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Case Study of BIM Handover to Support Building Operations

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Abstract: Successful maintenance of increasingly complex buildings is critical to reach the performance, sustainability and financial requirements of owners. The use of Building Information Models (BIM) to support facilities management (FM) functions has gained inertia over the past several years as an important ingredient in meeting these requirements. However, for many owners, particularly large owners, the business case for migrating to BIM is not entirely clear. Although the potential benefits are significant, the transformation towards a BIM-enabled process requires equally significant changes to work practices, information flows, and technologies across the entire organizational network. This paper describes a retrospective case study where we examined the current practices of information handover on a recently delivered high-performance building designed with BIM for a large university campus. We analyzed the building information handover process, the completeness and accuracy of the as-built drawings, the organization and content of the models created, the adequacy of the design to support building operations and maintenance, and the level of integration with building management systems. Our initial research identified inconsistencies and inaccuracies in the information delivered, limitations with the reusability of the information, and inefficiencies in the handover process. Although we believe that a more rigorous BIM delivery process will help to address these limitations, we have also come to believe that each organization will require tailored processes that fit ever-changing internal technologies, information requirements and organizational processes to successfully implement a BIM-enabled process.

1 Introduction

It is imperative that facility managers have up-to-date and reliable building information to support operations and maintenance (O&M) activities of increasingly complex facilities. When up-to-date information is missing, additional costs are incurred due to searching, validating and recreating information (Fallon and Palmer 2007). The quality, efficiency, and reliability of the information handover process is therefore critical for facility managers to reach the performance, sustainability and economic requirements of facility operations. *Information handover* is defined as "handing information over to organizations responsible for subsequent life cycle stages of the facility" (Fallon and Palmer, 2006). Jensen (2009) found that most building information is used solely for documentation of the building project without much active usage during the operations phase. East and Brodt (2007) describe the problems with the current handover procedure as: the information collection process is prone to error, information is less than satisfactory, the information format is inadequate for effective use, and there is insufficient information about the equipment performance in relation to the design intent. Corry et al

(2011) describes the issues in current information management practices as having a format that is not conducive to computerised analysis, limited ability to assess performance over time and limited use of digital information. These studies demonstrate that the current methods of information handover to owners are extremely inefficient due to the lack of timely, accurate, and complete information provided.

BIM has the potential to address these challenges by providing a data-rich, non-redundant information repository of facility information that is capable of supporting a broad range of FM activities. The consistence, continuity and traceability of facility documentation by BIM greatly reduce design re-invent, re-do and re-creation during different phases of building life-cycle and applications (Au, 2009). BIM use during design and construction has grown rapidly in recent years (Bernstein and Jones, 2012).However, the utilization of BIM for operations is a relatively new area and the business case for implementing BIM in the O&M phase is not entirely clear. Although the potential benefits are significant, implementing BIM in large owner organizations is a complex challenge and there are still significant hurdles that owners need to overcome to fully utilize BIM. It is imperative that work processes and software tools be aligned to produce and deliver the required information, and there has been little opportunity for owners to quantify the benefits of BIM in the O&M phase (Fallon and Palmer, 2007).

In this study, we examined the current practices of information handover on a recently delivered high-performance building designed with BIM for a large university campus. The purpose of this retrospective study is to examine and benchmark the current handover processes and information, and to start to lay the groundwork for assessing the business case for a large owner organization like UBC to move towards a BIM-enabled operations and maintenance process. We investigate the quality, accuracy, reusability of the handover information for facilities management, and examine and benchmark current processes and work practices throughout the organizational network. We believe that BIM implementation within large owner organizations is not only a technology problem, but rather the whole implementation process necessitates a significant structural change, and organisations need to reconfigure work practices to fully realize the benefits of BIM. We therefore approach this problem from three perspectives: *technology, information and process* based on the *organizational* context. Specifically, we investigated: (1) the building information handover process, (2) the completeness of the handover drawings and usability of the design BIM, and (3) the maintainability of the facility. Our objective with this phase of the research is to benchmark existing work practices, and to develop a richer understanding of the potential challenges in changing these work practices. This is an important first step in addressing our long term research goal which is to better understand both the business case for implementing BIM in the operations phase and the organizational transformation required to make this transition.

The next section summarizes related research on the information handover process and recent case studies that have investigated BIM use in the operations phase.

2 Relevant Studies

Recent studies have demonstrated that BIM has the potential to provide more real-time and accurate facility information in an integrated form, reduce redundant data collection, reduce uncertainty when making investment decisions, provide enhanced visualization of facility data, and provide better access to O&M information (NRC 2012, Fallon and Palmer 2007, Francisco Forns-Samso D. 2010). Some owners have recognized the potential for capturing the information needed to fine-tune building system performance, establish appropriate maintenance practices and schedules, and evaluate the feasibility of proposed expansions or renovations (Fallon and Palmer, 2007). Recently, there has been a significant effort to integrate BIM and different facility management software through information exchange specifications. Construction Operations Building Information Exchange (COBie) is “an information exchange specification for the life-cycle capture and delivery of information needed by facility managers” (East, 2013). COBie seeks to reduce the cost and improve the quality of information handover from commissioning to O&M. The COBie approach envisions capturing information exchange over the facility lifecycle incrementally throughout the facility planning, design and construction, and closeout commissioning processes.

Several studies have examined the use of BIM for O&M on university campuses. Anderson et al (2012) evaluated the current handover and COBie enabled processes, and found that organizational cultures and practices need to be developed around new datasets enabled by COBie and BIM. Specifically, the study found inconsistent naming, storage and data type conventions among projects, challenges with the usability of IT by staff, and concerns about information overload. Other case studies have analyzed the benefits of BIM/COBie for O&M and demonstrated that work order cycle time was reduced (East, 2011), time spent verifying as-built conditions was reduced (Kasprzak and Dubler 2012, Rojas et al. 2009), and time spent re-entering data was reduced (Autodesk, 2013). Recent efforts have tried to develop return on investment (ROI) calculations for lifecycle BIM that can be used by owners in assessing the business case for BIM. Table 1 (left) shows the areas of potential improvement and how an owner might quantify savings from BIM integration (Ecodomus 2013). Table 1 (right) shows some example BIM ROI calculations completed by the International Facility Management Association (2013).

Table 1: Lifecycle BIM ROI Calculator

	Areas of Potential Improvement	**Savings From**		**ROI Calculations**
EcoDomus (2013)	FM Labor Savings	Faster access to information	***IFMA (2013)***	Net initial investment $100K reduced by $41,667. Annual savings over 25-year lifetime of building $37,430 (present value over 25 years is calculated as $478,481). Reduced by the initial cost to yield net present value $420,184 An internal ROI of %64. Payback period for the net investment 1.56 years
	Utility Cost Reduction	Improved energy management		
	Risk Management	Risk mitigation		
	Fuel and Material Savings	Driving less		
	Comfort Management	Productivity improvement		
	Equipment Life	Better management		
	Data Accuracy (As-Builts)			
	Regulations Compliance			
	Space Optimization			
	Improved Inventory Management			
	Configuration Management			

These research efforts and case studies demonstrate the potential benefits of BIM utilization in building operations. However, additional work is needed to better understand the issues and challenges of BIM adoption from multiple perspectives and to better articulate the business case for Owners.

3 Case Study Project and Methodology

We examined the current practice of information handover on a recently delivered high-performance building designed with BIM for a large university campus, the University of British Columbia (UBC). UBC serves more than 37,000 undergraduate and 10,000 graduate students. UBC Building Operations is responsible for a 405 hectare campus area which includes 225 university-owned buildings (810,119 gross square meters of floor area).

This retrospective case study focuses on the building information handover process of the recently constructed Centre for Interactive Research on Sustainability (CIRS) building. CIRS is among the most innovative and high performance buildings in North America and aims to be “a state-of-the-art ‘living laboratory’ in which to conduct research and assessment activities for high-performance building systems and technologies (www.cirs.ubc.ca). CIRS was designed using BIM but the model did not progress past the design phase. We have been actively researching this building since the early stages of design all the way through construction so we have a deep understanding of the design and how it was created, and also have access to all the information that was created through completion of the construction process. Our focus now is on the operations phase and understanding how the information created during design and construction is being used to support operations.

Figure 1: CIRS Rendering (Left) and CIRS in Use (Right)

Data was collected using the following three methods:

1) Interviews with key personnel: We interviewed numerous personnel to understand their work practices and how building information is utilized (Table 2).
2) Reviews of current O&M technologies used: We observed the technologies used in the Operations Center where the buildings across the campus are monitored and managed. We were also shown UBC's new asset and maintenance management system. We observed the technologies used in the CIRS BMS operations room.
3) Reviews of numerous documents: We reviewed numerous documents about UBC's current procedures, technical guidelines, and work requests. We also reviewed all design information submitted to the Records department for the CIRS building.

Table 2: Interviewed personnel and information collected in the interviews.

Interviewee	Data Collected
Maintenance Technical Specialist	To identify operational and maintenance concerns about the building. This helped us to understand the requirements of O&M compared to the handover of building information.
Record Systems Administrator	To understand how the handover information is received, uploaded into databases, and used by different departments within the university.
Senior Analyst of Maintenance & Renewal	To investigate different tools and databases used for maintenance and asset management.
Head BMS Operations	To understand the different systems used to monitor and manage campus buildings, including the different visualizations and interfaces used by the different software.
CIRS BMS Technical Specialist	To investigate how the BMS and related building information is used to facilitate the operation of CIRS.
Technical Services Manager	To investigate the UBC technical guidelines and how these technical requirements are incorporated into the information handover.
Head Maintenance Engineer	To understand the maintenance personnel's information requirements, information availability, methods of accessing information, and the usability of information.

4 Examination of the CIRS Information Handover Process and Artifacts

This section summarizes the findings from our evaluation of the CIRS project models, handover process of the owner organisation and handover information supplied to the owner. The analysis aims to identify the technology, information and process challenges of the current practices. This analysis helps to inform where and how BIM implementation can be beneficial in reshaping the current practice to overcome the challenges with current use of handover information for operation and maintenance. We will be using this investigation of the current practice as a benchmark to evaluate BIM-enabled test cases in the future.

4.1 Current Building Information Handover Process

This section examines the current building information handover process from the organizational perspective, with a particular emphasis on the management of that information (the Records perspective) and the use of that information (the Maintenance perspective).

The Records Office is the main source of building design information at the university. All building information, such as as-built drawings, manuals, and specifications, are received and managed by this department. The Records office has created a structured data environment for drawings, specifications and manuals according to internal specifications. They have scanned or created PDF records of all building data for the entire campus. They also manually add meta-data[1] to make the information searchable and accessible. Metadata can be building title, building number, division, sheet number, date, drawing type, creator, project number, physical file location (if there is a hard copy), as well as any other additional information or comments.

Currently, the Records Department receives the building information *"simply when it shows up".* According to the Records System Administrator, the quality of information in the handover documents *"varies from building project to building project. Sometimes you get lot of information, and then sometimes you get next to nothing. There is no standardization of the way a building manual is put together. It really depends on maybe the contractor or the subcontractor."* The Records Department has no way of verifying the accuracy or completeness of the handover information: *"if you come in looking for information about any part of the building or any building I can show you what we have, that's the strength, I know exactly what we have, I can find it right away, I can show you when we received it. What I can't tell you is that it is right. We are entirely depended on what was sent to us."*

According to the operations personnel, the sets of information handed over to the Owner is typically insufficient to meet the needs of FM. For example, the Maintenance Technical Specialist mentioned that receiving installation manuals of equipment after the equipment is already installed is "*useless*" for them. In the current process, the Records Department sometimes receives information about equipment that is not even installed in the building because contractors have sent generic information from manufacturers' lists. Some contractors do not even black out unnecessary information in these documents which makes it harder to find the required information in the document sets. The Records System Administrator also gave some examples of missing information in the handover set: *"they will say, oh that will be in the specs, they specified what they wanted to use. The specs will say use new materials."* The problem gets more complicated for the projects that are built in phases or go for partial occupancies because it is more difficult to define project completion for such projects. In such cases, project participants wait for the project completion to submit the handover information, and operations and maintenance personnel are left with no documentation about the building while the building is already in use. Handover information from different phases of the same building are often completed by different consultants and contractors which causes additional problems with information uniformity and structure (e.g. inconsistent drawing and room names, multiple drawings for the same floors).

Departments within the university often require information at different levels of detail to perform their tasks. Databases that are accessible by everyone may not contain information in the required detail. We were told that, in such cases, people start building up and using internal sets of information in *"micro databases".* Data in these micro databases are easily accessible, with the required detail, and in a better format than the information available to all departments through the central document management and FM systems. These micro databases, however, lead to duplication of effort by different departments since information about a piece of equipment may be kept in two different databases. When a system or piece of equipment is replaced with a different brand, this information is forwarded to the Records Office to be

[1] "Metadata are defined as data about other data. Metadata are used to organize the information and to search for particular items" (Fallon and Palmer, 2007).

updated on Laserfiche. However, this information is added to the existing database without removing the old data. In such cases, users might be using outdated information without realizing it.

In terms of the usability of building information for maintenance purposes, we investigated the current maintenance information requirements and use from the mechanical maintenance perspective. We noticed that the current information sets do not allow specific queries in the data sets. The Head Maintenance Engineer mentioned that such an interface would be useful. For example, an electrician looking for a panel in the building has to look through different plan drawings rather than searching within a system or component data set. The same interviewee mentioned that he finds looking for information on Laserfiche frustrating, because he thinks that searching through the interface is slow compared to having a printed manual around and flipping through its pages. This interviewee also mentioned that sometimes scanned PDF documents on the system are of poor quality and do not allow interactions like copy/ paste which hinder the reusability of the "digital" information.

Maintenance personnel noted that having explicit definitions of systems and components is more important in research buildings with labs since there might be ongoing experiments during a required maintenance. For example, when a compressor in the building needs to be shut down for maintenance, sometimes the maintenance personnel may not know what labs if any are serviced by that compressor. As a result, they need to go through extra steps to make sure that the shutdown will not affect the safety of ongoing activities within the building. Maintenance personnel also noted that having a documented work history on systems and equipment is important to eliminate waste during operations*: "There is no one central point that you can see what maintenance, what history has been done on that piece of equipment, so you don't know how many times somebody has visited that, is there a reoccurring problem that somebody has fixed."* Through our interviews we learned that maintenance personnel have limited access to technology when performing daily tasks and the transfer of tacit knowledge between personnel often happens informally during coffee breaks or over radio conversations. The Head Maintenance Engineer noted that current practice in the campus is strongly dependent upon personal knowledge of maintenance personnel who become familiar with the buildings they maintain over time.

Maintenance personnel also emphasized the challenge of getting access to the required maintenance information: *"we have to spend the time and go over, set up, and pull the pump and hope that the data tag on the pump is there, so that we can get enough information to either get replacement part or tell us what the criteria of the specs are. And then we can go and try to find it or procure it. Whereas we click on something and it pops up what it is. I don't have to waste my resources in sending somebody over there… It would mean basically saving time, especially if it is critical and to not wasting resources pulling out (the pump) twice; one to have a look at what the problem is and then the second time to actually do the job."* Being able to see what is included in each system is also important for inventory management: *"… we think we have done them (fan coils) all, and then somebody complains about two months later and we go "we never knew this was here". And especially for ordering, sometimes we don't know if we order eighty or if we need one hundred and twenty".*

4.2 Completeness of the Handover Drawings and Usability of the Design BIM

We evaluated the completeness and accuracy of the as-built documentation that we retrieved from the Records Office for the CIRS building. We focused our investigation on the drawings from the basement where the main mechanical, plumbing and electrical system components were located. We identified building information that was either missing or inaccurate. Snapshots from the construction drawings, the mechanical BIM and the actual mechanical room are shown in Figure 3. It should be apparent from these images that most of the piping for plumbing design is not represented in the drawings. In this example, piping on the ceiling is not represented on either 2D drawings or the model, and the size and number of expansion tanks is misrepresented when compared with the picture taken after the project completion. 2D construction drawings and the model also misrepresent the mechanical control center's (MCC) size and location in the room. The actual picture from the room shows that the actual MCC unit is different in layout and size than indicated on the plan drawings and in the model.

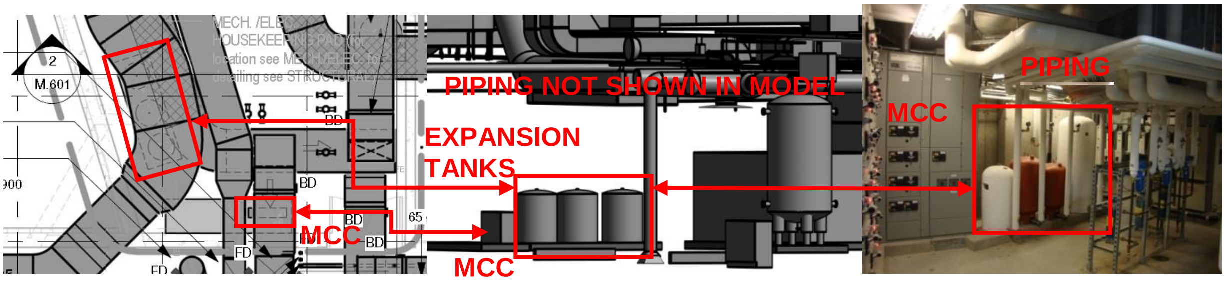

Figure 3: Missing and inaccurate information were identified in the model and in the as-built drawings.

We also analyzed the comprehensiveness and usability of the CIRS BIM for FM use. Although the CIRS design was created in BIM software, the design model was not included in the information turned over to UBC. As stated previously, the design model was not developed to reflect the as-built condition of the project. The owner did not require an FM model and there were no specifications for such a model. This was one of UBC's first BIM projects so FM model was not a consideration at that time given the lack of experience within the industry. Our interest was to better understand how useful the designer-focused BIM would be for FM. Naturally, the design BIM was at a coarser level of detail (geometry and information), many components of the MEP systems were incomplete, and these systems were not explicitly defined. Component and system information, such as performance, warranties, and manuals, were also not available in the model, which is to be expected in a design BIM. Our focus was to investigate the component and system information structure and availability in the model. We examined the consistency of the model information and representations and compared that to the campus operations and monitoring systems and processes.

We investigated the CIRS model in a lifecycle data management application called Ecodomus (www.ecodomus.com). Space names and zones had to be aligned in the architectural and mechanical models in the BIM authoring software. Later Navisworks files were created from the architectural and mechanical models and uploaded on to the lifecycle data management application. This enabled us to investigate the information in the CIRS model which showed that the mechanical model lacked useful information (Figure 4) such as spatial information, equipment type, equipment serial number, manufacturer, system name and classification, warranty information, circuit number, panel information etc. The lifecycle data management application we used enables us to add information and information structure through the interface. The interface allows us to use 3D visualisation to select components and investigate the attributes that are available or the attributes that we wish to add to the model components. Although we have not implemented yet, the application has the capability to integrate building automation system, work order management system, document management systems to make FM information more accessible.

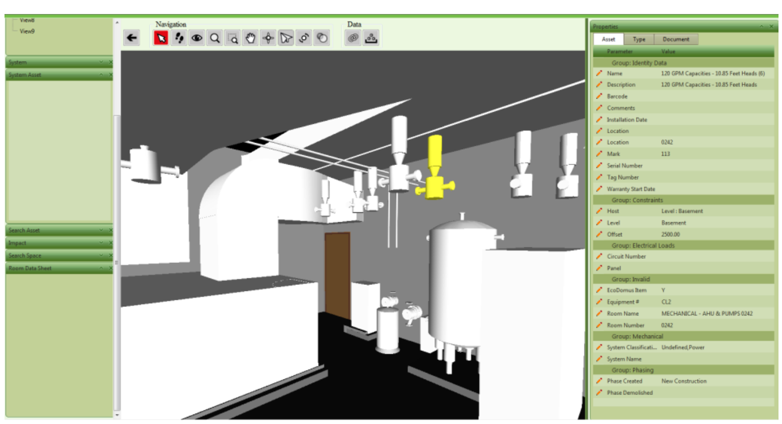

Figure 4: Investigation of the O&M information available in the design model using the lifecycle data management application.

4.3 Maintainability and Operation of the Facility

We evaluated the maintainability of CIRS based on interviews and a walk-thru with the Maintenance Technical Specialist. We focused on the maintainability issues in the basement where most of the complex systems are located. This task helped to inform how modeling requirements are established for design consultants so that the maintainability of the design is optimized. Most of the maintainability problems were related to not having the required equipment access space. We identified mechanical system components that are hard to access or impossible to access without removing other systems or building components.

In the current delivery process, O&M personnel had limited input in the design process and as a result system component maintainability requirements were not considered extensively during the design. This is particularly challenging with the current delivery process where the MEP systems are detailed during construction by the MEP trades, making it even more difficult to get early input from operations personnel. The Head Maintenance Engineer mentioned that sometimes they may not see some of the maintainability problems even during the walk-throughs performed before handover, because some components may have not been put in place at the time of the walk-through. In the CIRS case, the facility design posed significant challenges to the maintenance staff. The main mechanical room is considered to be very cramped and hard to maintain by the O&M personnel. In the main mechanical room, pumps are located underneath the ceiling and they are buried under a maze of pipes, and are almost impossible to maintain without removing other components. We were told that some of this equipment requires maintenance as often as every two years so this is a significant challenge. Many of the VAV boxes in this cramped room are also very hard to access which makes it challenging to see the position of the VAV setting. Figure 5 shows the control box for an air-handling unit installed at a location that is almost impossible to access. O&M personnel need to crawl into the tight space each time they need to access the control box.

Figure 5: Restricted Access to the Control Box of the Air Handler Unit (AHU).

Figure 6 from the bike room in the basement shows that required service space for a heat pump interferes with the piping located on the wall, making it very hard to access the pump from the wall side.

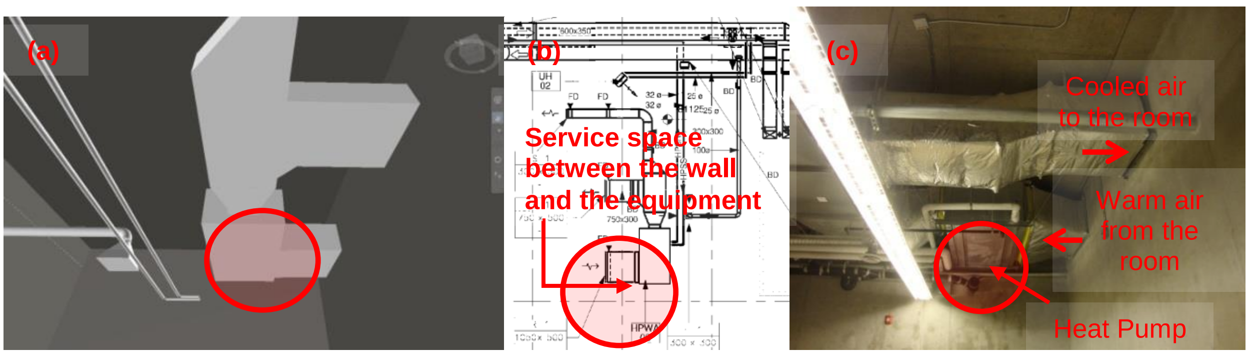

Figure 6: (a) Model view, (b) As-built drawing representation, and (c) Picture taken during operation.

The construction drawing does not show the pipe that is installed at the same height, therefore interfering with the required service space. We were told that maintenance personnel struggled to find a way to access the equipment from this tight space to fix a recent problem. We were also told that this problem could have been avoided simply by designing and installing the whole equipment about one foot away from the wall.

5 Discussion

Owner organisations face a significant challenge when moving towards a model-based process. Our initial research shows that each organization requires tailored processes that fit ever-changing internal technologies, information requirements and organizational processes, in order to successfully implement BIM-enabled digital handover and O&M processes. The business case has to make sense for owners considering the scale of the effort involved, particularly given the legacy systems, software heterogeneity, and organizational divisions that exists on university campuses. To establish the business case for large owners, we investigated the current processes, artifacts, and systems used and tried to understand how the handover process of one building fits within this bigger picture. This study identified a number of current challenges, including the accuracy, reusability, and the accessibility of handover information during O&M. The handover information lacks structure that is required for integration with FM tools; the FM information is not integrated in the campus. Achieving compliance with handover information structure and content with the available databases and software is a challenge. Our findings show that it is important to understand the challenges with getting the required accurate O&M information in a reusable format, in a timely manner and in sufficient detail. If the information is not received during handover, gathering basic system and asset information from campus buildings requires extensive effort.

Owners also need to decide what information they need for specific FM functions. Knowing how the owners are going to use the information effects modelling and the context of the handover BIM. A BIM requirements document, developed by each owner for their specific needs and uses of the models, can save all project participants considerable time and effort. We recognize that COBie and BIM planning guides (e.g., The BIM Planning Guide for Owners by CIC Research Program) will help with this, but the scope and scale of the transformation for an owner should not be underestimated. Challenges like resistance to change, the slow rate of adoption, getting buy-in from the users, and the many organisational and process issues show the scale of effort required for BIM integration in FM from an organisational perspective.

The challenge now is *quantifying* the ‘costs’ of the inefficiencies with the existing process and the potential benefits of moving to a BIM-based delivery process. This phase of the research helped us to establish a baseline in which to understand some of the issues that owners should consider, but translating these issues into metrics that can be quantified is a significant challenge. The next phase of our research will focus on this challenge.

6 Conclusions and Future Work

BIM use in design and construction has grown rapidly in recent years. We have learned a great deal about the significant challenges project teams faced when moving to a BIM-based project delivery process (e.g., Neff et al. 2010, Anderson et al. 2012). Although the potential of BIM to benefit owners has been widely cited, there are actually very few examples of successful implementation of BIM throughout owner organizations. We believe that owners face even more significant challenges with moving towards a model-based life-cycle process. Although the technological challenges are significant, it is evident that the bigger challenge is dealing with changes in processes and procedures, information flows and work practices throughout the different organizational units. It is for this reason that it is imperative that the business case for making this transition be thoroughly investigated.

This research study examined the current information handover process for a high performance building recently completed for a large university. We found inefficiencies in the handover process, inaccuracies and inconsistencies in the information delivered, a lack of integration between different FM systems and limited or inefficient access to building information in support of operations and maintenance activities. Leveraging BIM for FM has the potential to help solve many of the issues mentioned in this paper by providing a data-rich, non-redundant information repository of facility information. The next steps in this research will focus on developing the business case more formally by identifying quantifiable metrics based on the inefficiencies identified in this study. We will also begin the next phase of this research which will investigate the benefits and challenges of a BIM-enabled process for operations and maintenance.

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