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Article

BIM Guidelines Inform Facilities Management Databases: A Case Study over Time

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Abstract: A building information model (BIM) contains data that can be accessed and exported for other uses during the lifetime of the building especially for facilities management (FM) and operations. Working under the guidance of well-designed BIM guidelines to insure completeness and compatibility with FM software, architects and contractors can deliver an information rich data model that is valuable to the client. Large owners such as universities often provide these detailed guidelines and deliverable requirements to their building teams. Investigation of the University of Southern California (USC) Facilities Management Service's (FMS) website showed a detailed plan including standards, file names, parameter lists, and other requirements of BIM data, which were specifically designated for facilities management use, as deliverables on new construction projects. Three critical details were also unearthed in the reading of these documents: Revit was the default BIM software; COBie was adapted to help meet facilities management goals; and EcoDomus provided a display of the collected data viewed through Navisworks. Published accounts about the Cinema Arts Complex developed with and under these guidelines reported positive results. Further examination with new projects underway reveal the rapidly changing relational database landscape evident in the new USC "Project Record Revit Requirement Execution Plan (PRxP)".

Keywords: BIM; building information modeling; facilities management; FM; operations and maintenance; O & M; building lifecycle

1. Introduction

Building information modeling (BIM) is a set of digital tools and processes that is primarily used to streamline the design, engineering, and construction of new buildings. Whereas the phases from design to construction might typically last about 2–5 years, the overall life span of the building is conservatively 20 years, probably much more. BIM has a critical role to perform as a contributor to a well-designed facilities management (FM) system; by supplying 3D geometry and attribute data that can streamline operations and maintenance over the long term. BIM guidelines and deliverable requirements provided to the architect or contractor insure a standardization of data that can more easily be incorporated into FM software. In order to test this assumption, a single case study research method was adopted that included the following: a literature review of common uses of BIM for FM, a study of the openly available USC FMS BIM guidelines, a summary overview of the USC Cinematic Arts Complex project implementation, and non-structured discussions with three experts: the USC Associate Vice-President of Facilities Management Services, the CAD Services Manager, and a more recently hired virtual design and construction (VDC) architect for USC Capital Construction Development (CCD). This methodology resulted in insights as to the process of developing and applying BIM guidelines, the lifecycles of guidelines, and the current ongoing development of a shared FMS and CCD "Project Record Revit Requirement and Execution Plan (PRxP)".

This paper outlines key advantages of using BIM for FM, elaborates on a few specific examples, outlines the USC FMS BIM guidelines and their relationship to the Cinematic Arts Complex buildings, describes shortcomings, and discusses a current set of standards and processes. The inquiry is how BIM guidelines to supply FM deliverables continue to evolve as a result of practical pressures at USC from 2010 to 2015.

2. Advantages of Using BIM for FM

Many researchers, book authors, and even facilities managers have proposed using the data in the building information model to assist with building and operations administration. Advantages for owners and managers are apparent: Spaces can be managed; the model can help quickly populate the FM database saving labor time and money, and assets can be effectively managed; the model can be used for building performance simulations and commissioning; operation simulation tools may be able to use data from the model; and as-built information can later be used for retrofits [1]. The model can provide data needed for FM that is useful for maintenance and repair, management of energy, and the commissioning of the building especially if the concerns of FM are articulated at the early stages of design [2]. Other benefits include better visualization of system components, ease of modification, the ability to filter data for staff use, and the advantages of having one coordinated system with integrated BIM and FM [3]. Both authors also described novel uses of the model to also assist in planning routes, the former for path optimization for maintenance crews and the latter for smart emergency evacuation. In a special issue of *JBIM* on BIM plus facilities management, Jordani proposed that BIM should be used as the on-line portal for owners; he used the USC School of Cinematic Arts as an early example of what was accomplished by the Urban Design Group and "highly skilled people" for moving BIM data into a FM portal [4]. However, he also cautioned that for broad adoption, the "lean processes" of transferring the design and construction data are still under development and require further dialogue within the building industry.

However, worries were also articulated by users including how they were going keep up with maintaining the integrity of model over time in order for it to stay functional and that existing computer aided FM systems were already in use and familiar to users [5].

Ayayic *et al.* in a case study for a new university building in MediaCity UK, articulated similar issues: The importance of space planning, accurate quantification of assets such as furniture and equipment, and interoperability incompatibilities between software programs [5]. Accurate space management, efficient population of the FM database, and using BIM data for preventative maintenance are three common reasons for BIM to integrate better with FM; to achieve these owners need to develop BIM guidelines and insist on a record BIM for new construction and retrofits.

2.1. Space Management

Spatial BIM has as its primary focus the managing of space rather than building elements or inventory [6]. Space is itself a valuable and manageable asset. It has intrinsic value after the building is completed and is treated as a major tangible asset. It can be rented or re-assigned to other people and is often the key locator for other items like equipment, furniture, voice and data lines, lighting fixtures, people, *etc.* Detailed knowledge of its size, location, use, and contents is important. This information is relatively easy to insert into a building information model (either typed in directly or through spreadsheets), can be accessed through schedules within the software, and exported in a common used file format for FM use. Owners set requirements based on their needs, and architects provide further insights for the architectural program. The listing of spaces and their attributes should be thorough, systematic, and tailored to the needs of the client and occupants of the building [7]. FM should provide input also as to detailed requirements that can be incorporated into BIM guidelines.

2.2. Populating the Database of Assets from a Building Information Model

The building information model can be used for the efficient population of the FM database and managing assets. A post-processed 3D model can provide spatial data. Equipment (with detailed specifications) can be saved in a spreadsheet format or linked to a 3D model within a FM system. Data fields for each piece of equipment are searchable and modifiable in a CMMS (computerized maintenance management software) system. An example of this is the Veterans Administration Space and Equipment Planning System (VA-SEPS) for planning heath care facilities (Figure 1). It was initially deployed in 2007 to create a space program from a set of questions for user requirements; it would then generate an equipment plan and cost estimate [8]. This system has been used to connect a building information model directly to SEPS data through standardized Revit families [9,10]. Eventually the goal is to connect 217,000,000 square feet of healthcare facilities' assets to BIM and GIS for use for the VA-SEPS for facilities design and management [11,12]. A methodology to submit required FM data should be established through the use of parameters in the building information model or separate entry into a spreadsheet format.

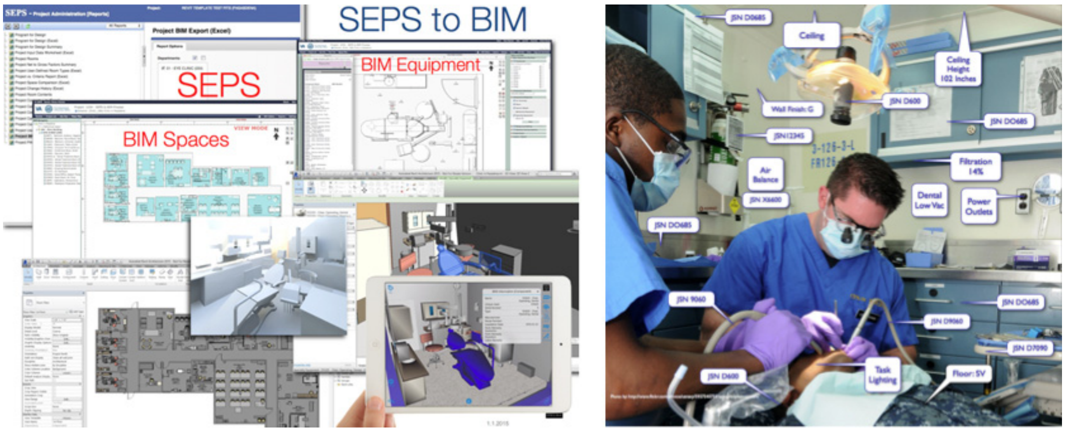

Figure 1. Veterans Administration Space and Equipment Planning (SEPS). Every piece of inventory is tied to the building information model (Image courtesy of Hagan Technologies and Onuma).

2.3. BIM Data for Preventative Maintenance and Retrofits

Repair and preventive maintenance require a database of what exists and when equipment ought to be fixed, upgraded, or replaced. This is exactly what an accurate and information FM database is. For example, an energy upgrade to a building might entail replacing low efficiency bulbs with LEDs; the location of the bulbs, characteristics of the fixture, and links to manufacturer sites can be in the model. "That said, maintaining a BIM file with regard to facility management information is very similar to maintaining the actual facility. As the components are replaced, repaired, or removed, those changes will need to be reflected in the BIM file" [13]. Of course, the 3D model itself is useful for remodeling, additions, and changes to the building. An accurate as-built model is necessary for FM future use.

The architecture firm Harley Ellis Devereaux used models of several buildings on a campus to calculated energy use intensity (EUI) (Figure 2). They were then able to advise their client which buildings might benefit from energy-saving upgrades.

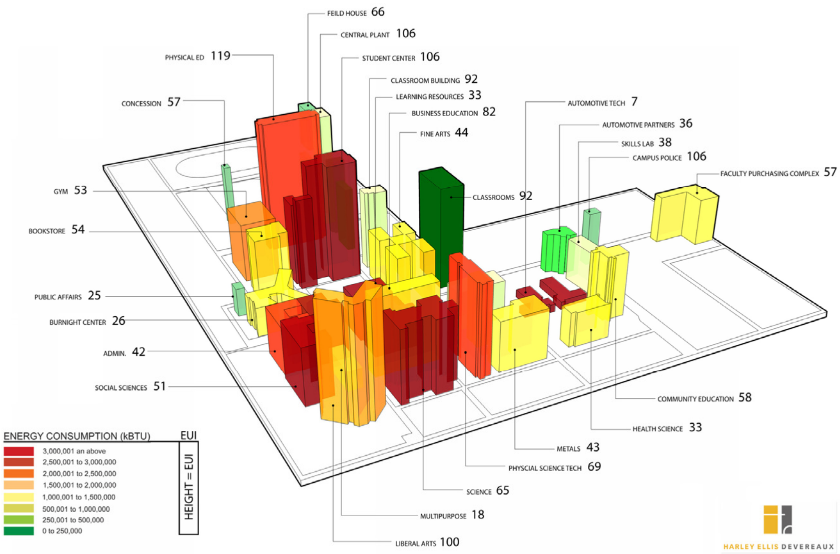

Figure 2. Deciding which building to upgrade first through energy use intensity (EUI) calculations (Image courtesy of Harley Ellis Devereaux).

For other clients with numerous buildings in their portfolios, many of them may need to be inspected and evaluated to establish a priority list and time table for upgrades. In a unique application of spatial BIM used for retrofit planning, the U.S. Coast Guard and U.S. General Services Administration created three indices for upper management to better understand the spatial status of their holdings: Facility Condition Index (FCI), Mission Dependency Index (MDI), and Space Utilization Index (SUI) [6]. Two key attributes (condition and mission criticality) were color-coded (red, yellow, or green). A red/red status indicated a space/building that should be prioritized to be upgraded first; this would be readily apparent to managers examining their building portfolio.

2.4. Record Building Information Model

Owners should ask for a record building information model, and the FM BIM guidelines partially determine what it should contain. It should be a combination of the best attributes of both the traditional as-built drawings and record drawings, and the record been should be fully populated with data that would make it useful for the continuing operations and maintenance of their building. It should contain a virtual description of the building and associated data: 3D model, 2D drawings, assets (e.g., furniture, furnishings, and equipment), maintenance manuals, specifications, and other information that is usually requested at closeout. “The intent is to include all information that is submitted at closeout linked to a fully functional BIM and highly organized for seamless immediate and future reuse” [14]. Other information can also be included such as training videos or post-processed 3D models (e.g., subsets of models for the energy management system or simplified models for campus maps) (Figure 3). However, owners should realize that this is extra work, and additional charges are needed to cover this.

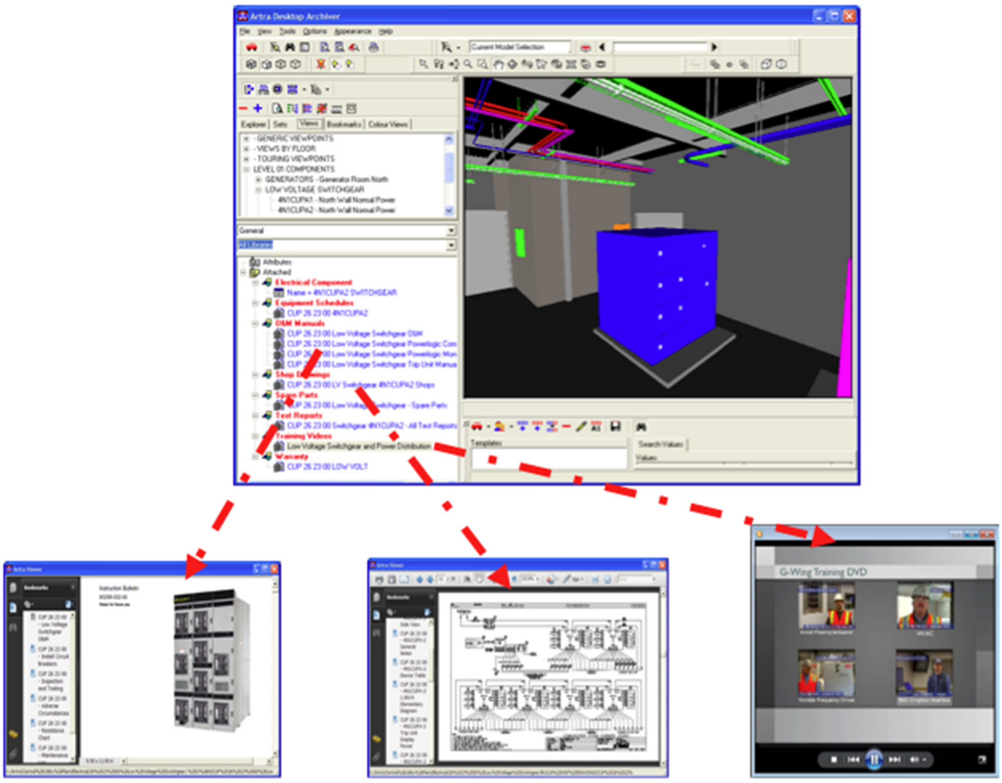

Figure 3. Post-processed 3D models, operating manuals, as built information, equipment schedules, and training videos (Image courtesy of Skanska).

BIM guidelines dictate details of what should be in the record building information model. This BIM data can be used for space management, populating the FM database, to anticipate maintenance needs, and to provide background information for remodels and retrofits—all pressing needs for the operation of a facility. However, interoperability between BIM and FM software is not usually seamless, and the BIM portal that Jordani referred to is not an off-the-shelf piece of software that works faultlessly in all practical applications [4].

3. IFC and COBie

The entire theoretical framework of BIM data being used for facilities management is predicated on the assumption that data can be exchanged easily between software programs, specifically BIM and FM.

IFC is an open source data model standard that encodes both geometry and data about objects; it is maintained by the buildingSMART organization [15] and includes definitions about building's elements, such as HVAC equipment, spaces, zones, furniture, and also includes specific properties. Tian and Liu proposed using IFC not only for the purpose of clash detection (this is based primarily just on 3D geometric data), but as a system model with three levels: Pragmatic (identifying services such as fire and life safety, IT communications, and energy management), semantic (physical objects and their attributes), and syntactic (a related set of components such as that which make up a fire safety system, e.g., "smoke detectors, heat detectors, manual call points, switches, *etc.*, or addressable output relays" [16]. Although IFC is gaining some acceptance world-wide including China, in the U.S., IFC is making slow headway [17,18]. Aside from the U.S. Government Services Administration which requires both native and IFC compliant BIM deliverables [19], IFC is not generally required for the record building information model. Autodesk Revit proprietary file formats are usually the final deliverable in the U.S., and spreadsheets or custom plug-ins are used to transfer data to FM systems.

Due to the simplicity of their inherent structure, spreadsheets are a useful means of moving data (text and numbers) between software programs (Figure 4). Modified versions of the COBie standard are often used to organize the information. COBie is a non-proprietary platform for the exchange of life cycle data needed by facility managers. The COBie methodology is intended to encourage, or to have owners require, that data is directly input into the building information model or otherwise linked to it as that information becomes available [20].

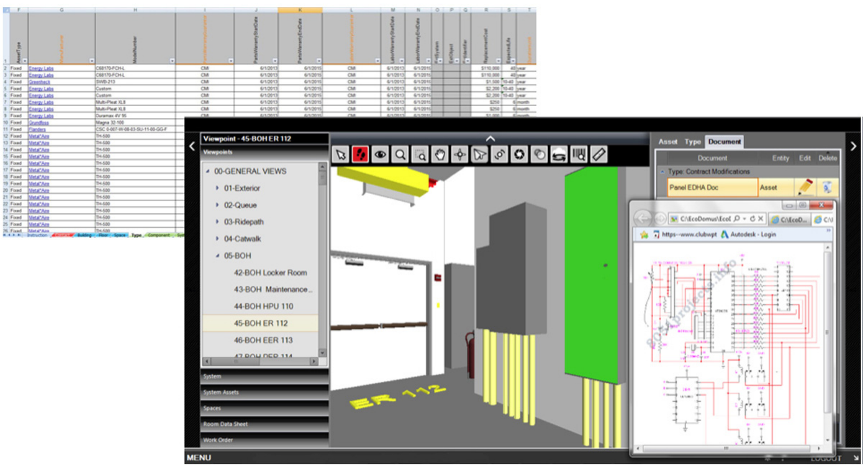

Figure 4. Data from Excel incorporated into model (Image courtesy of Clark Construction Group).

4. USC FMS Case Study: BIM Guidelines Defined and Applied

The USC FMS case study details BIM requirements (Revit based) for populating the FM database, guidelines for interoperability for data to be used in an EcoDomus portal (custom plug-ins), and the application of the standards on the Cinematic Arts Complex buildings (including modified COBie requirements). The information for the case study was primarily obtained on the USC FMS website, published material about the Cinematic Arts Complex design and construction, and discussions with FMS staff who were involved with the project.

4.1. USC Stated FMS BIM Requirements

USC requires the use of BIM for new construction on campus. The intended goal is to use the data in the BIM to populate facilities management database for more effective operations and maintenance of the campus. The USC FMS website contains several guidelines and standards, explanations of BIM requirements, and CAD guidelines [21], dated 2012. Several parts of them relate specifically to how the BIM (both the 3D geometry and data) would be used for FM and how they must be delivered to the client (USC). These protocols are focused on FMS's use of specific data extracted from the model post-construction.

4.1.1. *USC FMS BIM Guidelines* and Associated Documents

The *USC FMS BIM Guidelines* is an extensive document that details the scope of work and deliverables for new construction projects on campus. The table of contents included the following chapters: Introduction, USC responsibilities, design team (BIM process and modeling requirements), MEPF (mechanical, electrical, plumbing, and fire) specifications, design phase information (such as LOD, collision detection, BIM execution plan, COBie requirements), construction team (BIM process and modeling requirements), nine appendices (LOD, BIM data acquisition, nomenclature, installation change log, Revit model requirements, collision detection, facilities management data specifications, EcoDomus, BIM execution plan), glossary, and references/acknowledgements. Two Excel spreadsheet addendums are also available on the website that provide matrices for minimum model and class detection issues.

The *USC FMS Revit Parameters List* specifies parameters, where to put them, who is responsible to supply each one, and shows examples. A similar document details the requirements for shared parameters. A parameter holds attribute data for a building component (called a "family" in Revit), e.g., the cost of a door or the manufacturer of an air handling unit. "Shared parameter" is a Revit term for custom fields of data that can be added to Revit family. Shared parameter definitions are stored in a separate file so that they can be accessed independently of any specific project file. These are a crucial part of a building information model as they allow for standardization across files and building projects of their naming conventions along with the intended use are clearly articulated for the data entry people. This explains why there are two other documents detailing the proper naming of Revit families (types and instances), systems, and zones.

The *USC FMS BIM Guidelines* also includes a list of documents that are required to fulfill COBie requirements and what will be uploaded onto USC's 3D FM BIM Portal (EcoDomus). It specifies that PDF files are to be uploaded and attached to the correct piece of equipment/component or facility. There were also instructions for how to name these documents [22].

4.1.2. *USC FMS BIM Guidelines* Review

The *USC FMS BIM Guidelines* demonstrate an attention to detail that is important with integrating BIM procedures not only into the design and construction of new buildings, but also facilities management and operations. Three critical details were also unearthed in the reading of these documents: Revit is the default BIM software; COBie is intended to help meet facilities management goals, and EcoDomus is the middleware of the FM system.

(1) It is assumed that because the naming conventions, standards, and jargon were specific to Revit that Revit is the BIM software that is required for the final deliverables. Choosing Revit for the record set allowed data to be properly organized for all major managed assets. IFC was not mentioned as an option.
(2) A standard COBie 2.4 standard worksheet is used to make insure that the MEPF information (and other data) is available in the USC FM system. Initially custom templates were going to be supplied, but instead COBie compliance is required starting at the schematic design phase [17].
(3) EcoDomus FM is intended to serve as a central facility repository for helping owners by integrating BIM with building automation, computer-aided facility management, computerized maintenance management systems, and GIS [23]. It can do this through custom Revit plug-ins that ease the transfer of data.

Three appendices to the *Guidelines* are also important for understanding the intent of using the BIM data for operations and maintenance: B, G and H [21].

(1) *Appendix B: BIM Data Acquisition Guideline for Facilities Management Services* describes how the facilities data in general terms should be extracted from the BIM. This includes directions for applying shared parameters, lists space management objectives, and describes COBie standard worksheets.
(2) *Appendix G: USC FMS Outline Schedule Data Specification* lists database field requirements for numerous schedules: Sump pump, hot water generator, fixture, pump, fan, air terminal unit, re-heat coil, diffuser/register, sound attenuator, air handling unit, computer room air conditioning units, fan coil units, radiant panel, electrical panel, and lighting fixture.
(3) *Appendix H: EcoDomus* describes the process used for implementing EcoDomus on USC projects. It consists of five steps: Configuring the COBie quality control template, populating the equipment database, loading the as-built building information model into EcoDomus, performing COBie quality control, and updating the Revit model with the verified data (Figure 5).

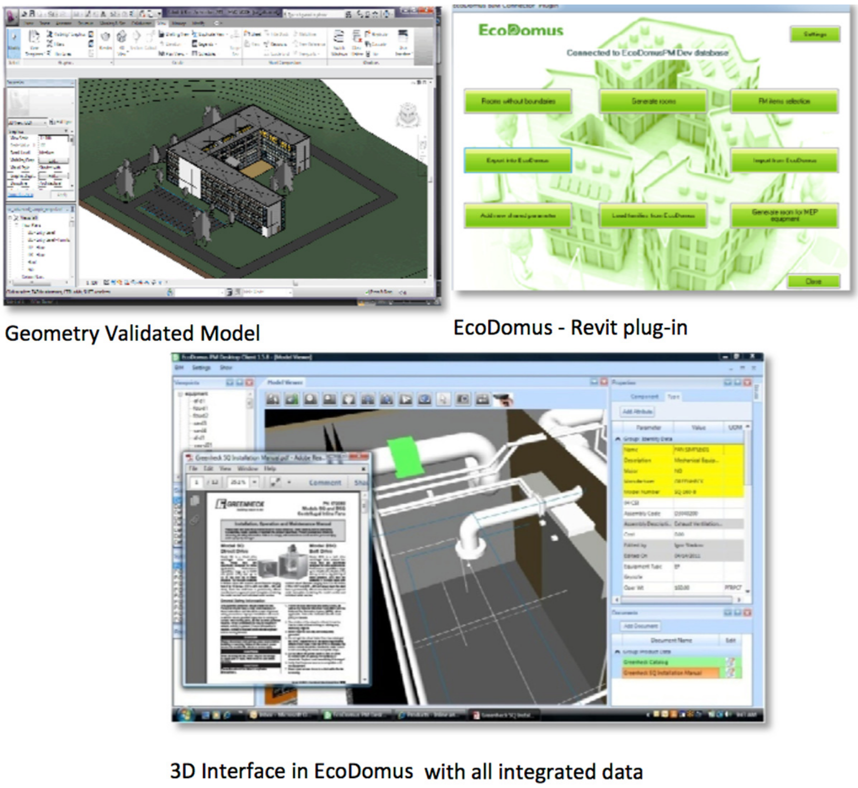

Figure 5. Revit data transfer to EcoDomus through the use of a custom Revit plug-in (Image courtesy of the University of Southern California (USC)).

4.2. Overview of FM System at USC

Although no specific mention is made in any of the posted USC documents described previously, the software tools FAMIS and Meridian Systems are also used at USC. FAMIS is an enterprise facilities management software that is used to create and maintain work orders and manage assets that require regular or periodic maintenance [24]. USC has modules for utilities management, key control, maintenance management, inventory control, space management, visual mapping, visual space planning, and Oracle discoverer. The FMS-MIS group also manages interfaces with other systems including AIS's General Ledger, Purchasing, Payroll, and Space Management, Cutler-Hammer, RS Means, ISES, Active Project, AutoCAD, and Meridian [25].

Meridian Systems serves as USC's O & M building records database. EcoDomus integrates with Meridian Systems. In most cases, the interaction between the two systems and FAMIS is semi-bidirectional in that the file still needs to be replaced a new updated file. One important FM goal has been to make the update process as automated and repeatable as possible so that when a building or asset changes the integration continues to work. An ideal system would also interact with the building control systems such those supplied by Honeywell [26].

4.3. USC Cinematic Arts Complex (2009–2012)

Although the guidelines on the website are very specific and the workflow highly defined, what happens when the BIM to FM guidelines were applied in an actual building project? An early success with the use of the BIM data for FM was realized with the completion of the Cinematic Arts building

(2012). "EcoDomus used its software to develop a custom solution and user interface for the facility that linked the Revit models and data to USC's existing O & M (operations and maintenance) platform, giving it a more accurate and interactive visual capability" [27]. Because the Cinematic Arts building was designed using Revit MEP and many physical sensors were installed in the building, USC is able to leverage the stream of information for smart building operations and live maintenance monitoring [28]. The final take-away was that the data from the BIM was more important than the 3D geometry; building the information into the model was more important for later use in facility operation and maintenance than the 3D architectural model.

A detailed case study is already available about this successful implementation [29]. The three major advances described in the case study were the development of the *USC FMS BIM Guidelines*, the realization that data is more significant than the 3D model for FM, and the creation and use of a facilities management portal made information easier to find [29]. There were three additional "most important lessons learned": New processes don't always need new software as existing FM software can be used with the BIM; recommendations for practices and standards are influenced by what each player already uses, hence all key stakeholders should be consulted; and BIM FM requires "new processes, new technologies, and new lines of communication" [29].

Great care was taken to assess potential needs of future stakeholders; for FM, three generic personas were created: Tom the Technician, Sam the Supervisor, and David the CAD Technician. Currently, most of the access to the model is done by David the CAD Technician who has the best access to the data on-line and currently USC FMS uses the space information and a subset of the information for O & M assets [26]. Originally seventeen parameters (e.g., manufacturer, part number, model number, warranty description, contractor, replacement cost, expected life) from the general contractor and fifteen from the design team were required. The space information that is still being updated includes gross, net, assignable, cleanable, and other categories. The O & M assets data went directly from the BIM into the CMMS system. ID and equipment descriptions also went into the energy management system. "These fields permit us to link bi-directionally from the CMMS into the model and from our energy management into our BIM system. Any data that is in the model can be found in a few clicks. This goes back to our requirement to have data rich and connected models. Part one was to have a process where this richness and connectedness is required in our contract and checked through design and construction. After construction the models are ready to be harvested and continued to be used" [26] (Figure 6).

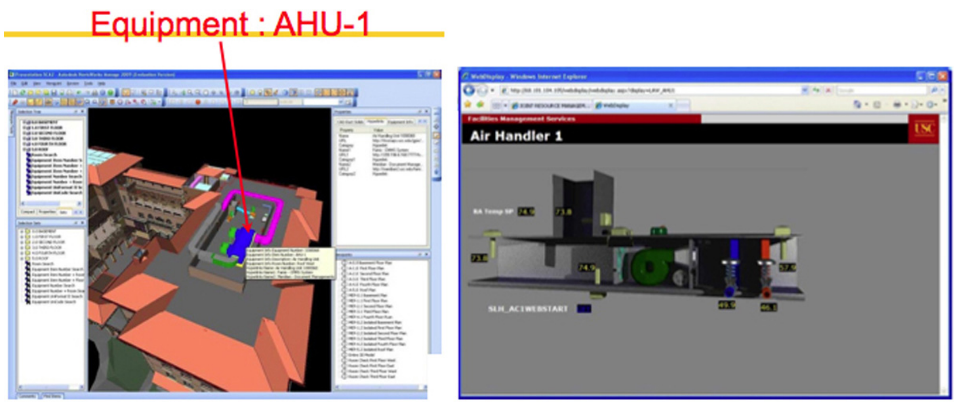

Figure 6. Hyperlink from air handling unit (AHU) to energy management system (EMS) (Image courtesy USC).

Overall, the BIM FM guidelines guaranteed that FMS received the data that it needed from the building information model for space requirements and population of the FM database of key components (mainly mechanical services). The 3D model is available to them for future reference for retrofits, and interoperability was achieved through the use of a Revit requirement, COBie, and custom Revit plug-ins for EcoDomus. The second phase of this research project was to inquire if the success of this project's process continued into the present.

5. USC FMS Case Study: BIM Guidelines Revisited

In order to understand the current arena in which the BIM guidelines are being created and deployed, it is necessary to understand more about the original context of the development of the guidelines.

5.1. Cinematic Arts Complex Backstory

It is critical to note that the BIM guidelines, standards, and processes were being developed **simultaneously** as the Cinema Arts Complex buildings were being designed and constructed. With a committed donor, a skilled project manager, and a team working together to achieve the goals, it was possible to develop the BIM standards that would allow future integration of the BIM with the FM system. However, paraphrasing Welsh (in the bulleted sections below), trying to implement the same process and standards on new construction has been challenging for several reasons [30]:

- Although is some ways an extension to the CAD models that had been developed over 25 years, the integration of BIM data was a new endeavor; EcoDomus was being developed concurrently; and given advances in hardware, software, and cloud computing, other methods of implementing the process might make more sense now. Software changes. New features become available, but some old processes no longer work smoothly. A balance needed to be taken between innovation and evolution of current practices. For an owner with one or two buildings, it might be easier to take chances. However, this is more difficult on a large campus. Replacing core technologies is disruptive, even when it is necessary and valuable.
- New construction concerns and priorities are not the same as facilities management needs for operation, maintenance, and retrofitting of buildings. BIM data needed for construction is different from O & M and adding data is not free. For the Cinematic Arts Complex, the team saw benefits in requiring BIM data for future use. Other groups might decide on up-front cost savings instead. It is difficult to place a metric on the payback for doing BIM data collection upfront. Welsh talked about the concept of this work being more like a bank, where you do not expect immediate payback, but will be happy in the long run. "Customer satisfaction is a payback without a good metric" [30]. The collection of data in the building information model for future use in operations, preventive maintenance, and retrofits makes sense, but verified financial savings in the long term have not been established that could bolster the argument for this investment of time and money.
- USC is experiencing a significant increase in concurrent new building projects; this was not the context when the first School of Cinematic Arts building was underway. This new construction has different architects and contractors with varying levels of BIM expertise, programmatic

requirements, sizes, and time schedules. For example, the Glorya Kaufman International Dance Center, a moderate size building, will house studio performance space, five medium and small dance studios, a dance wellness center, dressing rooms, space for future classrooms, and offices for faculty and administrators [31]. USC Village (several buildings) will have nine residential colleges, retail, and open space on a 15 acre site [32]. Although these structures have overlapping data requirements for FM, there are also many that are unique.

- Several projects on campus were completed following the intent of the BIM guidelines, but the contracts were individually negotiated and had some differences. The project schedules of campus construction vary. New guidelines need to reflect rapid advancement in information exchanges.

The posted FMS guidelines detailed an advance view of requirements in 2010-11, but were not the only set of BIM requirements that had to be met. As was stated in the document "Documents List for COBie (Digital) Upload":

> *"This requirement does not in any way, explicitly or implicitly, exempt you from fulfilling your contractual obligations related to project close-out. The documents listed below do not substitute or represent the entire document set listed in USC's Close-Out Package. They are specific only to the uploads onto USC's 3D FM BIM Portal, EcoDomus"* [22].

The *USC FMS BIM Guidelines*, as stated previously, were developed during and for a particular project from 2010 to 2012. While the framework was a significant step forward, its greatest success was the amount of information that was accessible to a broader range of professionals. This explosion of both data and the structuring of it into project information is being acknowledged by the leadership of the two groups (CCD and FMS), which are reviewing their project controls needs.

5.2. Evolving Processes

2014–2015 has seen a surge of building construction at USC and a re-emphasized that the previous BIM guidelines needed updating. Conversations underway between FMS and CCD produced new requirements, templates, and changes in processes. These changes are being led by a virtual, design, and construction (VDC) architect, Matthew Miller AIA who was hired specifically to work with CDD and FMS in updating USC's BIM implementation [33]. He provided the underlying content and images for Section 5.3. Two types of changes have been made towards updating the BIM guidelines since 2012: Improvements to specific guideline requirements including shared parameters and a growing reliance on collaborative processes.

5.2.1. Project Documentation Requirements

USC FMS and CCD now jointly provide project documentation requirements through a USC "Project Record Revit Requirement Execution Plan" (PRxP) template, which is based on a United States Army Corps of Engineers BIM project execution plan [34]. Although the general content of the new project documentation requirements is similar to the earlier FMS guidelines, a critically important update took place in the PRxP template is the USC shared parameters document, which lists attributes utilizing a customized COBie format for the universities' major managed assets. In particular, the expansion of engagement with the project data has led to the expansion of the original list of shared parameters. These shared parameters are loaded into the Revit project files at the earliest stages by the architect and contractor (Figure 7). Parameter values are populated on-line by the building team through web-based spreadsheets. This is done throughout the design-construction process at specific project phases: Design development, construction documentation, submittal review, and construction installation. This improved standardized list of shared parameters is currently being used on many USC projects under construction: Glorya Kaufman International Dance Center, Mark Tennis Stadium, Jill and Frank Fertitta Hall, Stevens Hall, Norris Healthcare Consultation Center, Michelson Center for Convergent Bioscience, and the University Village.

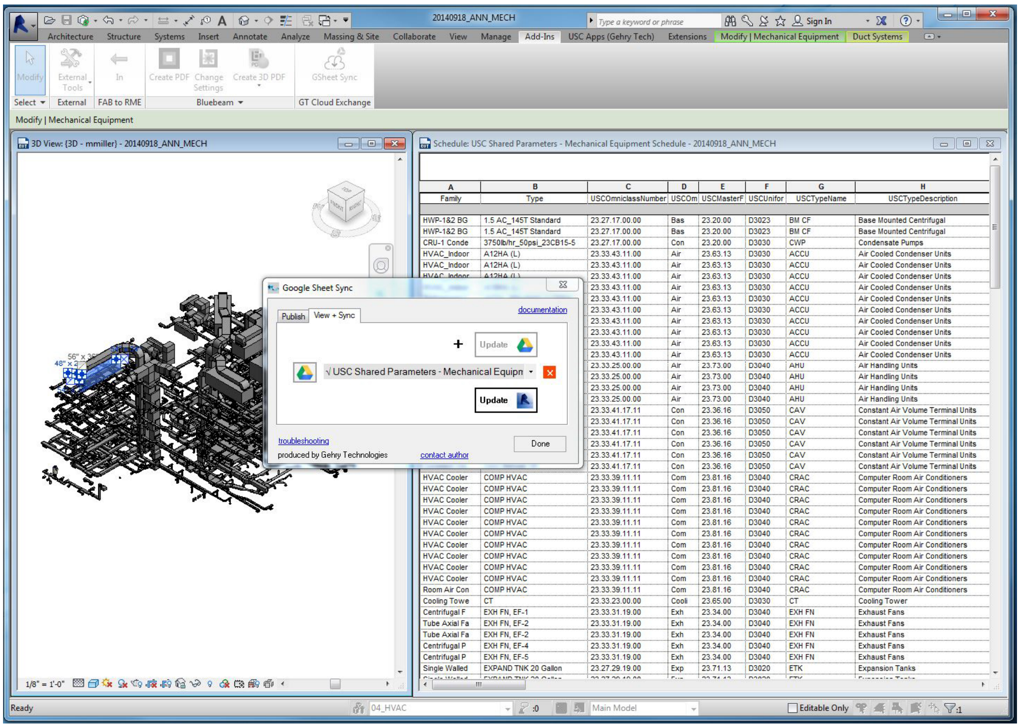

Figure 7. 3D view with mechanical equipment schedule and shared parameters developed by Nuri Miller of Gehry Technologies (Image courtesy USC Capital Construction Development (CCD)).

Other notable differences since 2012 include the following [35]:

- An as-built model completed by the construction team will to be delivered via e-Builder. E-Builder is a project controls document tracking, sorting, and record keeping tool.
- Trimble has developed Revit API tools automate parameter checking, change tracking, and parameter filtering and sorting.
- A combination of industry standard nomenclatures (OmniClass Tables 2 and 3 Products and the U.S. National CAD Standards (NCS) 3.1 Module 5: Terms and Abbreviations) and an equipment operation description will be the standard for naming equipment types and instances.
- Unique FMS IDs are auto-generated by FAMIS and Honeywell.
- No mention of EcoDomus. EcoDomus used a customized template to display the text from grouped CADD blocks in the Navisworks viewer. So while Ecodomus is good for displaying the

results of CADD/COBie processes it does not function as bi-direction middleware. One major intent of the newer processes being developed is to encourage bi-directional interconnectivity.

- Data collection for the record building information model will be performed during the design and construction phase and entered directly into the Revit models thru Google Docs.

5.2.2. Collaborative Processes

That record data collection will be performed during the design and construction phase and entered directly into the Revit models thru Google Docs is an important change in the workflow process of attaching data to a 3D model. Additional shared parameter attributes provide more refined data for operations and maintenance staff. Design and construction professionals will now interact with the model based documents through the synchronization of web-based spreadsheets. The feedback loops stemming from this bi-directional information exchange is enabling non-modeling team members to provide input information directly into the contextual framework. This is a critical change from the previous approach. In supplying web-based spreadsheets as the method of entering data professionals who are not directly accessing the building information model can still contribute to it (Figures 8 and 9). Model based documentation is moving away from being shrouded in BIM jargon and the interfaces made more understandable for new users and for example, cost estimating and scheduling professionals, who amongst others, are needed to provide the backbone of data and logic to model based documentation.

New methodologies are also under development for exchanging of information. Testing of multiple beta cloud environments is underway. For example, the process of Revit spreadsheet exchange continues to expand with an Office 365 exchange, similar to that of Google Sheet Sync, and custom Dynamo Revit spreadsheet exchange tools (Figure 10).

Figure 8. Process from Revit model and material schedule to spreadsheet using a Revit Add-in and Google sheet synchronization (Image courtesy of USC CDD).

A	B	C	D	E	F	G	H	I	J	K	L	M	N
from model			from model		submittal/commissioning process						USC id data		
USCDesign ModelName	USCDesign ModelNumber	USCEMSId	Level	USCMaster FormatNumber	USCInstall Manufacturer	USCInstall ModelName	USCInstall ModelNumber	USCBarCode	USCInstallWarranty Description	USCSerialNumber	USCEquipment Number	USCFMSId	USCHWLId
GREENHECK SINGLE WIDE BLOWER	8-CSW-BI-21-10-0-4	7896074	ROOF T.O.C.	23.34.00									

A	B	C	D	E	F	G	H	I	J	K	L	M
from model			from model			submittal/commissioning process						
USCDesign ModelName	USCDesign ModelNumber	USCEMSId	USC.Design. Supply.CFM	USC.Design. System	USC.Design.Zone	USC.Install.Belts. Quantity	USC.Install.Belts. Types	USC.Install.Filters.Part Number	USC.Install.Filters. Quantity	USC.Install.Filters. Types	USC.Install.Supply Fan.HorsePower	USC.Install.Supply Fan.ModelNumber
GREENHECK SINGLE WIDE BLOWER	8-CSW-BI-21-10-0-4	7896074	120	SF-01	FAN COIL UNIT OUTDOOR AIR							

Figure 9. Sample web-based spreadsheet of attributes for a supply fan synchronized to the Revit model (Image courtesy of USC CDD).

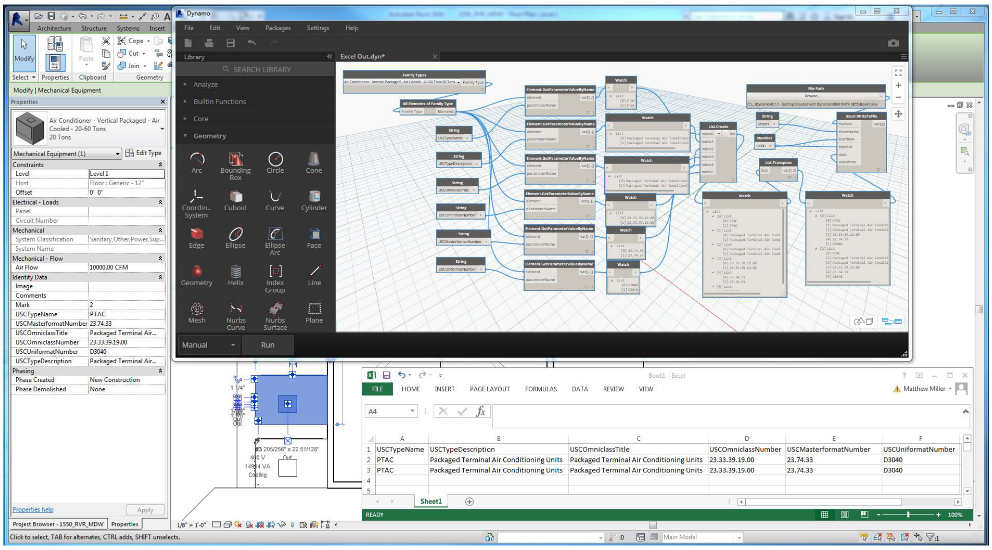

Figure 10. Use of Dynamo for data exchange for Revit families. Dynamo is a visual programming language that can interface with Revit for the creation of custom tools (Image courtesy of USC CDD).

5.3. Future Goals

Welsh is optimistic about the new USC "Project Record Revit Requirement Execution Plan (PRxP)" being developed and for other uses of building information modeling his team in facilities management were envisioning [28]. These goals extend beyond using the information-rich model as a database repository of information about facilities management. Future goals for the use of BIM with FM include incorporating GIS data, investigating new technologies such as drone 3D scanning, incentivizing mobile computing, and the integrating cloud resources. For example, tablet based computers and smart phones with post-processed building information models can stream real-time data about the current status of HVAC systems for immediately accessible information for operations and maintenance staff.

6. Conclusions

USC FMS has been at the forefront of integrating and absorbing BIM into their life-cycle concerns of facilities management, operations, and maintenance. Spatial information is acquired from the 3D model. Major assets and installed equipment are tracked, and other data such as cost, expected life, and replacement information is recorded. Mechanical equipment information is also extracted. Yet despite early successes, there is still a gap between the building information models created by the architect and contractors and the information desired by the facility managers. While working on the Cinematic Arts Complex, a set of BIM guidelines was developed that required data be input into the BIM for future use by facilities management. However, complexities of constructing and maintaining new buildings in a large campus environment have resulted in re-evaluation of these guidelines to provide a standardized list of required data for all projects and a strong inclusion of experts not involved in modeling to provide information on web-based spreadsheets. This re-evaluation process is critically important for the profession and leads to an evolution of processes. Since 2012, additions to the USC FMS BIM guidelines have focused on clarifying what data needs to be deposited during the design and construction of a building and more importantly, a shift in thinking towards prioritizing collaborative, cloud based approaches for data entry and later staff (and others) retrieval. In both 2012 and now, the innovations have been specialized tools to allow the disparate software to work better together in acquiring, storing and allowing access to data, and Revit, as a relational database solution, is central to the current cloud transition strategy. One can expect much progress in the coming years as the industry is still at the infancy stage of incorporating BIM data into facility management processes for the efficient operation of increasingly complex buildings.

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Matthew L. Miller AIA contributed information and insight into the development of the USC "Project Record Revit Requirement Execution Plan (PRxP)". John Welsh and Jose Delgado from the University of Southern California, Facility Management Services, contributed background material about the USC use of BIM to FM and future goals. I would also like to thank Greg Smith and Anthony Colonna of Skanska USA Building for supplying seed funding for studying BIM gaps.

Conflicts of Interest

The author teaches at the University of Southern California, but has no financial stake with topics discussed in this paper.

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