provides the asset data, but work orders are not linked to asset profiles, a portion of the COBie value is disregarded. Work order history track of an asset is very crucial, specially for CM work orders. With having the asset history, shops can make better decision on how to repair the asset. This is while in current process, a few CM work orders are linked to the asset profile.

PM work orders need to be specified for each asset, and this is while some work orders are done manually and without being tied up to the asset profile in AiM. COBie can ease the process of PM work order planning by providing the asset data, but it can not help with the PM management. With the new change in FS and having PM management team back to the board, the PM work orders hopefully will be handled with a better strategic plan.

7.2.3- Other Needs

Besides the O&M manuals, and as-built drawings, shops also need more technology for doing their job. As mentioned before, the as-built drawing are used in either paper based or scanned digital version. The plans can not be changed, and there is a need for using CAD files which can be changed.

Mechanical, electrical, and plumping shops are mostly working with 3D systems. Sometimes 2D drawing are not very helpful. Some of them use semi-visible plans on top of each other for different floors to understand the system, or prefer to go to the site. These shops, and engineers at CEO are more willing to have 3D models of the buildings for better understanding the system to do the work orders and do the shutdowns.

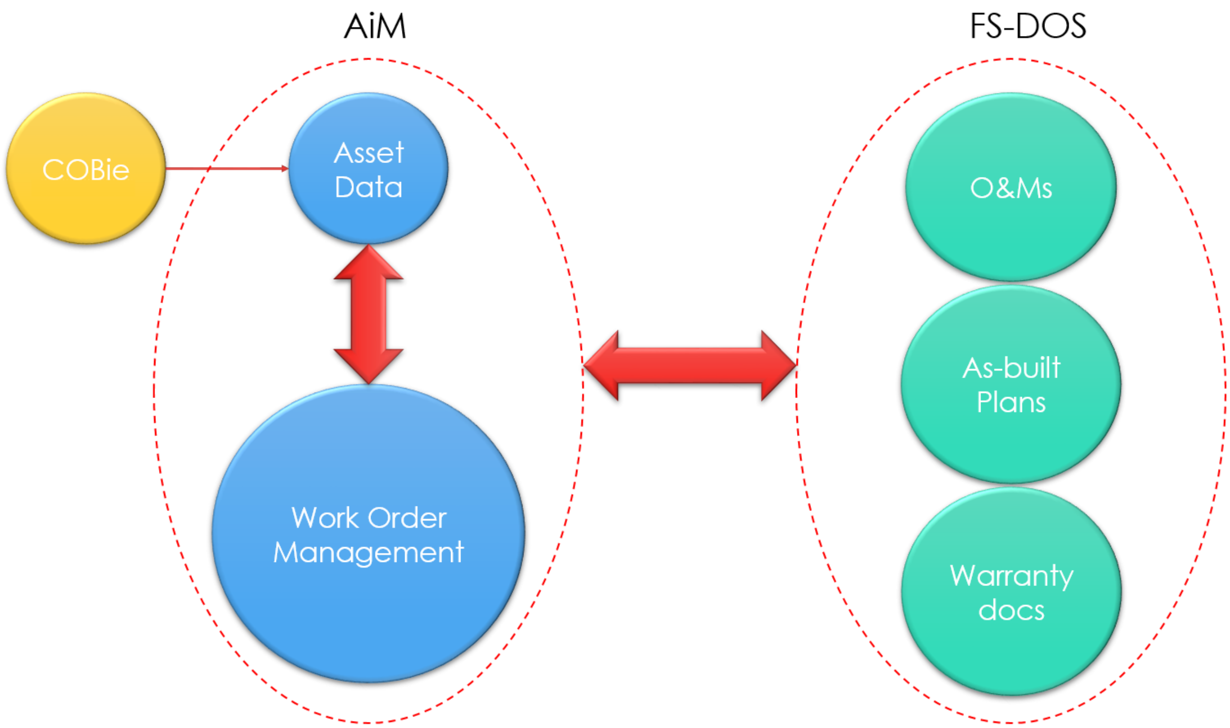


Figure 29 Need for Hyperlinking Two Sources of AiM and FS-DOS, and Linking WOs to Asset Profiles

7.2.4- Solution

While there are two separate sources available for shops, AiM system has the capabilities for hyperlinking these two systems. The link of the related O&M manual, as-built drawings, and warranty documents in FS-DOS or any other sources, like online O&M manual in manufacturer website, can be attached to assets. Any type of document can also be uploaded as an attachment to the asset profile in AiM. The property profile in AiM has the option for uploading files like warranty documents, CAD files, and commissioning documents.

CAD files can be uploaded in AiM. Some of the interviewees were supporting this idea a lot because of the challenges they are facing with paper or scanned plans. But some of them were not supportive since they do not have the CAD skills and are not willing to work with it. They prefer having someone with CAD platform skills hired in the zone to do it.

Since COBie is extracted from BIM model, the 3D model of the building can be provided for shops and campus engineering. Working with CAD and BIM models require training. Since most of the shop leads are trained by trades, they do not have skills to work with technology. As the technology advances, and the buildings become more complex, the need for using technology becomes more important.

By hyperlinking AiM and FS-DOS and even providing the CAD and 3D model to shops, there are still some processes which COBie and AiM can not help with, and some steps is needed to be taken to get the full benefit of COBie. Stablishing a standard for work order management as the first step to unify the way work orders are handled in different zones and different shops. A good mandatory training program for shop leads to use the AiM, FS-DOS, Submittal Exchange and any other tools like CAD and BIM to be used in future is very important.

Considerable number of shop leads are retired recently, and new fresh shop leads with willingness for learning have started their job. Planning a better PM management, and balancing it with the number of labor to do the job is one of the crucial management decisions which FS needs to take with their new work order management team.

7.3- How Much Time Can Be Saved

COBie impact was determined in the work flow previously in this chapter. Those parts include some key activities which will be omitted or effected in the duration of time they are being done. For determining the amount of time being saved in the work order process, these key activities needed to be determined. Then the research team tried to quantify the amount of time saved by shops based on interview results. In this section the key activities, and analysis of time is provided.

7.3.1- Key Activities Impacted by COBie

Site Visit:

For collecting asset data one of the best sources is visiting the site. Manufacturer, model and serial number along with some operational and functional characteristics can be read from the nameplate. Crew or shop lead needs to spend time going to site, finding the nameplate which sometimes is very difficult to find due to accessibility problems after occupation, write down the information, and come back to their office. There is a time waste for not having asset data in AiM which requires them to have site visit.

Extract of Asset Data from Documents:

Some asset data is extracted from O&M manuals and plans like the type of the belt, and locations the asset is serving. Warranty validation dates should also checked in warranty documents. As discussed in chapter 6, there are multiple challenges for finding the right document or plan, and look for the data. Time is being wasted to gathering the information. It should be noted that, those documents are also used for looking up other types of information besides the asset data.

Asset Profile Creation:

After the data is created, shop lead needs to create the data in AiM system. There is an extra time being spent on asset profile creation, and there is a time lag between the asset approval request and the approval, due to the administrative process. Work order can be tied to the asset only if the administrative process is done which sometimes takes 3 to 4 days. But it is usually approved upon a request by phone.

Additional Phases:

PM or CM work order might need multiple shops to involve in the process. Those shops have the same challenge and time waste as described in previous sections. It is also the same for CEO engineers specially during the PM planning.

7.3.2- Time Analysis

Research team decided to quantify the amount of time which COBie can save during the work order process. The main challenge for quantification, was the dependency of COBie data on other information sources. COBie provides asset data in AiM which can ease the job done on work orders or PM planning, but shops usually need to look up for information in other sources like FS-DOS. These activities were tied up to each other, and couldn't be studied separately. For example, most of the time a site visit is a must to do in CM work order. While crew is visiting the site to specify the problem, they take notes of the asset data from the nameplate. They call the shop leads and provide the information they have extracted from site visit with the part needs to be purchased to be replaced in the equipment. In this case, only the asset data was needed to be available to fix the equipment. This is not always the case for all the equipment. A complex equipment will need both the asset data, and O&M manuals, and maybe as-built plans to be checked. Old equipment are one of most challenging cases for shops which their information is usually hard to be collected.

Interviewees were asked to pull out multiple work orders for the interviewer, and explain the challenges they face for each of the work orders, and how much time they could have saved if they had the sources available for them to do the work order. The interview results showed that time being saved differs from work order to work order, and shop leads were not able to estimate how much time can be saved in a single work order.

Research results show that time is wasted because of not having the asset data in AiM, and not having other documents handy in FS-DOS or paper based format, which results in delay in doing the work order. As a result, interviewees were asked to report the amount of time they can save on average in percentage by having the sources available for them in both AiM, and FS-DOS. Figure 30, shows the results of the interview with shop leads. Shop leads who had previous experience working with asset data were reporting high percentage value for time saving, this is while the new shop leads had an estimation of lower amount of time savings.

Based on the interview results, on average **20%** of the time can be saved with having sources available for the shops. One of the shop leads estimated time savings of 50% in the first year of the occupation when he tries to understand the systems and equipment, and plan the PM work orders. One of the CEO engineers estimated 20% of time saving. He mentioned that it can help to save time from 15 minutes for a small work order and up to 6 weeks in a single PM planning work order. Two FMC managers also had reported 20% of time saving based on their experience.

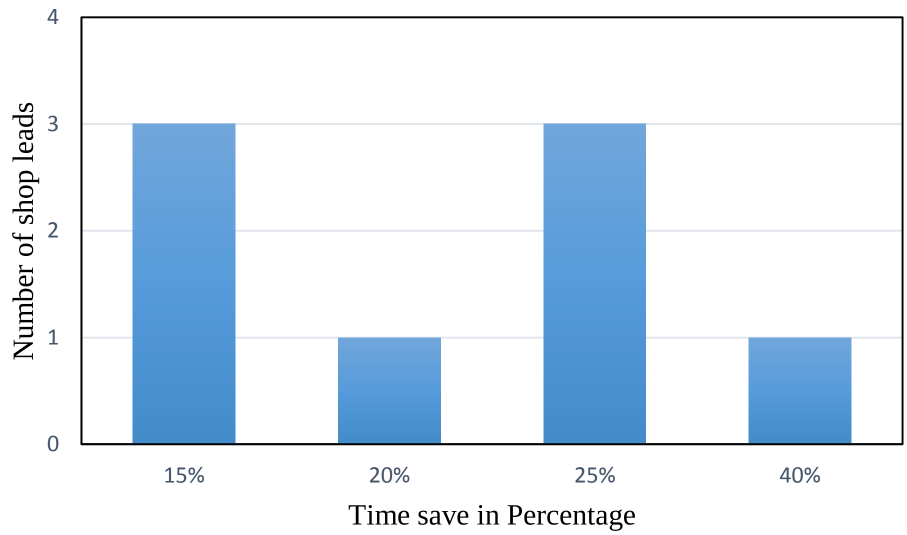


Figure 30 Time Saving with Having Sources Available to Shops

7.5- When COBie is needed

Pilot III project is about the implementation of COBie on a new construction, and rebaselinign the existing building. For future studies, and COBie implementation, there is a need to identify which buildings need COBie and prioritize them. For this purpose, the first question to be answered is if it is possible to retrieve asset data from FME system and insert it to AiM system. As discussed before, there was a considerable amount of data which was not transferred to AiM after the system change and there is no exact information about how much was inserted manually by shops within 2009 to 2015. For new construction built after 2009, it is also not clear how much of the data is in AiM. If the data can be retrieve from FME system, then based on the asset data availability, and criteria like system complexity, size, age, and usage purpose, buildings can be prioritized.

Age of the building is an important criteria for prioritizing the buildings. In old buildings, specially the ones built in 1980s and later, the equipment and systems are old and most of them are discontinued manufacturing. When a CM work order comes for these type of equipment, shop leads usually send older technicians with having experience with those type of equipment. Most of the time, shop leads have to call the manufacturer to know the replacement parts for the equipment which are discontinued manufacturing. And the manufacturer may not exist anymore to get the information. Sometimes they need to replace the asset completely since it's not functioning well after so many years of service. Most of the asset data is not available in AiM. Documents and plans are hard to locate and the paper documents are fading by time and not readable. Finding the asset information is hard for both the shop leads and for COBie team who wants to do the rebaselining.

In mid-age buildings, age, the system complexity, availability of the data, and usage purpose is very important. Shop leads are more familiar with systems and equipment of the buildings which they have done PM, and CM work orders on for several years. It is also very important to keep the track of the asset history. As a result, the newer the building, the more priority. Usually small buildings have less asset data in comparison to large scale buildings, which reduces the priority of them. The more complex an MEP system is, the more COBie can add value. Complex systems have more assets, and 3D model is very beneficial for understanding the systems. Application of the buildings is also very important. A hospital, or chemistry laboratory has more priority than a small trailer office building. Mid-age buildings can prioritized based on the criteria discussed. Relatively new buildings with large scale and complex MEP system, having less available data and high importance in usage purpose, have the highest priority for rebaselining.

The best practice of COBie is when it is implemented from pre-design to construction and then to operation phase on new construction. With implementation of COBie, PM work orders can be planned earlier than other methods, and all the asset history and work orders can be tracked from the first day of operation. Warranty validation date will also add value to the CM work orders. This is while in rebaselining process, the asset history track is lost for the occupation period before rebaselining. Warranty validation dates are also not very important for existing building unless they are very new in their very first years of operation. Applying COBie to all the new constructionis ideal, but because of budget limitation, buildings can be prioritized based on the same criteria discussed previously about mid-age buildings.

Apparently, COBie will be much beneficial to be implemented on new constructions at UW where the asset data can be available from the first day of operation. COBie implementation on new constructions and doing the rebaselining can be prioritized based on the criteria discussed.

7.6- Why ARCF project needs COBie

Animal Research and Care Facility (ARCF) is basically a habitat for animals, and the facility maintenance is very crutial. The environment needs to be healthy and the vital needs of the animals must be available. For example, water is one of the vital needs of the animals. The pumps of water suppliers must be functioning all the time. Another example is the sensitivity of the animals to the frequency of the vibration, and machines should vibrate in a limited frequency range. This means all the building systems, like HVAC systems, must be functioning efficiently and be maintained very carefully.

ARCF has a complex vivarium system. The MEP cost of this building is like a hospital which is about two times the cost of the MEP of a typical building with the same size. The complexity of the system makes it harder to specify all the assets needs to be gathered by shop leads in case COBie is not implemented on building. Since animals will be occupied from the first day of operation, having access to different parts of the building will be very limited. This will add the challenge of site visit information collection. A huge number of assets needs to be inserted in AiM system, and it need plenty of time to gather information from site visit, O&M manual, and plans, this is while facility services need to have the information from the first day of operation. There are also new assets like bedding machines, or cage washers which are new for most of the shop leads. Experience has less to do with these type of equipment.

ARCF building has a high priority for COBie implementation. It has a complex MEP system, and it has a very crucial usage. PM work orders must be planned from the first day of operation, and there are lots of regulatory PMs which needs to be done regularly and the reports must be sent to the regulatory agencies. Based on the request of the FS, design and construction team are asked to provide the preventive maintenance guideline for the equipment in ARCF. The combination of this guideline along with the COBie information can ease the PM work order generation. COBie will also help the asset history track from the first day of operation and by providing the warranty information, it will ease the CM work order process.

Chapter 8: Discussion and Conclusion

8.1- COBie Value

The value of COBie for Facility Management is determined in two phases of turn over, and operations and maintenance. In COBie information exchange process, the O&M information is collected during the pre-design, design, and construction phases, and is transferred to the owner in turn over phase. In current practices of the information exchange, facility managers on the owner's side has the responsibility to collect the O&M data and insert it into the CMMS. COBie eliminates the information collection effort done on owner's side, and shifts it to the designer's and contractor's side. As a result, COBie can provide the O&M information from the first day of operation, while in current practices, the information collection process starts after the turn over phase.

The O&M information provided by COBie can ease the PM planning and performing CM work orders. For doing PMs and CMs, besides the O&M data provided by COBie, information in other sources like as-build plans, and O&M manuals are also needed, and COBie is not enough on its own for Facility Management. Based on the owner's COBie standard, and the information provided in COBie format for each project, performing PMs and CMs can be more reliant on COBie data than other sources. For example, COBie can provide PM, and impact information which are very helpful for PM planning and shutdowns. It can also provide parts list to prevent FM Managers looking into O&M manual for ordering the parts in performing CM work orders. This is while, not all the COBie specifications require the designers and contractors to provide these types of information. Overall, the more O&M information COBie provides, FM managers has less dependency on other sources to perform the work orders. There are also some information that COBie do not provide, like troubleshooting tricks of the equipment which still makes FM Managers to be relent on other sources besides COBie.

By eliminating the time spent on the owner's side for data collection after the turn over phase, and providing comprehensive and more accurate information from first day of operations, COBie adds value in the turn over phase. This information eases the PM planning and performing CM work orders, and as a result, COBie contributes to the operations and maintenance process.

8.2- COBie at UW

At University of Washington, usually there is no effort for collecting asset data, and creating asset profiles in CMMS system of UW, AiM, for new constructions. Only some important assets which usually have mandated or regulatory PM work orders are created in AiM in the early periods of the occupation, and the rest of the assets might be entered into AiM system if shops receive CM work order.

Analysis of time being spent on information exchange in COBie format, and current process showed that the time being spent is relatively close to each other in two methods. In COBie format the time is spent by design and construction team members, and in second format shop leads spend closely the same amount of time on FS side for data retrieval and asset profile creation. COBie provides the asset data from first day of operation, while shop leads start doing this process after the building occupation. Paper based process usually takes 1 to 2 years to be completed, and it only covers a part of the asset data in the building. In Dempsey Hall case study, only 62% of the data could be collected by shop leads in current process. Additionally, due to the control on the COBie process, data is more accurate than the current process.

This study focused on the value of COBie in operations and maintenance phase at UW. Research results show that COBie value in turn over phase is tied up with operation and maintenance phase. For a PM planning, the asset data needs to be collected, and asset profile needs to be created in AiM system. COBie provides this information in turn over phase. As a result, COBie eases the PM work order planning by providing the data from the first day of operation.

Despite the PM work orders, CM work orders are not planned, and they are received by shops in case an asset does not function properly. When all the assets are available in AiM, shop leads can check the attributes of the assets and perform the CM much easier in comparison to the case when the data is not available and they have to spend time looking for information. Asset profile availability in AiM will also let the shop leads to link the work order to the asset. Having the track of the asset history is very important for CM work orders, and asset operation planning. This is while in current process, asset data needs to be collected, and then asset profile should be created in AiM. There is an administration process for asset approval in the system which sometimes takes

3 to 4 days. Just a few shop leads are waiting for the asset approval and linking the work order to the asset. Most of the shop leads either do not link the completed work order to the asset or do not create asset profile at all. In current process, shop leads need to find the warranty document to check if the equipment is under warranty or not. This is while COBie provides the validation date of the warranty for the equipment which eases the CM process.

Asset data in COBie is not the only information shops need to do the work orders. They also rely on O&M manuals, and as-built plans. Those documents are digitally stored in FS-DOS system, or are available in paper format. The available sources for shops are not organized well, and shops are having challenges using them. There are two main sources available for shops, AiM and FS-DOS, but they are completely separate systems. COBie inserts asset data in AiM, but all other documents are stored in FS-DOS. Research results show that there is a need for linking these two systems for better efficiency of using the sources.

If the sources are available for the shops, and they do not have the challenge for using them, on average they can save 20% of their time. Due to the few technicians working in the shops, mandated and regulatory PMs are taken care of the most, and other PMs are canceled since the CMs have more priority. The 20% time saving can be spend on more PM works. A good standardized work order management plan, and asset document architecture, along with training programs can help UW to have a better facility management. With a new work order management team, and the effort of UW IT team, it is hoped that FS department starts working more efficient.

8.2- Future Study

The research results arises some questions about the actions needs to be taken in future at University of Washington. The first question is “Can FME be transferred to AiM?”. This is a question which must be answered for taking the further steps of COBie rebaselining for buildings built before 2009. This question would be of the interest of UW IT team, and FS to see how this data transfer can be done, who will be responsible for doing it, how long will it take, and how much of data can be retrieved?

Research also reveals that there should be a connection between AiM and FS-DOS. These are two separate main sources that shops are relying on. AiM has the capability for hyperlinking the documents in FS-DOS or any other source to the asset or property profile. The implementation has some of challenges. Some questions regarding implementation of this method arises: Which documents are needed for different types of assets? Who will be responsible for finding the related documents and put the link in the asset profile manually? How much time needs to be spent to create the link between these systems? Is there other solutions? Is it more reasonable to replace FS-DOS with a more efficient system? These are all the questions which needs to be answered for taking the future steps.

ARCF and Foege Building are two great case studies which can add a huge value to the COBie studies in United States. Track of the COBie implementation in turn over phase, and its effects in operations and maintenance phase will be very beneficial. Another case study can be the non-COBie information exchange in a new small scale construction in which all the shops participate in earlier stages of the project, and start gradually collecting the data using Submittal Exchange and getting help from design and construction teams.

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Appendix A – Interview Tool

Interview Tool – Stage 2

Interviewee Code:	**Date:**

1. Please define your job description.

2. Could you please walk us through a typical day for you?

3. What are the activities you do?

4. Which tools and software do you use for doing your job?

5. What resources and people do you rely on to get information?

6. What are the challenges you face doing your job?

The Work Flow diagram for PM and CM work orders are provided to the interviewee in this stage

7. Could you please walk us through the PM and CM process?

8. Where is your position in this workflow? What are your responsibilities?

9. Is this work flow current? Does it need a modification?

Providing information about COBie, implementation of asset data into AiM system, and talking about capabilities of AiM.

10. How implementation of COBie and access to asset data in AiM may change the workflow?

11. Which activities might be impacted by COBie?

12. If you were given the perfect tool, what would it be?

13. Do you have any questions for me?

14. Is there anything we haven’t discussed?

Interview Tool – Stage 3

Interviewee Code:	**Date:**

1. Please define your job description.

2. What type of systems and equipment you work on?

3. What are the specific needs your shop/zone have?

4. What are the resources you are relying on for getting asset information?

5. What are the tools and software you use? Hoe familiar you are with them? How often you use them?

6. What are the challenges you have using sources/tools/softwares?

7. Could you please walk us through a PM work order process? (It will be appreciated if you show the work order management in AiM system)

8. Could you please walk us through a CM work order process? (It will be appreciated if you show the work order management in AiM system)

9. Do you need help for doing your job in work order process? Who do you get help from? When?

Providing information about COBie, implementation of asset data into AiM system, and talking about capabilities of AiM.

10. How implementation of COBie and access to asset data in AiM may change the work order workflow?

11. Which activities might be impacted by COBie implementation?

12. Could you please pull up 10 different work orders you have done recently, and let us know the challenges you had with the WO, and how COBie can address the issue?

13. How much time on average can you save if you have asset data available in AiM with COBie implementation?

14. How much time on average can you save if you have all the information sources available to you?

15. Which type of buildings you suggest having COBie implemented on?

16. If you were given the perfect tool, what would it be?

17. Do you have any questions for me?

18. Is there anything we haven’t discussed?

Appendix B – Facility Services at UW

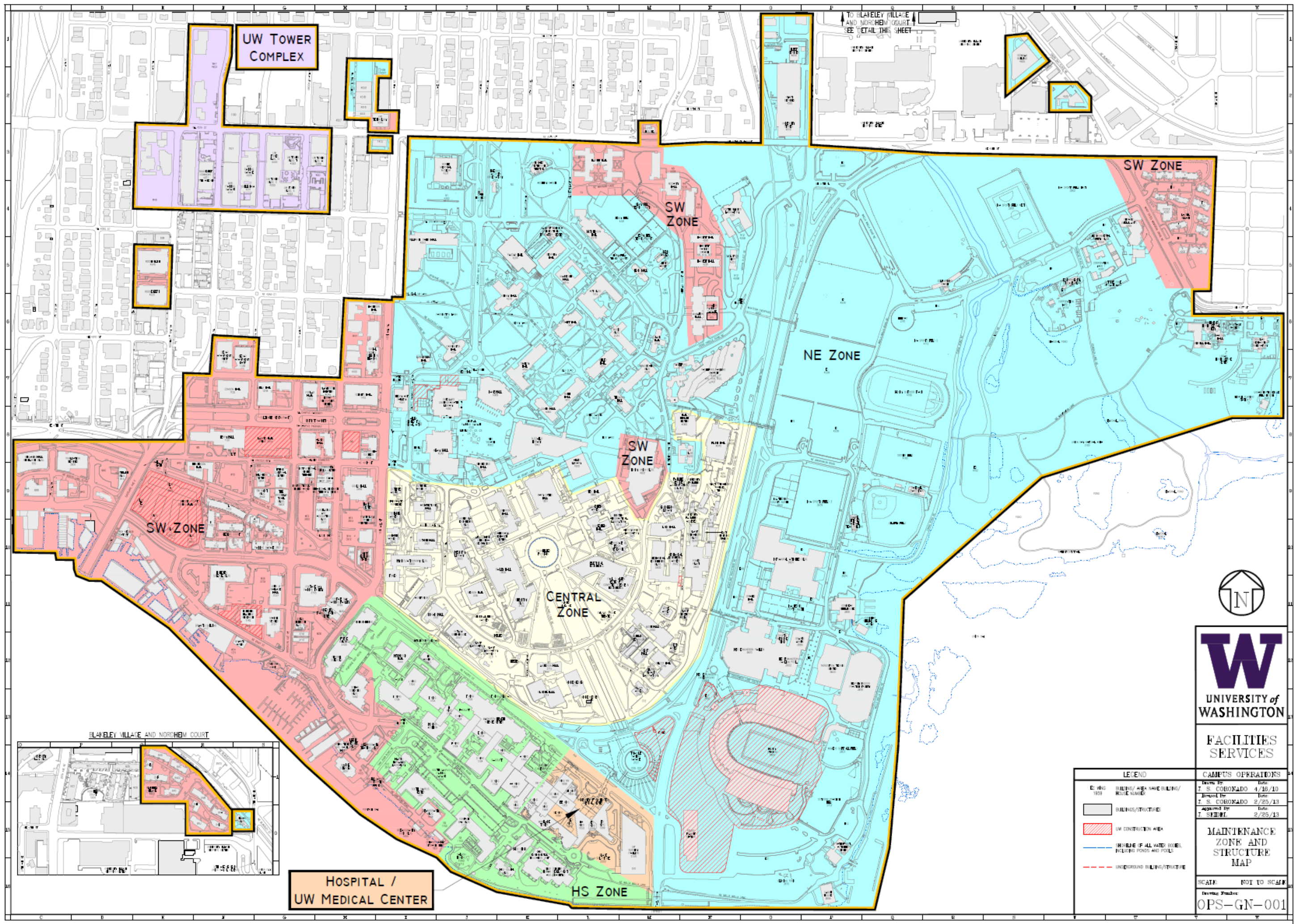

Figure 31 Four Zones of Facility Services at UW (UW FS Website)

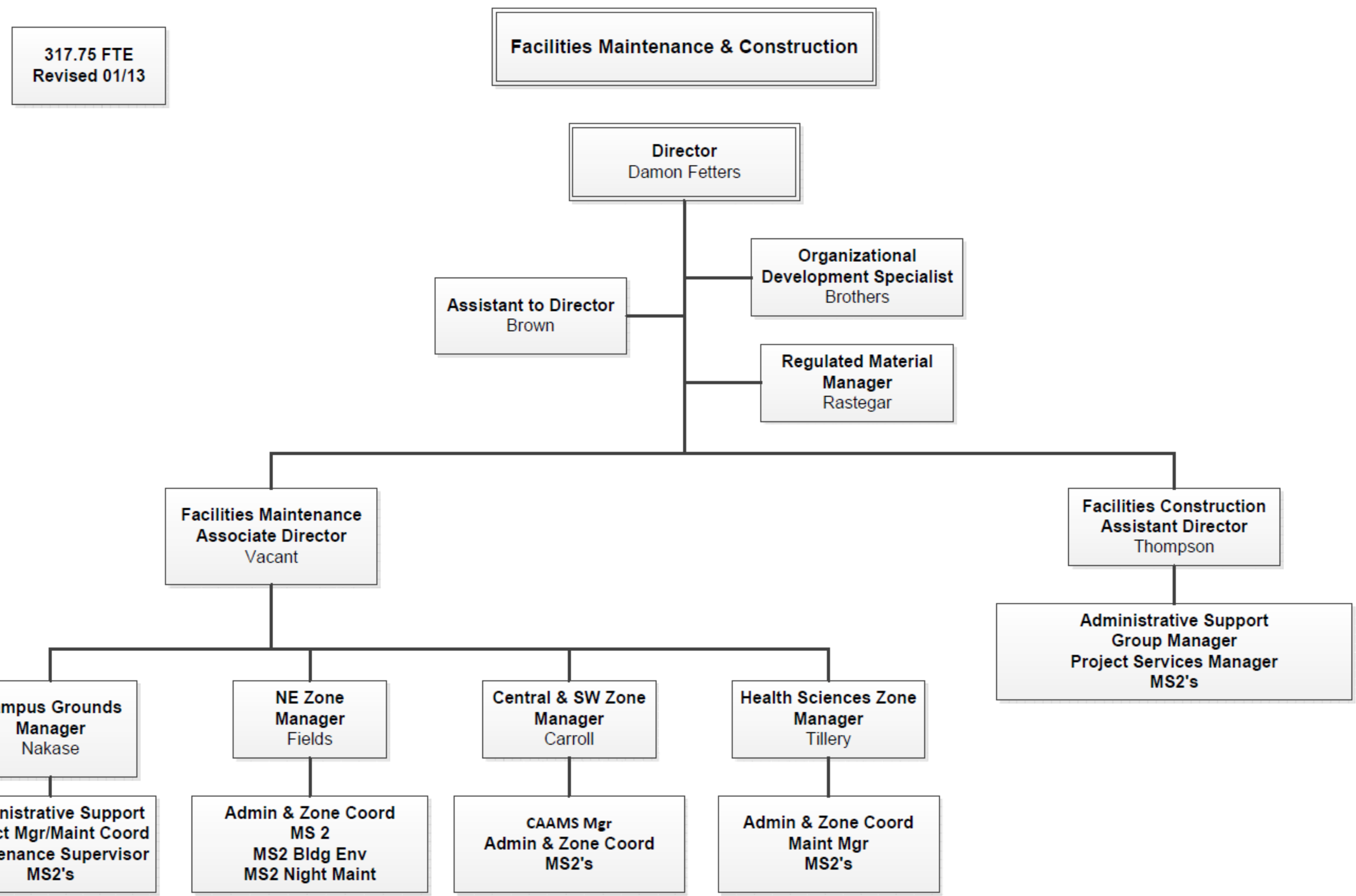

Figure 32 Facility Maintenance ad Construction Organization Chart (UW FS Website)

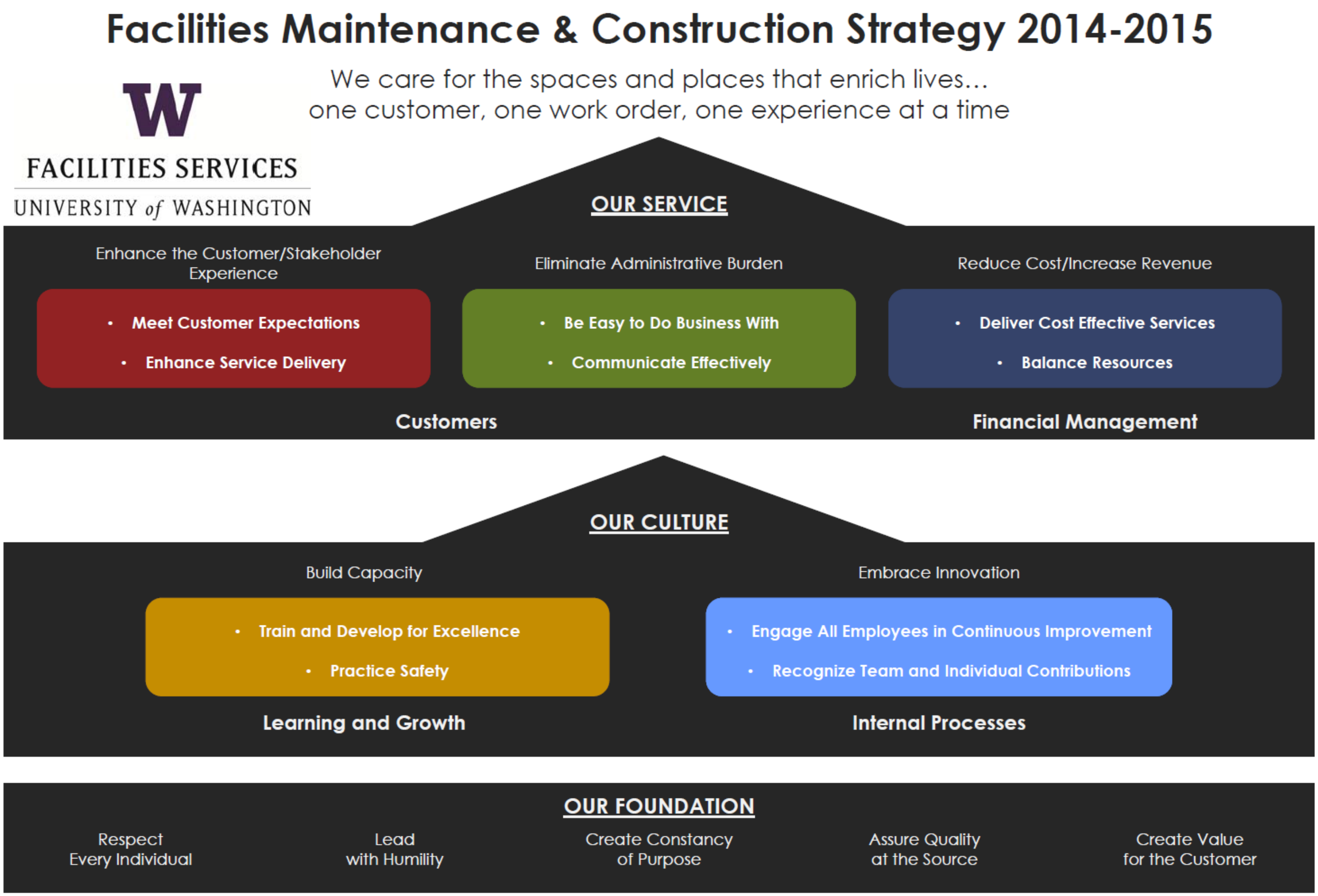

Figure 33 Facility Maintenance & Construction Strategy

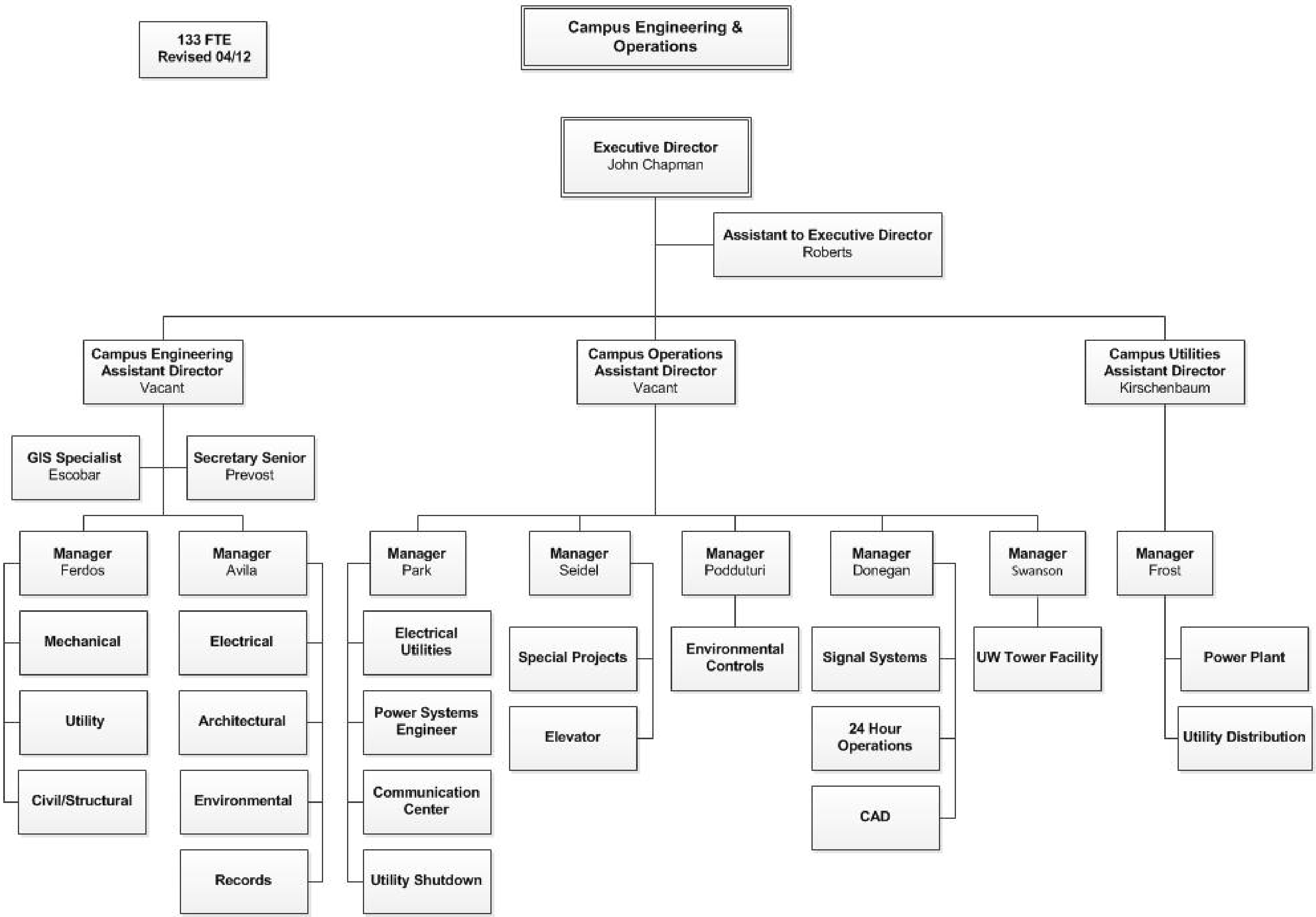

Figure 34 Campus Engineering & Operations Organization Chart (UW FS Website)

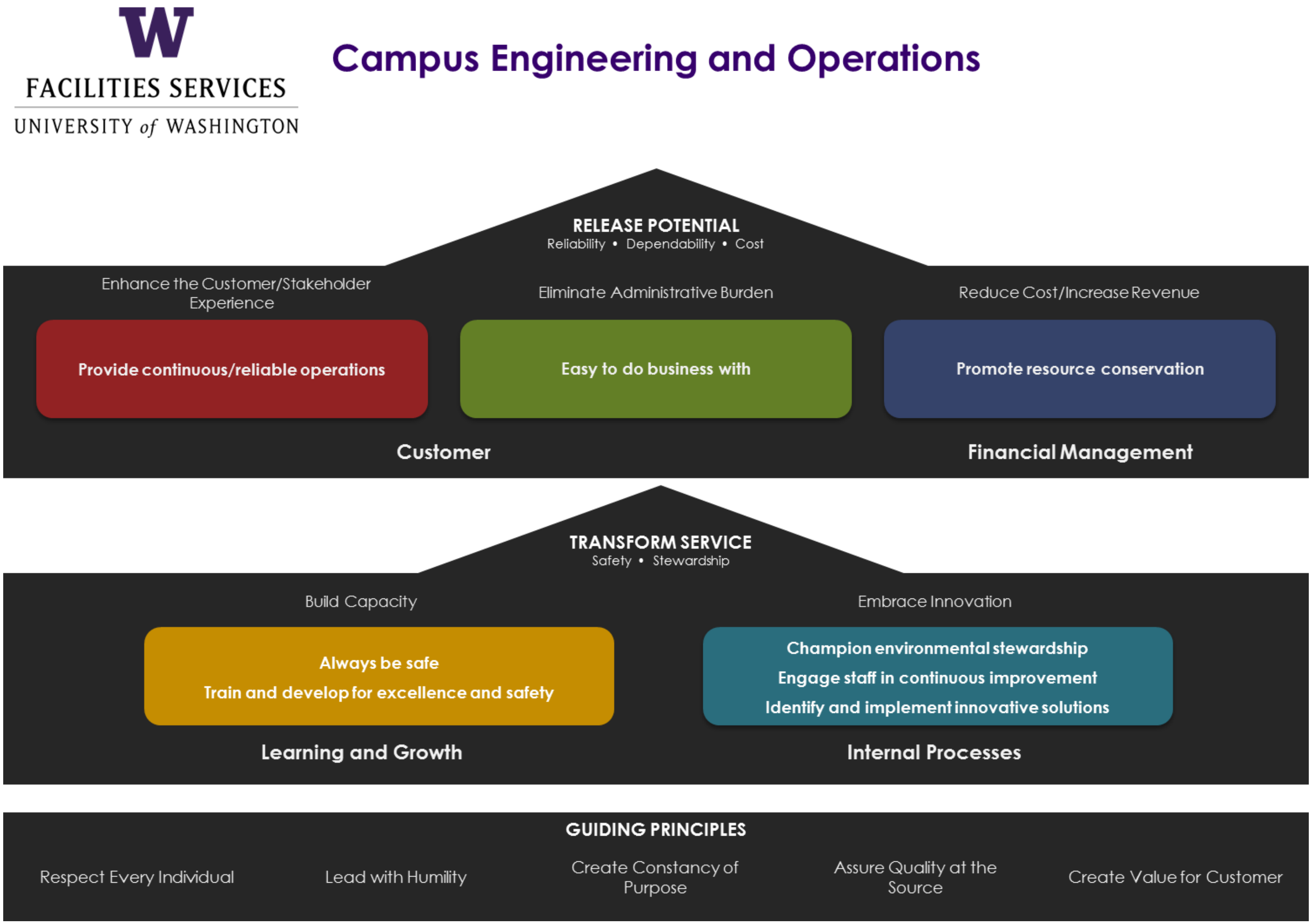

Figure 35 Campus Engineering and Operations Strategy (UW FS Website)

Appendix C - Swim Lane Diagrams

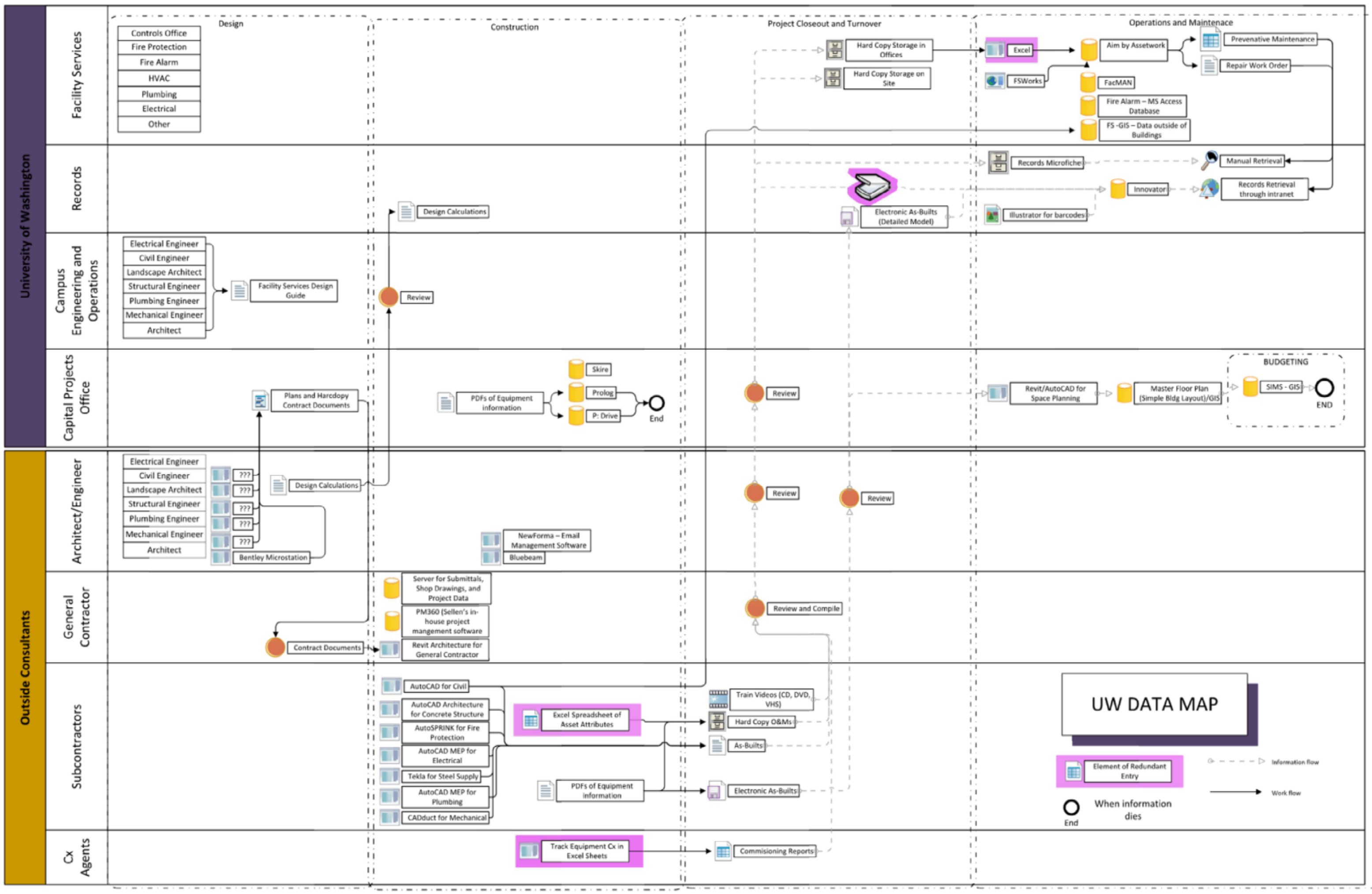

Figure 36 Swimlane Diagram of the different software programs and how where their products flow based on phases of construction project (Marsters, 2011)

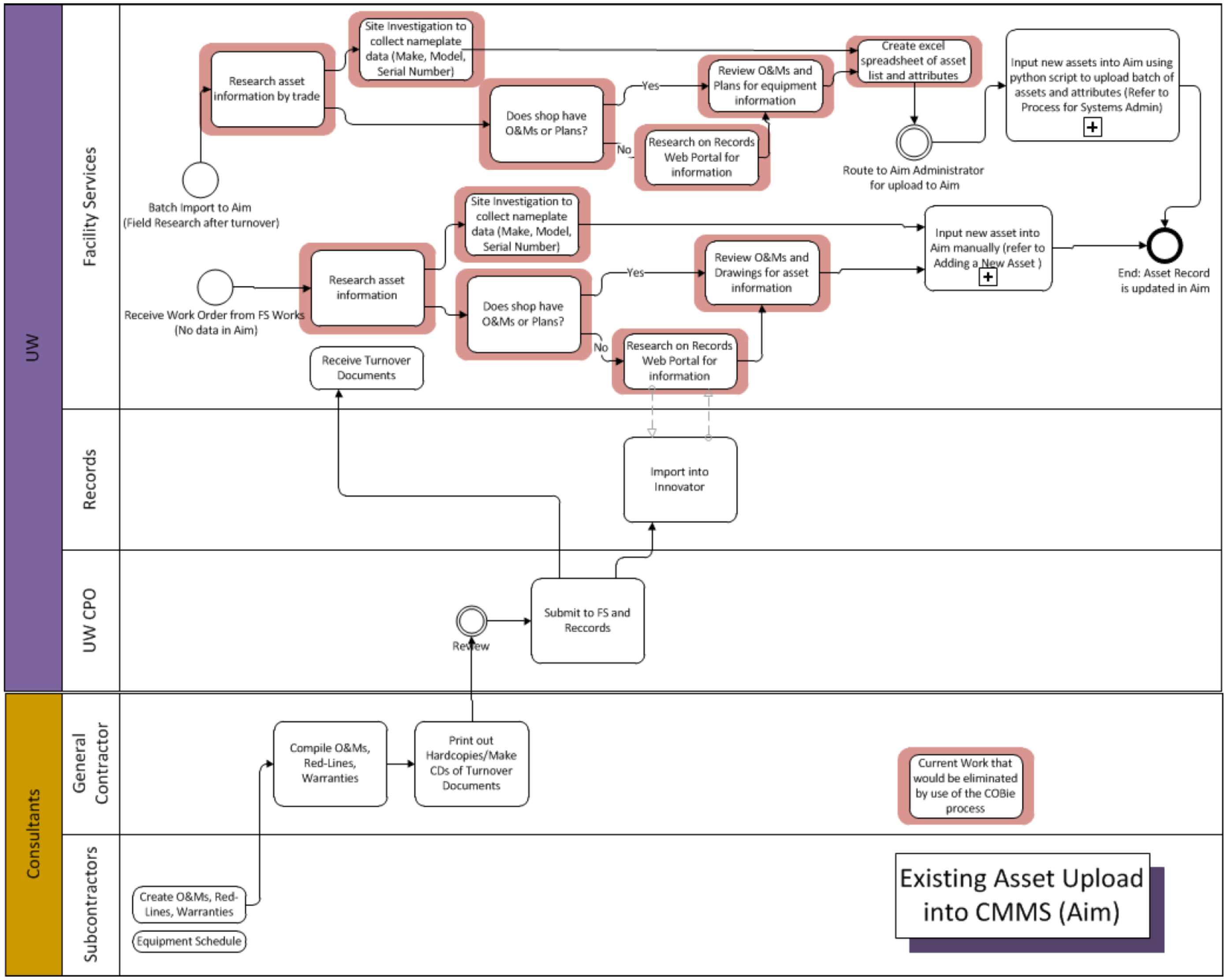

Figure 37 Current Information Exchange Work Flow

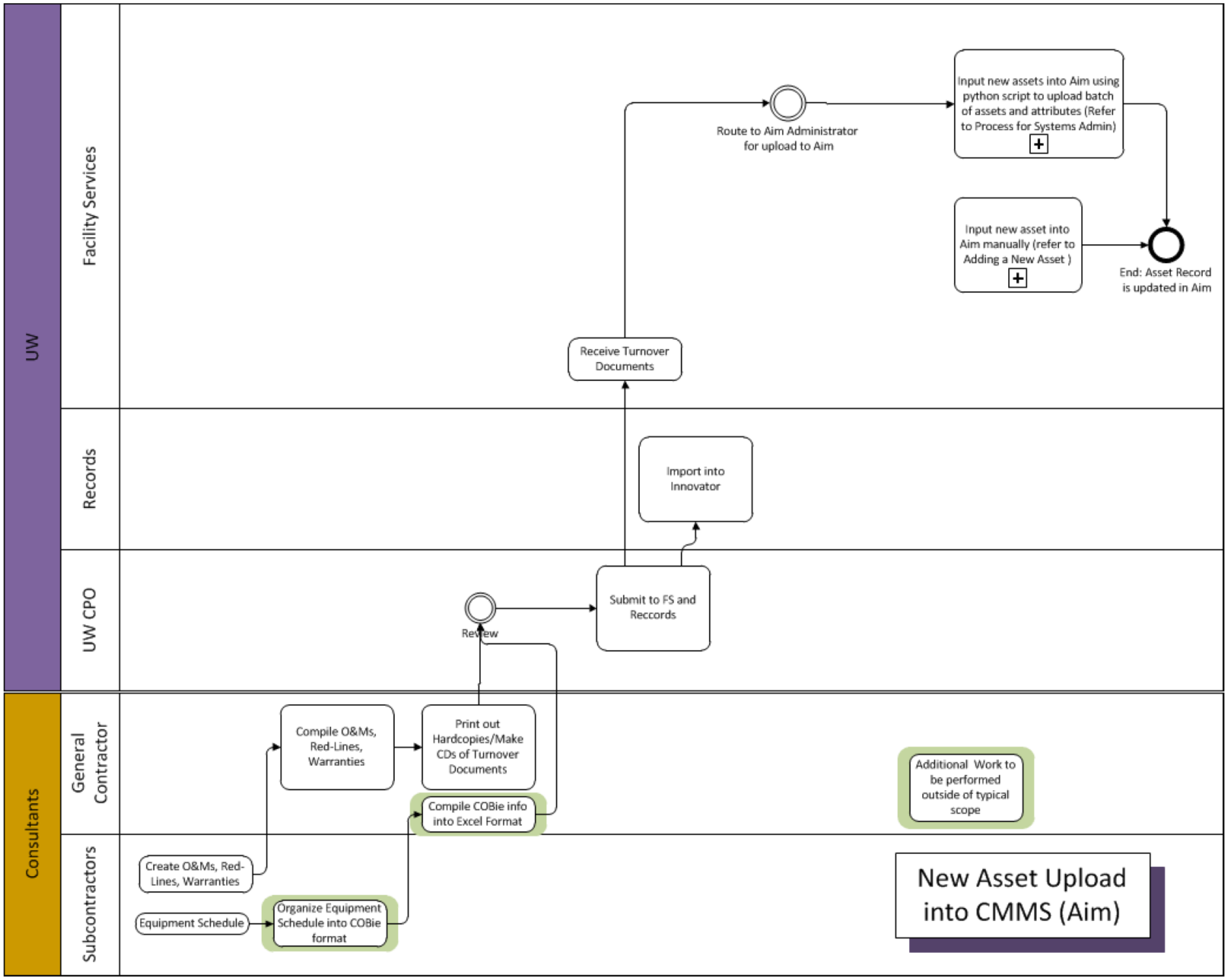

Figure 38 Information Exchange Work Flow in COBie format (Marsters, 2011)

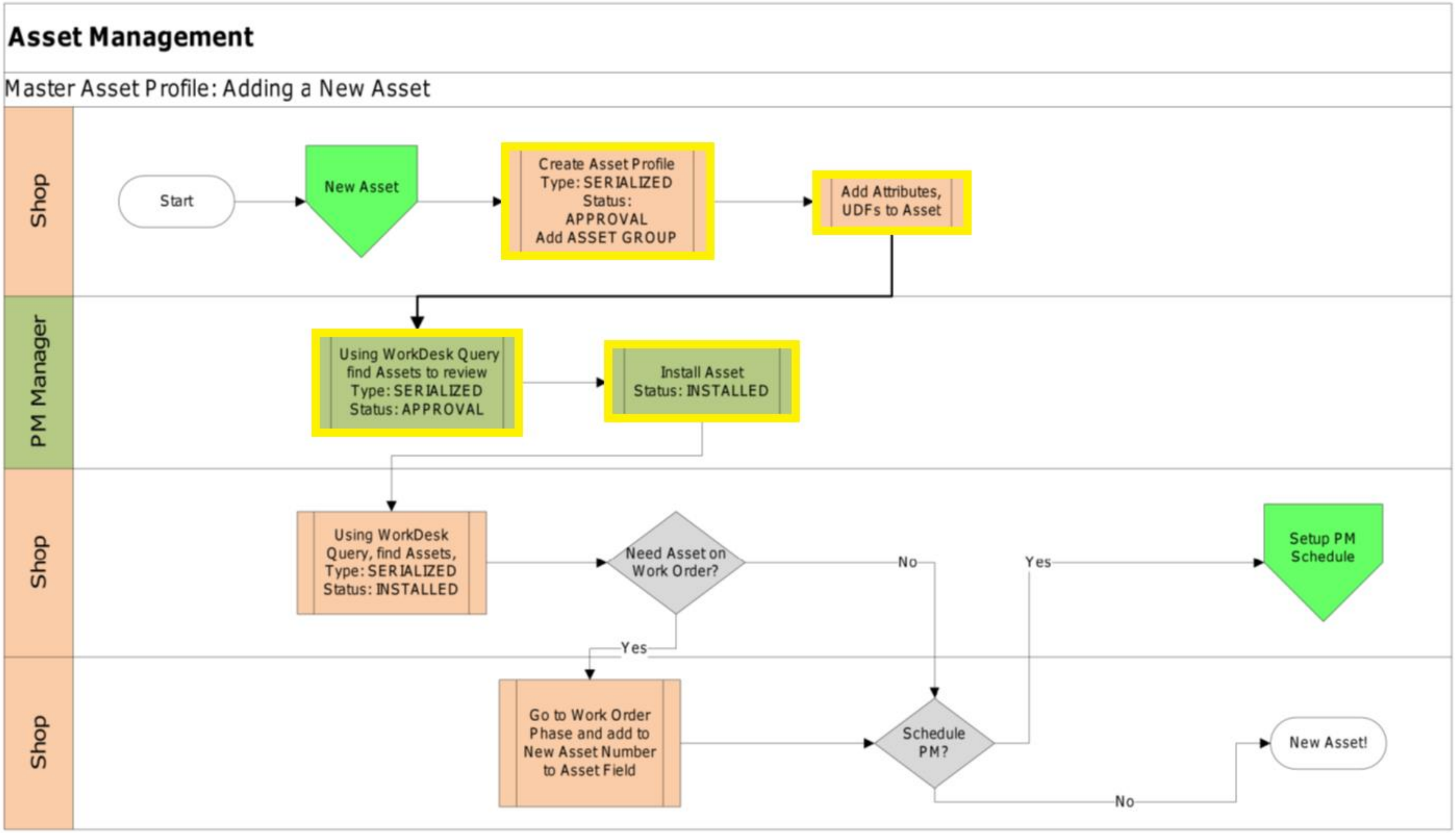

Figure 39 New Asset Creation in AiM System. Impact of COBie is highlighted in yellow (Source: UW FS Technology Toolbox)

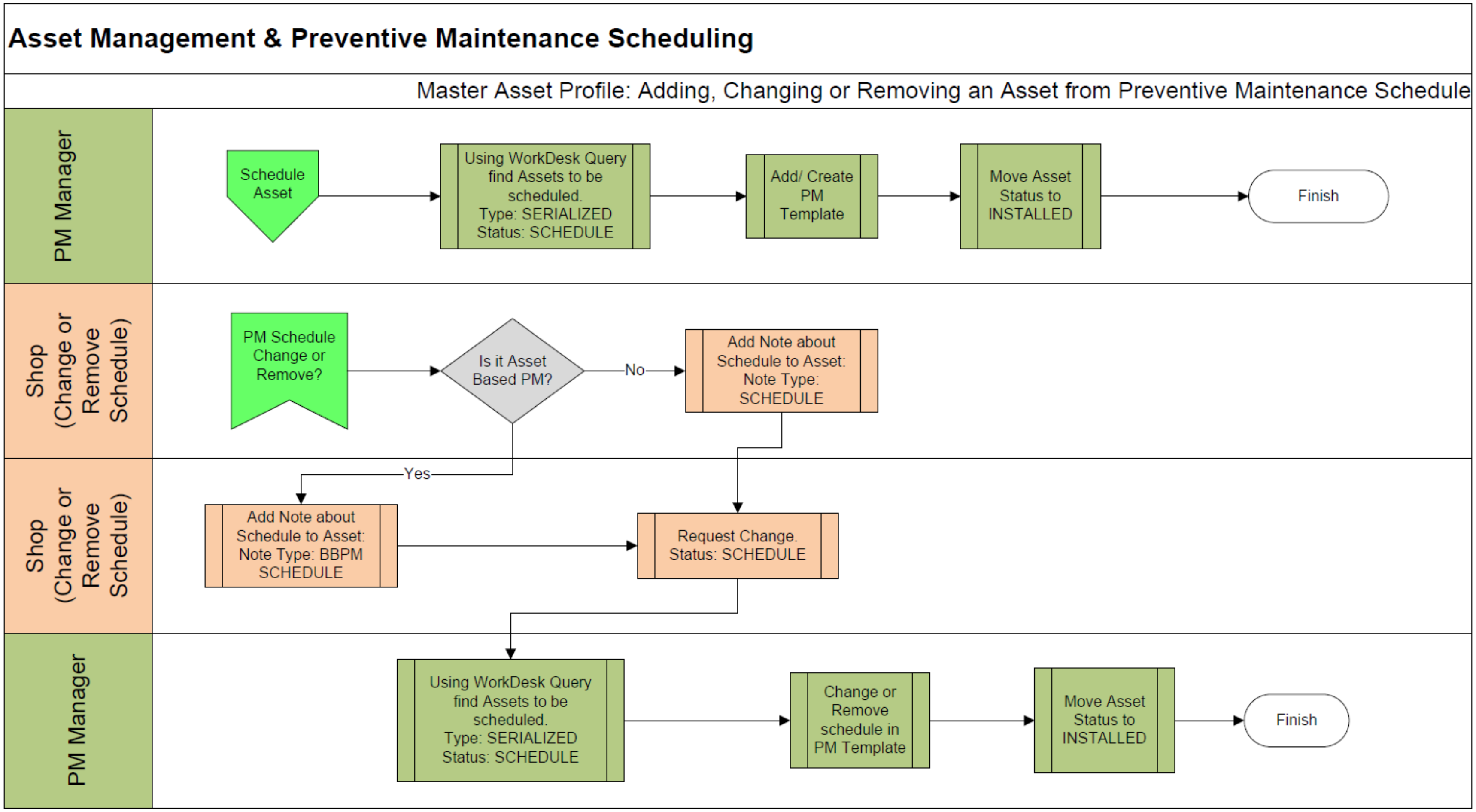

Figure 40 Asset Management & PM Scheduling (Source: UW FS Technology Toolbox)

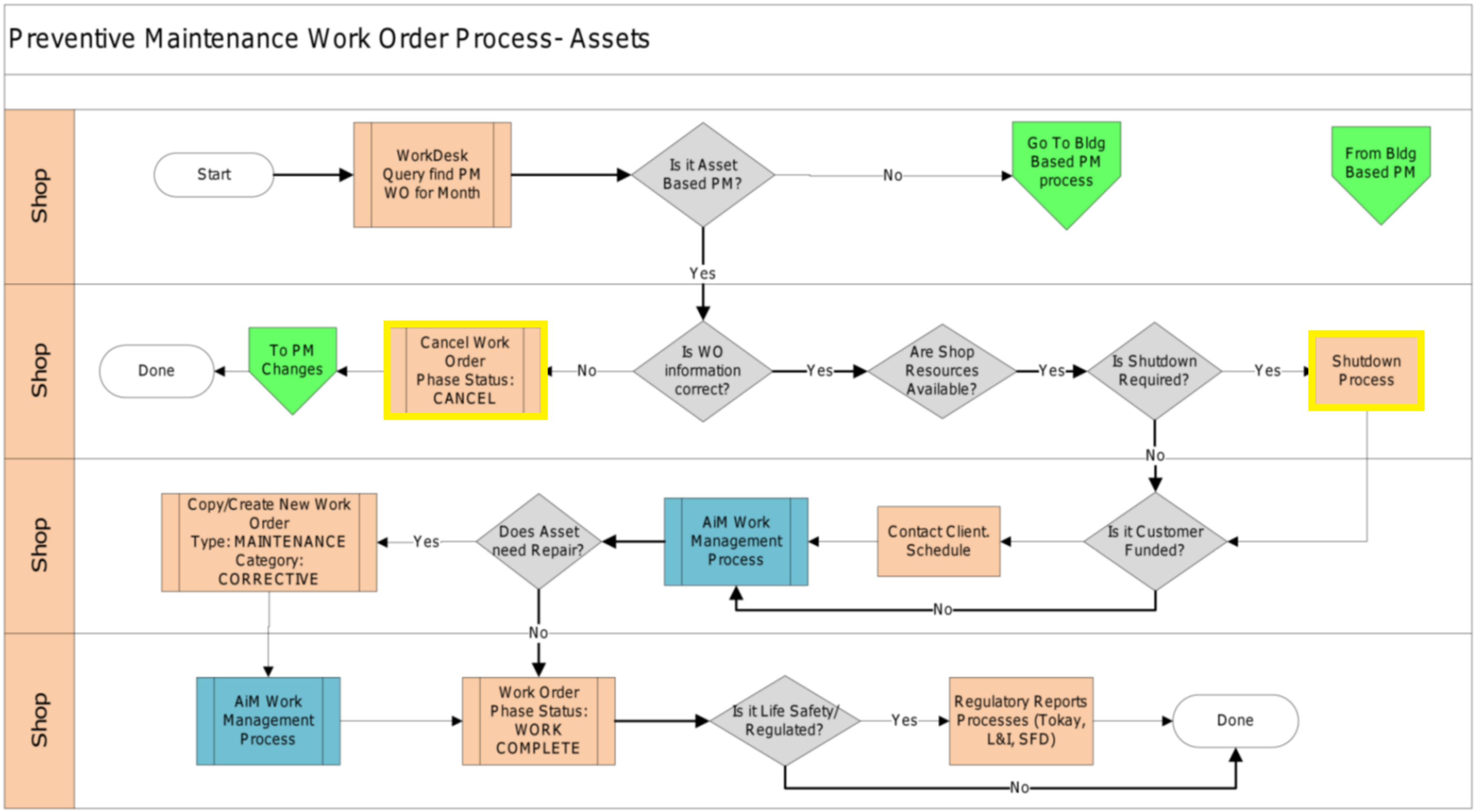

Figure 41 Asset Based PM Work Order Process. COBie impact is highlighted in yellow. (Source: UW FS Technology Toolbox)

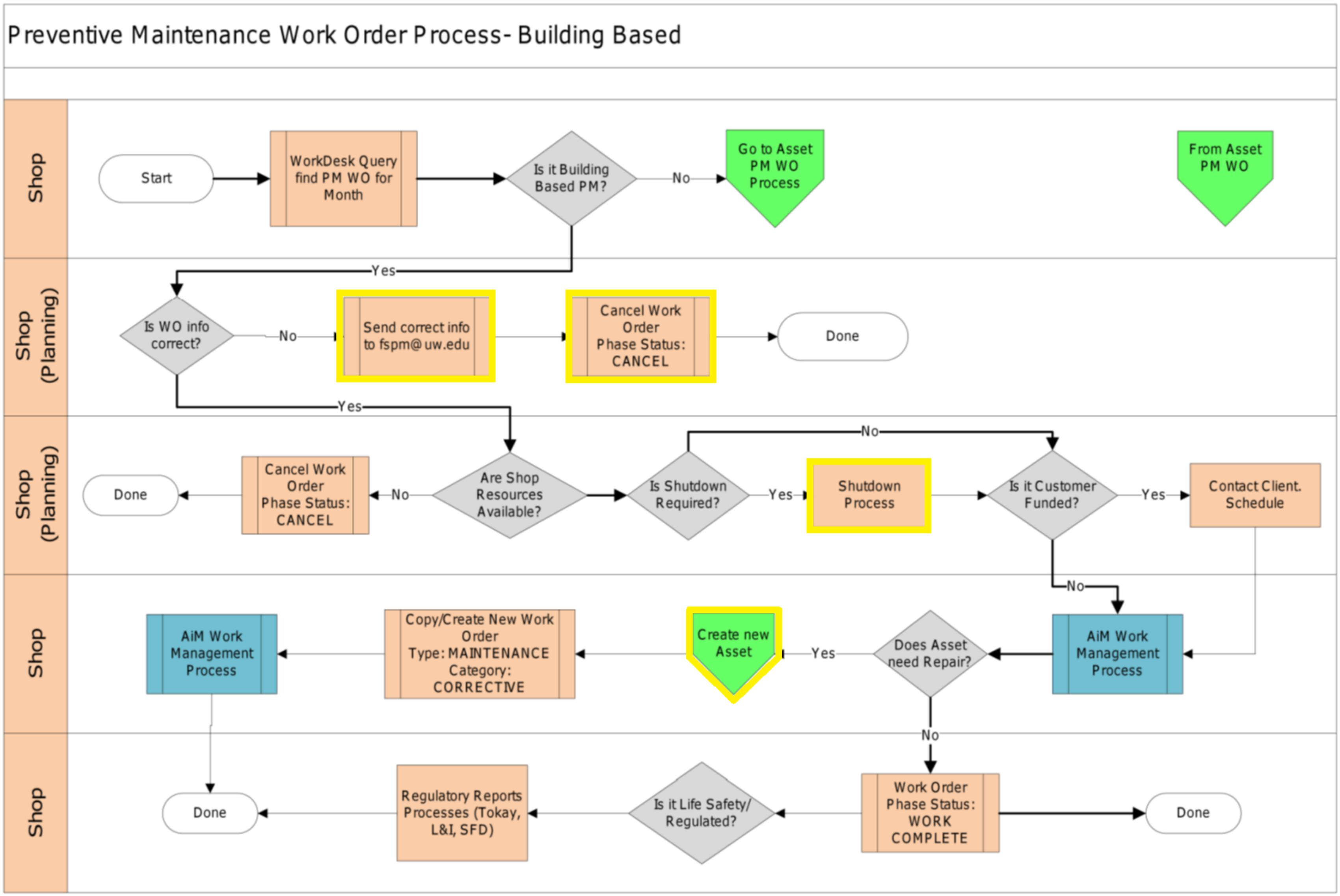

Figure 42 Building Based PM Work Order. COBie impact is highlighted in yellow. (Source: UW FS Technology Toolbox)

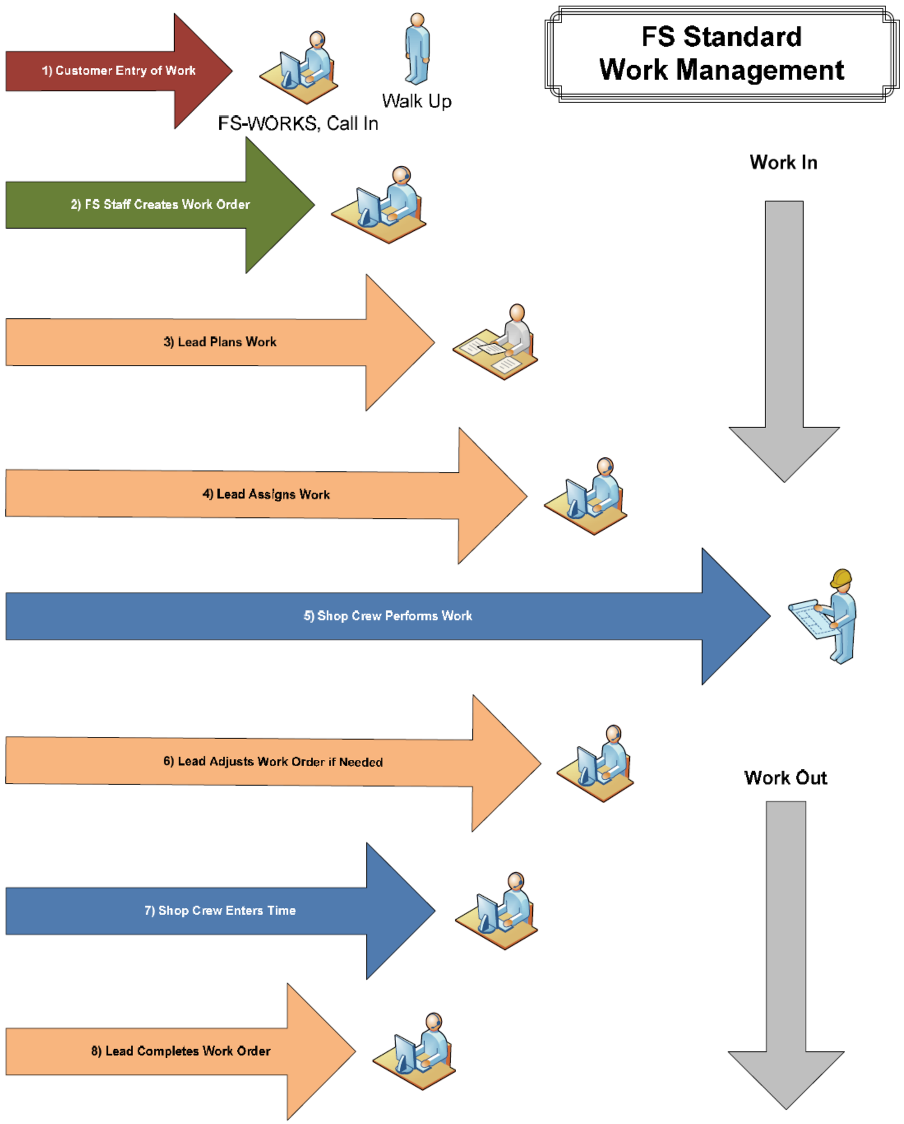

Figure 43 CM Work Order Management (Source: UW FS Technology Toolbox)

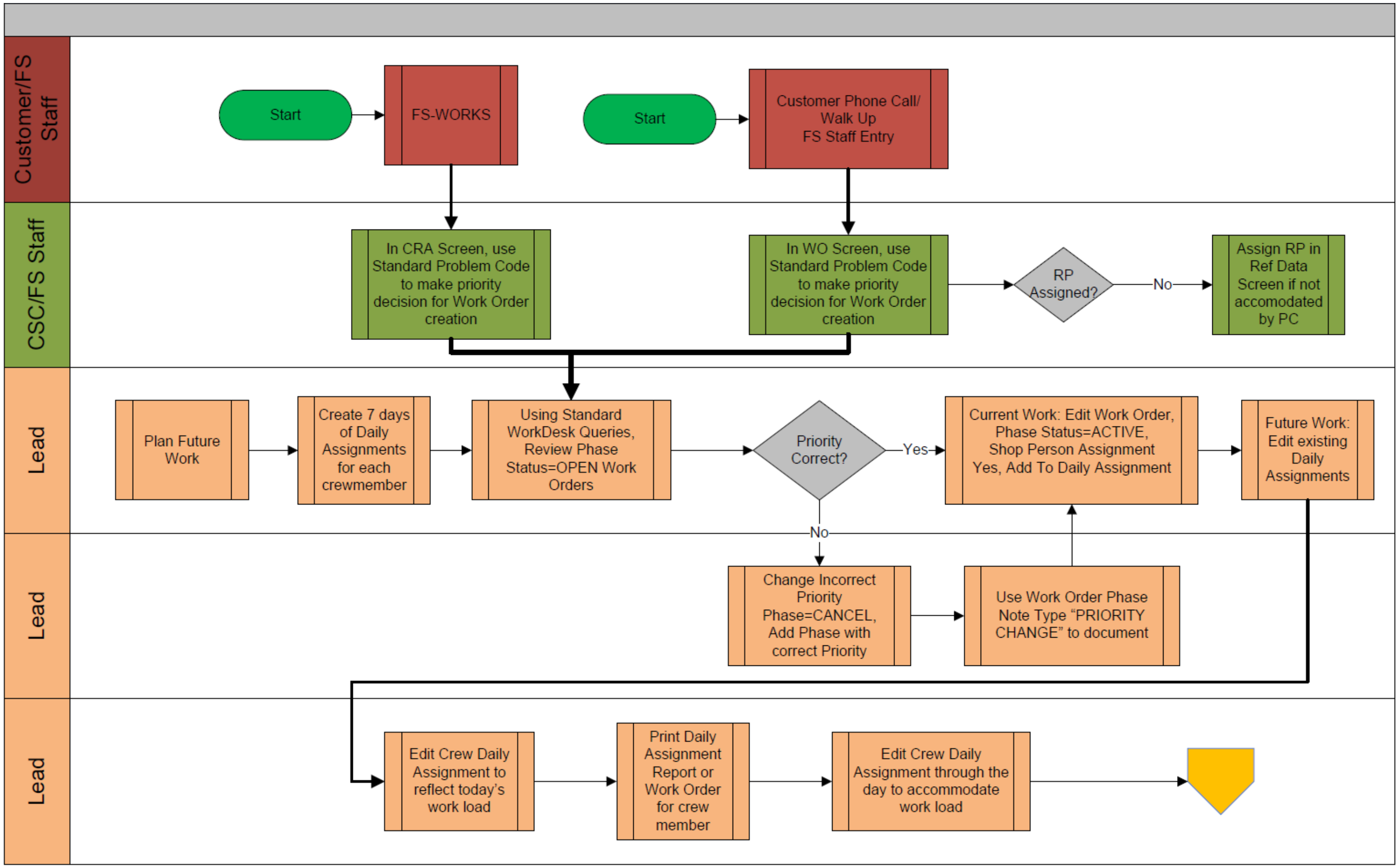

Figure 44 Work Order Management based on Priority (Source: UW FS Technology Toolbox)

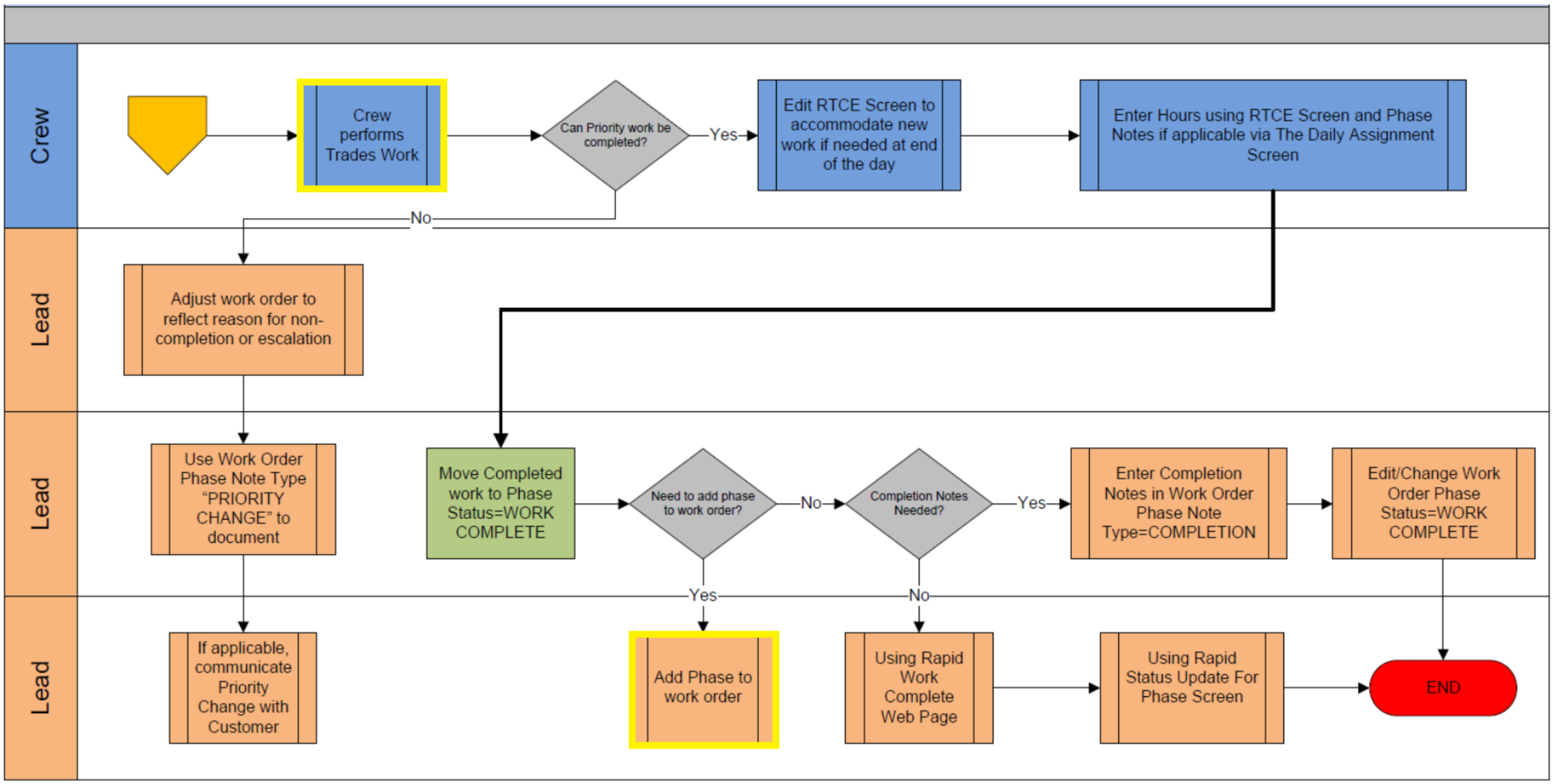

Figure 45 Continue of Work Order Management Based on Priority. COBie impact is highlighted in yellow. (Source: UW FS Technology Toolbox)