

BIM to CAFM: An Investigation of Adapting a Building Information Model to a Legacy Computer Aided Facility Management

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ABSTRACT: An investigation has been conducted to explore the steps required to move information from a Building Information Model (BIM) to a Computer Aided Facilities Management System (CAFM). The growing popularity of BIM draws heavily upon a perception that the technology can facilitate all major operations during the building lifecycle. Current deployment of BIM in the AEC/FM industry has significant impact on the acceleration of design and construction phases. Of equal importance, however, is whether BIM can provide information for reuse in facility management and operations. This paper presents a research study in order to determine how to capture information about existing buildings in a BIM and reuse the information to support decisions about facility use. Our study includes findings from focus groups and in-depth interviews with facility managers and owners which produced well-reasoned arguments about deployment, challenges and obstacles of BIM utilization for the FM operations. Based on the findings, a BIM utilization framework was developed for FM. A link was established between BIM tools and an in-house CAFM system that consists of databases accessible through Web sites and incorporating pixel-oriented images and Web-enabled vector drawings. Four buildings supporting a college of architecture on a large university campus are incorporated into the system. The investigation revealed that the BIM can provide much information for use in the CAFM system, but there remains a need for intermediate CAD products and additional tools.

1 INTRODUCTION.

The development of computer tools to aid in the creation, use, modification, and reuse of information about a building has been the goal of researchers and software developers for many years. Building Information Modeling is the latest catch phrase in that development, and has achieved substantial market appeal and industry attention. However, whether a BIM can assist in management of information for the operations stage in the life of a building has not largely been addressed. This “downstream” application is often overlooked by the designers and builders who are focused upon creating information about the facility (Clayton, Johnson and Song 1999). We will present our experiments in employing a BIM tool (Autodesk Revit) to create information and populate a Computer Aided Facility Management (CAFM) System used to support a college of architecture. The CAFM system roughly follows the outlines of Just-In-time Operations Documents that use data-driven Web sites over an intranet to provide information to customers such as the general corporate population, maintenance workers, and facility planners (Clayton et al. 1998).

This article will explain a set of applications provided by the CAFM system as a reference target for producing information out of the BIM. It will then present pipelines for creating and delivering the information for each application. It will include a brief discussion of planned and future applications within the CAFM system and anticipated challenges in using the BIM tools to further populate the CAFM system. The article concludes with an assessment of the strengths and weaknesses of using the BIM tools to support facility operations.

2 BIM, DATA STANDARDS AND FACILITY MANAGEMENT

Substantial research over the past several years has fostered the emergence of new practices in the AEC/FM industry with respect to data standards and interoperability (Eastman 1999; Eastman 2008). Nevertheless, significant questions about information flow and data integration and exchange in the building lifecycle remain unanswered. Existing technologies and data standards provide solutions yet create new problems. Industry Foundation Classes (IFC) provides consistent and wide ranging

data about the facilities. However the implementation of IFC's to CAFM systems is still in progress and industry lacks native software and tools for the effective deployment of IFC for FM purposes. Studies have been conducted to explore documenting design information over the lifecycle of a building (Park and Krishamurti 2005). However a major issue remains to link the complex and information rich BIM models to CAFM systems for simplified and applicable information for FM workgroups. Our findings from the focus groups and interviews with owners and facility managers indicated that the use of BIM and data standards like IFC's for FM is rare and adoption is in progress.

Most recent development in Engineering, Procurement, Construction (EPC) and Plant Industry is the deployment of ISO 15926 for facility lifecycle information management (FIATECH 2009). The FIATECH ADI project drove prominent technology vendors to implement a BIM-IFC derivative standard to hi-end tools for capital projects management. Demand for the deployment is coming from owners, contractors, and other industry stakeholders so we may expect the increased diffusion of BIM and related data standards for FM in the short and mid term.

3 FOCUS GROUPS, INTERVIEWS AND THE PROTOTYPICAL FRAMEWORK

This study consisted of focus groups, follow up interviews, case studies, and discussions by the research team to collect data and develop the framework and corroborate the findings from the implementation. Two groups were conducted over a seven month time frame in 2007. A diverse participant group actively contributed to the research effort. One focus group consisted of faculty members who have a common interest in BIM and integrated practice but diverse expertise in information technology, design, construction, and facilities management. During late 2007 and early 2008 we also conducted comprehensive interviews with a government agency and facilities coordinators of a large international corporation.

Content analysis of the focus groups and interviews indicated that the use of BIM is not widely implemented within FM workgroups. Many owners are aware of BIM methods and emerging technologies but basic issues are preventing them from adopting BIM. Many FM divisions within owner organizations are heavily committed to other information technology, such as Computer-Aided Facility Management (CAFM) systems. Large amounts of legacy data, training costs, and software acquisition costs are major impediments to adoption of BIM for FM.

On the other hand there are sophisticated owners who demand BIM utilization from their consultants in design and construction processes. The basis for this demand comes from potential saving of significant percentages of design and construction costs and high expectations of future developments that will integrate BIM into the operation of buildings.

An example from the focus group and interviews is the largest public owner in the United States. The agency is requiring BIM use by setting a minimum standard for "space measurement". In order to increase the benefit from BIM, the agency's current strategy is to customize BIM approaches to the specific needs of each project. In the future, the agency also looks forward to set additional standards for topics such as energy, security, circulation, existing conditions, and cost estimating as BIM technology matures. In summary, the small progress toward comprehensive use of BIM across the owner's entire portfolio suggest that the current business environment has not reached a critical mass to permit full integration of design, construction and operations.

Another example is a very large international corporation who has taken strong public stances endorsing BIM technology and adoption. Although the owner is reaping the benefits of BIM in design procurement and construction process, the ability to capture, preserve and reuse the data for FM remains one of the biggest challenges. Currently subcontractors do not have the available information nor do they have the graphical representation of manufactured object. The owner can not capture data for the actual objects that are installed nor access the O&M manuals in a standard digital format and organized framework for commissioning the facility. As a result, the owner's FM initiatives have to deal with data from various sources and various media including electronic, paper, verbal, and others.

Drawn from these findings and arguments, our prototypical framework is based on the following:

- A simple, applicable and low-cost system using available BIM tools and a legacy CAFM system with Revit, AutoCAD, ASP and visualization software;
- Use of legacy documents for the creation of an abstract BIM model for an existing facility;
- Creation of useful and wide-ranging information for an FM organization consisting of novice users and graduate students addressing the skill and human resource balance;
- A stepwise process methodology starting with generic models refined through data

collection from the facility for convenient data capturing;

- Creation and utilization of space plans, occupancy and assignment information linked to the BIM model.

Considering the findings from the focus groups and the system architecture of our in house CAFM system, we devised a compact solution framework for BIM-CAFM use. The framework is exploratory with an inductive approach similar to that used in an FM organization. Based on the derivation for FM specific information from the BIM model, the approach is flexible to incorporate IFC's with appropriate software for further applications.

4 THE REFERENCE COMPUTER AIDED FACILITY MANAGEMENT SYSTEM

The college makes use of four buildings, which we will refer to as Building A, Building B, Building C and Building W. Building A houses the primary administrative units, faculty offices, support services such as computer labs and gallery, studio spaces, classrooms, and graduate student offices. Building B contains a large auditorium, a few research labs, and a woodworking shop. The spaces in Building C are designated as design studios, faculty offices, video studios, darkrooms, classrooms, and research labs. The first floor of Building W was assigned to the college in recognition of space deficiencies. It houses several research labs, faculty offices, classrooms, and graduate student offices.

The college is a multidisciplinary academic unit, offering degree programs in architecture, landscape architecture, construction, urban planning, and computer visualization. Degrees range from unaccredited undergraduate design, through accredited master programs and PhD programs. The college maintains a balance among general education, professional education, continuing education, and research. It thus has a very complex set of spatial requirements with respect to physical facilities and scheduling.

At the simplest level of facility information, the college maintains floor plan drawings of its facilities as a general reference. These drawings, although they originated as Bentley Microstation files, are currently managed using AutoCAD in DWG format. Scale plots are produced in PDF format for printing and distribution to administrators, faculty, students, and visitors on demand. The information and format needs of this application are PDF files and paper printouts of floor plans showing room walls, room numbers, and areas. An example is shown in Figure 1.

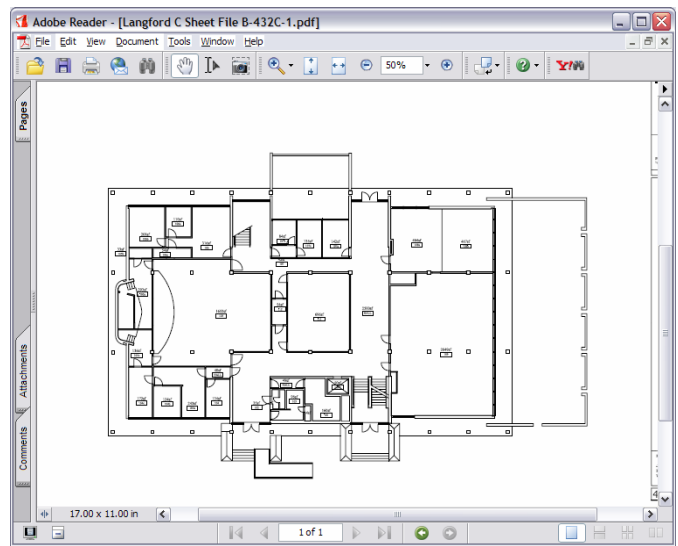


Figure 1. Example of as-built reference drawings produced with CAD tools.

Recent major renovations have produced sets of Building B and portions of Building A in DWG and PDF format. These drawings are essentially working drawings for the renovations provided to the University as “as-built” drawings.

One of the most important facility management tasks in the college is the scheduling of rooms for both classes and special events. This complex task is handled by using a data-driven Web site. Nearly 90 rooms are managed using this application. Although the site can be viewed by anyone in the college, only a limited number of staff people have permission to post records to the database. This approach enables conflicts to be identified and negotiated by personal interaction rather than being intermediated by software. The application permits retrieval queries of seven different kinds:

- Report 1: View schedules of a selected room at a given time
- Report 2: Search rooms available in College for a special event by selecting date and time slot
- Report 3: Search rooms available in College for a weekly event by selecting semester, week day, and time slot
- Report 4: View All Class Schedules for a Selected Semester
- Report 5: View Class Schedules of a Single Room for a Selected Semester
- Report 6: View Schedule of selected Room for a given month
- Report 7: View Schedule of selected faculty for a given semester

Some of these queries produce results that may be further sorted by a field designated by the user, as shown in Figure 2. These tools are effective in ena-

bling a user to check the availability of a room for scheduling either class or events when the time is flexible but the room is fixed or when time is fixed and the room is flexible.

Course-Section	Instructor	Day of week	Time	Room	Last Updated
ARCH 305 - 501	REIMERS C	F	8:00 AM-10:30 AM	ARCC 304A	1/31/2006
ARCH 305 - 501	REIMERS C	MW	8:00 AM-9:15 AM	ARCC 304A	1/31/2006
ARCH 305 - 501	REIMERS C	MW	9:15 AM-11:45 AM	ARCC 304A	1/31/2006
ARCH 305 - 502	ERMINY M	F	2:00 PM-4:30 PM	ARCC 206C	1/31/2006
ARCH 305 - 502	ERMINY M	MW	2:00 PM-3:15 PM	ARCC 206C	1/31/2006

Figure 2. Scheduling application used in the college

The database also drives news items on the public side of the Web, such as event calendars and class calendars. The Web site also describes each room to enable a person to identify an appropriate room for an event.

The information needs of this application include a space audit that lists all rooms, their areas, their capacities, and their equipment lists. For allocation, benchmarking, and planning purposes, the university and the college conduct audits of space, space quality, and space utilization. These audits are generally compiled by inspecting paper versions of plans and putting areas and space classifications into a spreadsheet for summarization. In some instances, plans are also needed so special drawings are produced using AutoCAD.

Locating people and rooms is a simple but vital service provided by facility managers. The college provides Web-based faculty and staff listings that include office assignments. It also lists courses with classroom numbers. Web services are being constructed to assist in identifying the location of rooms on interactive plans. The capability will be provided using Drawing Web Format (DWF) versions of plans that highlight a specific room based on interactive Web queries. Both classrooms and offices will be displayable using a query to the DWF file.

The college is studying whether to provide a GIF file version of the locator maps for those who do not wish to use DWF. However, the maintenance costs of such an approach are considerably higher than the approach using DWF.

The size of the college results in the situation of almost constant remodeling. Projects can range from

the relatively trivial, such as buying new furniture or replacing carpet, to significantly complex, such as a recent \$2 million conversion of a shop building into a visually oriented auditorium. Remodeling has typically involved the production of 2D AutoCAD drawings, primarily plans, to show demolition and construction of walls. These drawings, in paper format, are conveyed to the University Department of Physical Plant for procurement or conduct of work. Of course, once work is completed, the as-built drawings must be updated.

The current systems are only mildly integrated. Where possible, databases are used to support several applications, such as scheduling, locators, and auditing.

5 OVERVIEW OF THE BIM USED FOR THESE TESTS

Autodesk Revit was chosen as the BIM platform for the tests. Revit models of the four buildings were constructed by seven students in a graduate course focused on facility management and a team of three paid graduate assistants with responsibilities to produce documents for facility management and campus planning. While the students in the course contributed substantially to a peer learning environment around Revit, the ultimate 3D BIM models were created by the paid assistants.

The models were constructed using underlays of the AutoCAD DWG files. A large number of dimensional inaccuracies and inconsistencies in the DWG as-built drawings presented a challenge. Although the origination of the DWG files is long forgotten, it is likely that they were produced in Microstation using field survey data. Out of plumb columns and walls, construction errors, settling and shifting, and other real conditions lead to small dimensional errors (often a few inches) from one grid line to the next and from one floor plan to the next. It is consequently impossible to trace 2D as-built drawings and produce convincing 3D models. The 3D model, and the BIM, require a conceptual abstraction akin to the designers' intent for the building. For example, it is unlikely that a building was designed to have columns spaced at 20'2", 20'1½", 19'11¾" and 19'6". It is even more unlikely that the designers' intended each column on the floor above to differ in horizontal alignment by a few inches in random directions, yet that is the surveyed state. Much more likely is that the building is intended to have a 20' column grid. It must be modeled in 3D as having a 20' column grid as these tiny variations will ruin the drafted products and renderings that can be derived from the model.

Ultimately, five files were produced: one for each of Building A, Building B, Building C, and Building W, and one for a site model that links the four building models. The models are complete 3D representations of the buildings. The students produced the models in about 2 ½ months. The time spent producing the models could probably be reduced by at least 50% if the modeling was done by an experienced team.

6 AS-BUILT PLANS

The Revit BIM was capable for producing conventional plans, sections, and elevations for use as reference as-built drawings. The default settings in Revit were largely adequate, so that, once the 3D model was completed, the plans, sections, and elevations could be produced in merely a few minutes more of effort. PDF files were then produced using the PDFCreator printer driver. The pipeline for this production is very simple, as shown as an IDEF0 diagram in Figure 3.

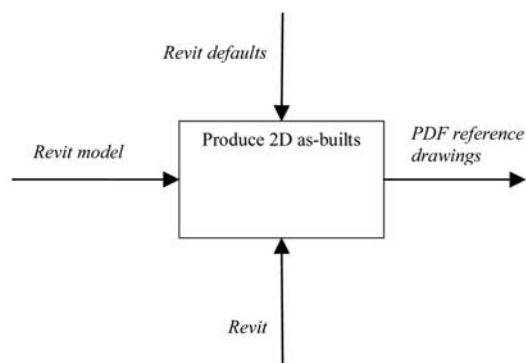


Figure 3. Pipeline for creating as-built reference drawings from the BIM

Some small tweaks to settings enabling the production of as-built reference drawings that are superior graphically to the ones previously produced using AutoCAD. In addition, because the BIM is 3D, sections and elevations are now available when they were previously unavailable. Furthermore, new sections can easily be produced as needed.

7 SPACE AUDIT

The BIM also proved very powerful for producing space audits of the four buildings. Revit was used to produce color-coded space plans which were the basis for extracting schedules with the room area quantities. These schedules were imported into Microsoft Excel for preparation of summaries and generation of charts. The pipeline is shown in Figure 4.

The first step was to create a color coded floor plan that categorized all rooms and spaces according to university standards. The process was facilitated by working simultaneously with both a plan view for displaying the color-coded rooms and a schedule that showed non-graphic data about the rooms, as illustrated in Figure 5.

A new floor plan type was created for the room plans by creating a new view for the space plan, adjusting settings, and then saving it as a View Type. Then a new schedule view was created for capturing the room audit data. Built-in parameters for rooms captured information for Area, Comments, Department, Level, Name, Number, Occupancy, and Occupant. A custom parameter was created for designating the audit category for the room. These dialog boxes are shown in Figure 6. Finally a Color Fill was added to the floor plan and keyed to the audit category field, a step shown in Figure 7.

Upon placement of a Room Tag within a defined room or space, Revit then automatically finds the boundaries of the room, and adds the new room designation to the schedule. Once the audit category is added to the record in the schedule, the floor plan automatically updates with the appropriate color fill for the room depending upon its audit category. An example of a room plan with fills completed is shown in Figure 8.

For many rooms, this step was extremely simple as placement of a tag led automatically to identification of the correct room boundaries. However, in some cases the room area would “leak out” in a way similar to a fill in a paint program added to a shape with an open boundary that floods unwanted areas and spaces. Close inspection of the precise endpoints of walls and their relationships to columns led to identification of errors in the way the building was represented in the drawing. Temporary Room Separator lines were drawn to identify where spatially there were “cracks” in the boundary. Once the wall endpoints were moved to conform to the conceptual model of a building imposed by Revit, the fills worked perfectly. In some cases, it was necessary to draw a Room Separator to establish an imaginary boundary, such as between one space in an open plan studio and another space.

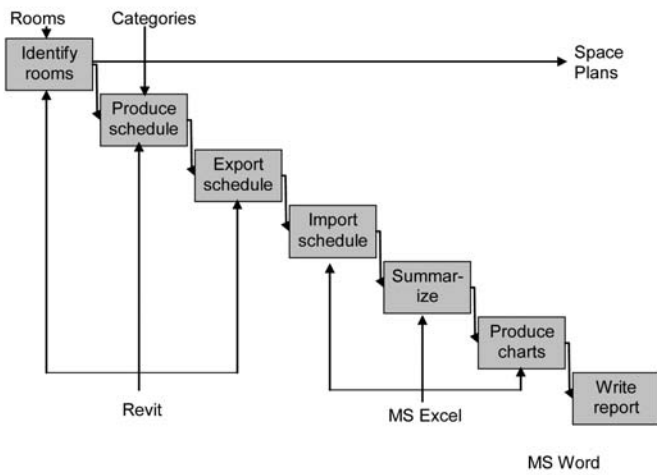


Figure 4. Pipeline of production of space audit from the BIM.

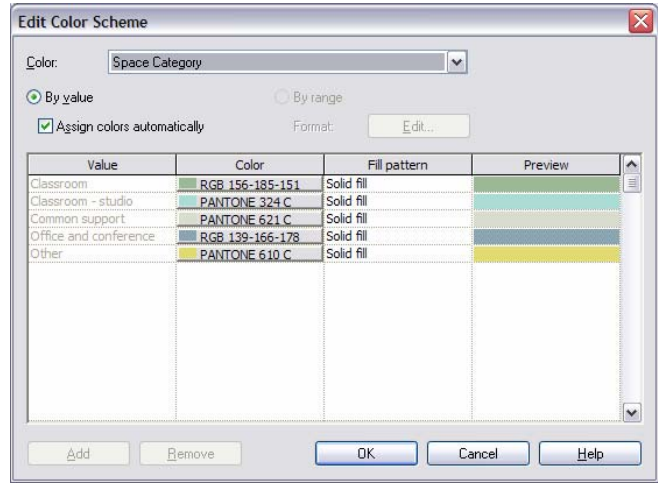


Figure 7. Defining a Color Fill for rooms based on a custom parameter for Space Category

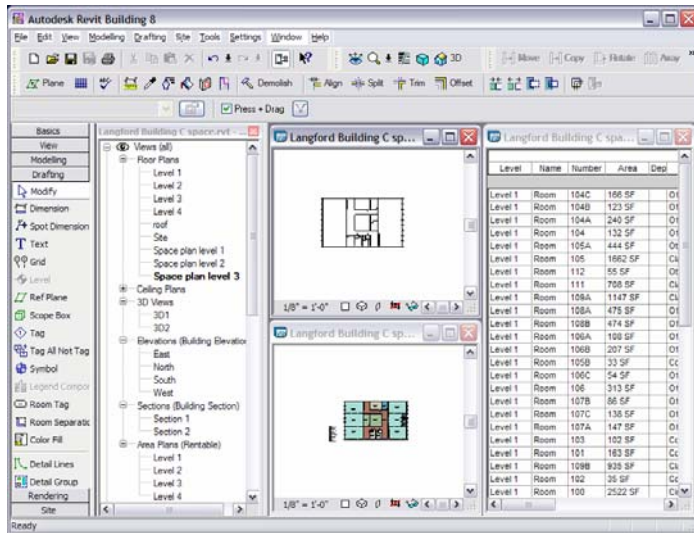


Figure 5. Example of Revit window with both plan and schedule displayed simultaneously. A user can edit either one and see updates in the other.

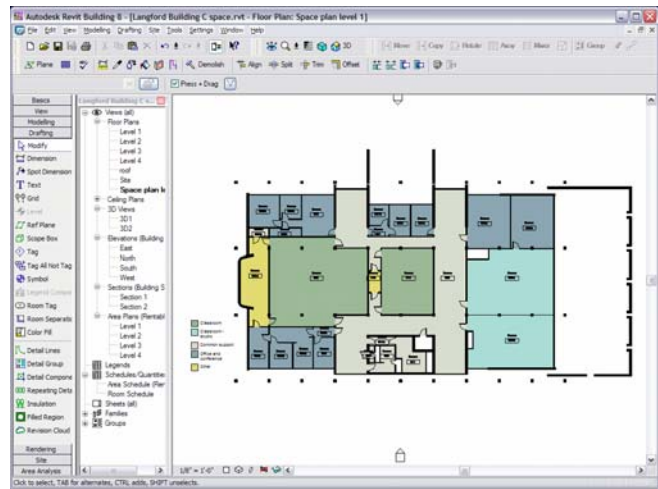


Figure 8. Completed space plan in Revit.

Overall, the process of producing a space audit from the BIM is smooth and easy. It produces high quality and attractive documents and enables categorization of spaces by any and as many classification systems as needed. The one difficult part of the process is to assure that walls and columns are drawn according to the expectations of Revit to achieve closure of rooms and spaces.

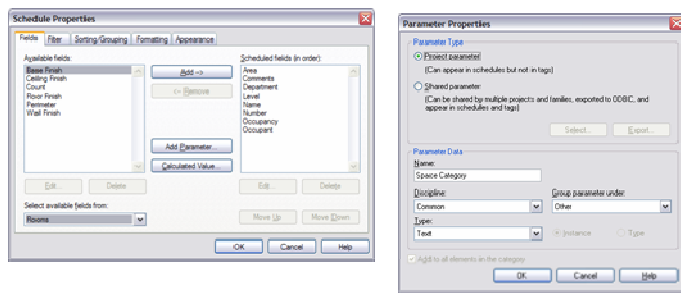


Figure 6. Defining a room schedule using the BIM.

Upon completion of the space plans, the room schedule was also complete, including area quantities. These reports are exported to MS Excel for further processing.

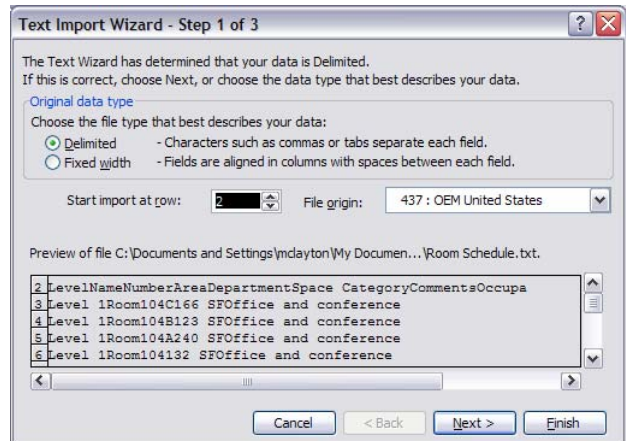


Figure 9. Microsoft Excel Text Import Wizard, used for importing the room schedule produced by Autodesk Revit.

8 INTERACTIVE MAPS

The production of interactive maps on the college intranet is a goal that has not yet been reached in the college information systems. The concept is to provide a Web interface to floor plans that are linked to databases to enable queries from the floor plan that retrieve data in the databases or queries in the databases that retrieve specific floor plans and highlight rooms graphically.

A system has been devised and tested that provides the required functionality. It employs Drawing Web Format (DWF) files with embedded hyperlinks. DWF is a vector based format designed by Autodesk to permit exchange of drawings on the Web. Drawing files are very small, allowing for rapid upload and download on the Internet. They may be zoomed, panned, and manipulated with viewing tools. They may include embedded hyperlinks. The hyperlinks clearly are able to call Active Server Pages (ASP) that include execution of Web code to retrieve information from databases into Web pages. The DWF files also accept parameters that can be parsed by a Web script to change layer visibility and view factors of the drawing display.

The target locator system relies upon a DWF plan for each floor. Each room fill must be separated onto a distinct layer so that particular room fills can be turned off or hidden, while others are turned on. Each room fill contains a hyperlink to a single ASP file, but with parameters that are specific to the particular room. The ASP file then can process the Web page request by calling appropriate databases and inserting appropriate HTML code.

Autodesk Revit was unable to directly produce the DWF files needed for this application. Revit could neither produce the 2D DWF files nor permit the user to embed individual hyperlinks on each space fill. Instead, the development team found it necessary to export the Revit space plans to 2D AutoCAD DWG files.

The resulting DWF files are being installed in a series of Web pages. One page allows a user to click on a room and find out what classes are scheduled in that room, or if it is an office, what staff member is assigned to the office. Another page allows one to click on a room and file a maintenance request for that room. In reverse, from a faculty person's directory listing, one can click on the office number to retrieve a floor plan that highlights the appropriate office. One can also retrieve the courses taught by the faculty person. Another page allows one to click on a course and section and retrieve the floor plan showing the classroom.

The pipeline for producing this application is more complicated than desirable. Translation difficulties affect the color of fills so that color selection must be handled carefully.

9 REMODELING DESIGN

A final, although complex, application was investigated: the use of the BIM to support remodeling. We studied the use of BIM models to produce perspectives, renderings, and abstract images. We also looked at the pipeline for making photorealistic images. We studied the use of schedules to automate quantity take-offs and bills of materials for use in cost estimating and construction scheduling. Finally, we investigated the use of special features of Revit for managing phases, design alternatives, and collaborative design.

The BIM was very effective in producing perspectives and renderings. Unlike AutoCAD, perspectives are fully editable; building components may be selected and modified or even added in a perspective view. The interface for setting viewing parameters is unusual. Instead of using a camera metaphor with zoom settings, one must manipulate the viewing angle or the borders of the perspective image. It is easy to toggle among wireframe views, hidden line removal views, and shaded views.

BIM model provides clipping tools that can be used to produce abstract images and renderings, such as sectional perspectives. It also provides tools for hiding individual components or isolating components, or showing some objects as wireframes and some as shaded objects. Its ability to produce explanatory and expressive abstractions is very good, as illustrated in Figure 10.

BIM provided powerful tools for managing design projects. A user may define phases, such as existing, demolition, and new construction. These phases may be applied to any object so that views may be quickly defined to show the state of the building at any phase. The phases may be used for a primitive 4D CAD model by defining phases for each time unit in a project so that one can successively show the planned progress. A user may also define alternative design using the Options feature. An Option works well when much of the building is common between two options. For each option, the user draws the additional components. Views may then be quickly generated to show how options differ. The system appears very appropriate for examining options for facility renovation.

An especially powerful feature in Revit is the ability to share a model across editors, time, and space.

One may define a model as shared and then assign different parts of the model to different editors. An editor may then check out components and edit them off-line. The checked out components remain viewable by other users in their previous state, but users are warned against changing them. When the editor who checked them out checks them back in, the shared model is updated to contain the changes. The shared model appears to be an excellent way for a facility management organization to share models among multiple users, such as by assigned areas or assigned projects.

10 FUTURE CAFM TOOLS

Further experiments are planned, including those with 3D DWF files and with Industry Foundation Classes (IFC) export.

3D DWF is very powerful. The files produced in 3D DWF are very small but allow extensive viewing capabilities. One can move around and through a model similar to manipulation in a VRML model. Most interestingly, each component in a 3D DWF produced from Revit is identifiable by name and class. Quantity data is accessible, allowing the 3D DWF to serve as the source for cost estimating take-offs. The existing CAFM system will be supplemented with 3D DWF files as an added locator service and novelty for use in marketing college programs. The 3D DWF's may be useful in supporting renovation projects.

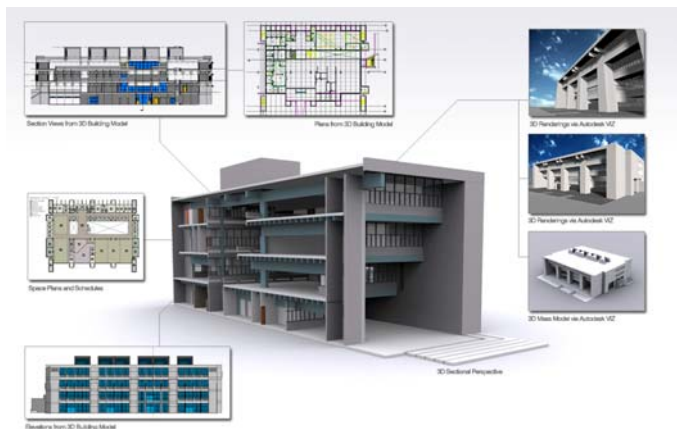


Figure 10. Examples of the kind of images and representations produced using the Revit model directly and after export to Autodesk Viz.

Revit provides tools for exporting its BIM into IFC format. It can also export its BIM into external databases. These capabilities may be very useful for future facility management support systems, but this study is focused upon the legacy CAFM system currently fielded by the college. There is a distinctive value in basing the CAFM system around essentially uneditable spatial models so that editing of the spa-

tial models is reserved to specialists who understand the consequences of changes and the fragility of the models.

11 ASSESSMENT AND CONCLUSIONS

The use of Revit as a BIM platform was very effective for supporting the facility management and operation needs of the college. For the reference test suite, it was very effective at producing as-built plans, space audits, and design imaging. It was adequately effective in supporting the locator maps, although the pipeline seems unnecessarily complicated because of its reliance upon editing in AutoCAD.

The problems with fills in the space plans accentuate that the modeler must be aware of the concepts of a building and its components that are expressed in Revit. For example, a room must be bounded by wall objects or room separator objects. A column may graphically contribute to the enclosure of a wall, but in the conceptual model of Revit does not enclose the space. Likewise, stacking several wall segments vertically was used by the students to represent a thickness that varied depending on height above the floor. However, Revit requires the objects to adjust the thickness of walls. The stacked walls behaved incorrectly when viewed as a space plan and room schedules were produced.

Special feature of Revit, such as the ability to make 3D DWF files, the ability to manage options, the ability to manage phases, and the ability to share a single model across multiple users, are very attractive and practical for facility managers.

In general, Revit is a more effective tool for managing facility management documentation than AutoCAD. It accelerated and streamlined several processes that the college uses to update and maintain its facility information systems. Because of its inherently 3D approach, it greatly extends the imaging and visualization capabilities of our facility information systems. We suggest that for organizations newly implementing a CAFM system, it may be very reasonable to employ a production pipeline in which the primary building data available for editing is stored in a BIM. Furthermore, the Just-In-Time CAFM system appears to be a viable solution.

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