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Building Information Modeling in Support of Space Planning and Renovations in Colleges and Universities

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BUILDING INFORMATION MODELING IN SUPPORT OF SPACE PLANNING AND RENOVATION IN COLLEGES AND UNIVERSITIES

By
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Abstract

The construction industry is responsible for approximately $1 trillion in work annually. A large percentage of this work is tied to the renovation of older structures. Due to increases in sustainable initiatives and the growing lack of green field development sites, the renovation of older buildings is becoming an even more substantial portion of construction work. Old, or urban based, college and university campuses require renovation of their buildings to sustain an efficient and comfortable campus. Renovations on a college or university campus are often the effect of a change in space requirements, and the planning of the space in a building is a major driver for renovations.

The renovation of an older structure on a college or university campus has many inherent issues associated with it. Included among these is the likelihood of unknown existing conditions, constantly evolving needs of the campus, cost implications of minor changes, and scheduling and phasing conflicts. Improvements in technology have the potential to increase the efficiency of the renovation and space planning process. One particular technology that could be of particular benefit is Building Information Modeling (BIM), a technology based collaborative process utilizing 3-Dimensional visualization software as its tool.

It was the objective of this research project to explore the benefits of using Building Information Modeling (BIM) in the delivery of renovation projects as well as its possible utilization in space utilization management. This study attempted to identify opportunities for BIM to improve upon the process that universities and institutions, in particular, currently use for their renovations and space utilization management.

This research project collected information from the WPI facilities management department specifically and from surveys of other institutions to better understand the current issues associated with renovations and space planning and to attempt to validate the use of BIM as a viable solution. A case study was performed on a building on the WPI campus, Salisbury Laboratories as part of this research study. The case study utilized 3-Dimensional Building Information Model to validate the possible use of the platform to streamline the delivery of renovation projects as well as its ability to benefit space planning process.

The study was able to identify several benefits of utilizing BIM in the delivery of renovation projects, including increased efficiency in the design phase and generation of conceptual estimates and phasing plans for the owner. The principal benefit found by the study in the utilization of BIM was the ability for spatial visualizations and the ease of modifying the design in a consistent and efficient fashion. There were several observed barriers to the utilization of BIM in this regard, namely the lack of knowledge of the software and the cost of implementing and updating the system.

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I have made every attempt to ensure that all intellectual property of others was properly credited to quoted sources, and I thank all those that contributed no matter how small or large the contribution.

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Chapter 1 Introduction

The modern construction industry is well known for being a fragmented and departmentalized one. In the industry there are several parties that act mostly independent of one another, the group who plans the project, then the ones who design the project, the party that builds the physical project, and there is the party that maintains and operates the completed project, which may be the same(but isn't always) as the last party, the user. By proxy of the nature of each individual parties entailed tasks the separation is inherent, but no bigger separation exists than that of the party responsible for the operation and maintenance of the building (typically the owner or an agent thereof) and the party(s) responsible for the design and construction of the building (Mendez, 2006). This separation is responsible for loss of information detail resulting in poor databases to provide necessary information for the facilities management team that will be responsible for the operation and maintenance of the structure (Autodesk, 2007).

This problem is exacerbated for institutions that are responsible for the operation and maintenance of several buildings or structures. The problem is further intensified by the likely possibility of the diverse use of buildings that need to be operated and maintained. One particular sector of the industry which has an innately larger number and range of buildings to operate and maintain is higher level education, colleges and universities. The range of use of buildings is variably large on any given campus and is related to the size, age, and type of campus. A college or university campus may have a wide array of building use types ranging from laboratories to dormitories and common space, with the age of the buildings and level of detail in the documentation ranging widely as well. The longer a campus has been established and the more diverse the usages of their buildings, the wider the scope of the operation and management team must be.

There are several major aspects to operating and maintaining a college or university campus to ensure that a certain level of efficiency and comfort is maintained for the users of the buildings and for the buildings themselves. The charge of ensuring the buildings themselves are operating at that level of efficiency and comfort is charged to the Facilities Management department or the Physical Plant Services on any given campus. The charge of guaranteeing that the space contained in those buildings is being used for its proper and intended means falls to the space planning committee involving faculty, staff, and administrators.

The management of the campus buildings themselves on a college campus involves many factors due to the aforementioned diversity of building types. Such factors are including location restrictions, historic value, cost implications, space usage restrictions, and current market factors including monetary restrictions and sustainable initiatives. The need for renovating existing space occupies a large part of the time and resources used in maintaining buildings on a college campus. As pointed out previously the inherent diversity of data due to the fragmentation in the industry results in a lengthy process when seeking out building documentation in order to begin the process of renovating any space. This results in many issues when discussing the renovation of an existing building in any institution.

Among the many issues directly related to the renovation of a space in one of these buildings includes the likelihood of unknown existing conditions, ever changing needs of owner's use of space, cost implications of seemingly minor changes, scheduling conflicts of space in buildings that may still be in use during renovation process, structural stability, and lack of accurate dimensioning. There are many reasons for the renovation of a space in a building including health and safety, code compliance, change in needs or use of space, and typical renovations to maintain the building to current standards. If the renovation of space in a building impacts the day to day activities that are held within the building, the charge falls to the aforementioned provost department to ensure that those same day to day activities will be able to continue to ensure the integrity of the institution. This service on a college campus is typically referred to as space utilization management, or space planning, and possesses its own very unique set of issues.

The issues involved within space utilization are many, including the difficulty in continuously changing the uses of the space and being able to clearly identify the owner of the space, the type of space that it is, and what is contained inside the space. A good organization will continuously do space utilization surveys to ensure that the spaces they own and operate are always being used to their maximum potential. Another difficulty involved with this is one that is directly related to the duration of the renovation process, which is where to place the resources that were contained in the space being changed, and what the effects of these moves are. These challenges will be present in every change of space project and any project that needs to shut down any amount of space for any given time to update, change the use of, or renovate.

These issues are ever present when managing a college or university campus and need to be dealt with as efficiently as possible, unfortunately the current methods utilized to deal with these issues are inefficient, costly, and most of all; completely separated from one another. The use of technology as a solution to inefficient and redundant processes in the construction industry is not a new idea, in fact we see the trend going back for centuries, from the invention of mechanical tools straight through to today with the advent of computer aided drafting (CAD) and now with the initiation of the 3-Dimensional Building Information Model.

3-Dimensional Building Information Modeling, BIM, is an idea that has been around for over a decade now, and the benefits of using this tool in the design and construction phase are well documented and almost common knowledge. But, the advent of using this tool for the operation and maintenance process is one that is still in its infancy, and furthermore its specific possible use in the aid of the delivery of renovation projects and space planning. This study will attempt to analyze how BIM can attempt to redefine the process by which colleges and universities currently perform renovations and space planning, by clearly defining the process by which they are currently performed and then the ways in which BIM may improve upon these processes, if at all.

Chapter 2 Background

As part of this study a review of the current state of the industry was performed. The study examined the current state of facilities management across the industry and the role of space planning and renovations in the operation and maintenance of a building. Common issues with the current practices were examined as well as existing research into solutions to these issues.

2.1 Communication Gaps in Project Delivery

The construction industry is a crucial part of the economy in the United States, as well as world-wide. The construction industry accounts for approximately 8% of the gross domestic product (GDP), while being the largest contributor to the manufacturing industry, and the second largest employer, only coming behind the government as the largest (Bogdan, 2000). In January of 2009 the construction industry alone accounted for approximately 974 billion dollars in spending (seasonally adjusted annual rate) (Census, 2010). Not to mention, the construction industry is responsible for the development of the built environment.

Within the construction industry there are several key parties that contribute in the delivery of any project. These parties play different roles in the project development phase and contribute with their distinct abilities. Because of these specializations, there is an inherent need for communication among the members on a construction project. The designers propagate their mental images and idea of a project primarily via a 2-

Dimensional (2D) media to the design detailers, who then attempt to further develop that image while attempting to ensure the constructability of the project and preserving the original design intent. The details are then communicated to the contractor who in turn transforms those details into a physical project without losing any of the design intent along the way. Throughout the process the owner must attempt to stay in the fold of all this transfer of documentation to ensure they are going to receive a building that is going to serve their needs at the correct price and by the time they need it. Deficient communication methods and inadequate exchange of information are the cause of approximately sixty percent of all construction problems (Australian CD-ISR, 2004). Figure 1 below shows a diagram of this traditional delivery process in the current construction industry (Yang/Wang, 2009).

Image 1

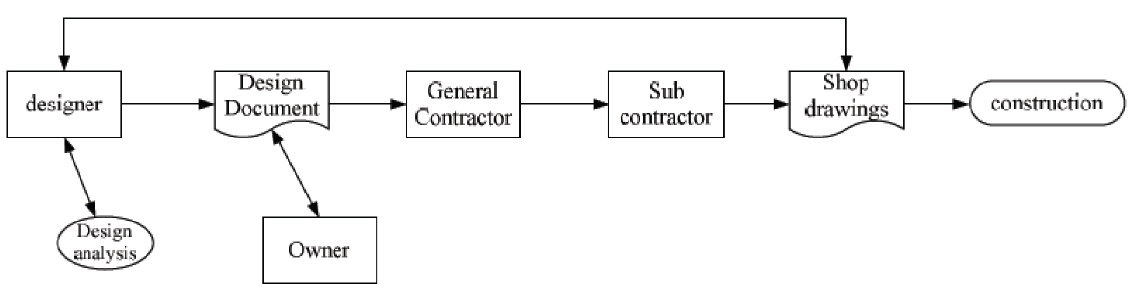


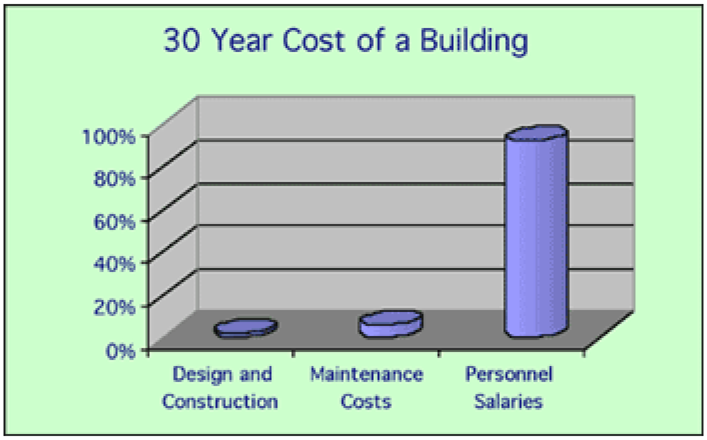
Figure 1: Traditional Construction Project Delivery Flow

This delivery process lends to an increased transfer of information gap between the owner of the project and the construction process. This is due in part to the aforementioned areas of specialization and to the sequential nature of the process. Another contributor to this is the sheer amount of individual "trades" involved with a single building project, owners of projects are hardly involved with the construction process, the birth and growth of the construction management industry testifies to that. It is because of this detachment from the construction industry that the owners find themselves relying upon the construction manager of their project (and any agents they have representing them) to coordinate and transfer the information about construction to them after the final delivery of the project.

Another major factor contributing to the communication gaps is the lack of alignment of the project participants with regards to schedule and cost. Which often produce heated debate among the members of a project delivery team and may even be the cause of negative relationships among themselves, which again results in the owner/client separation from the construction process (Mendez, 2006). In the end, there are gaps in the information about the project transferred to the owner at the completion of the project. With incomplete and unreliable information to use, operate and maintain the facility.

2.2 Facilities Management

The owner of any project, as soon as it is turned over to them becomes responsible for the operation and maintenance of that project. As shown in Figure 2 this portion of the life of a building accounts for approximately 6% of the total building cost over a 30 year (average) lifetime, while the design and construction of that same building accounts for only 2% of the total cost, with the rest of the cost being tied up in the salaries of the personnel utilizing the structure (Fuller, 2010).



Source: Sustainable Building Technical Manual

Figure 2: Life Cycle Cost Analysis of a Building

This data would suggest that more attention should be paid to quality and completeness of the information being passed to the owner to facilitate a smooth transition from construction to operation and maintenance (O&M). There is also a variably large period of time in which the owners have to wait in order to receive design documents that reflect the actual construction, also called As-built drawings. This waiting period can be as long as 12 months, and is usually a painful process for the owner to ensure receipt of this information (David, 2006). Beyond this, the owner needs information regarding all equipment, utilities, and materials used on the project such as the HVAC units, lights, or windows/doors. With this amount of information, and the number of sources that it comes from, it is no surprise that an owner cannot retrieve or produce, in a timely fashion, the warranty of a given item, or the floor plans to quantify amount of space in a given room, which in many instances does not reflect as-built conditions.

There is also a tendency to overlook the idea that the information received post construction phase is not even worth using, that the information contained in the traditional form is not even worth sharing (Autodesk BIM/FM, 2007). This is clearly seen in the 2004 NIST (National Institute for Standards and Technology) study analyzing cost of inadequate interoperability in the capital facilities industry. The study found that 15.8 billion dollars each year was spent on interoperability issues in the facilities management industry (Gallaher, 2004). It also mentioned that over 10 billion dollars of this was borne on the owner of the project. This number accounts for approximately 1-2% of the total amount spent across the industry. This money is accounted for in the everyday labors of the facility manager. Tasks including hand quantifying items for replacement, field verification of locations for equipment, or computing spatial data from a 2-Dimensional drawing (Khemlani, 2009).

The issues that are encompassed in every owners operation and maintenance of a building are compounded when referring to the same operation and maintenance on several buildings, or an institution. When referring to the O&M of several buildings, several new issues are encountered. Included among these is the fact that instead of a single person, or small group, needed to maintain a single building, the operation now requires an entire department acting on behalf of the owner to ensure the functionality of the buildings as a whole. This department is charged with the responsibility of guaranteeing the efficient and safe operation of the buildings as a whole.

College and university campuses are a particular institution that has several unique issues involving the operation and maintenance of its buildings. All of the college and university funding accounts for approximately 3% of the gross domestic product in the United States, making it a vital part of our economy. The nature and purpose of colleges and universities, one of research, learning, and cultural advancement; lends itself to the need for having a diversity of building types. These buildings vary in age and size presenting issues with the level of documentation needed to satisfy compliance with modern codes and regulations as well as construction standards. Most often with older buildings there is a lack of documentation or with the documentation of the changes made to the building over the years. This is compounded by the fact that the construction type of the building may not be up to the current construction standards such as handicap accessibility. Another issue is the likelihood that the building does not perform efficiently in terms of energy use and space utilization, as modern construction standards are built in an attempt to maximize building efficiency and performance.

Another manifestation of this building diversity is in the different building functional uses. Building functional use types range all the way from athletic use to laboratories and everywhere in between. This difference in building functional use lends itself to an operation and maintenance team that has to have a wide knowledge and skill to guarantee building performance. With over 3000 regionally accredited colleges and universities in the United States alone, the variation in campus types is large. Therefore, the operation and maintenance of any given two colleges or university campuses differs greatly, and requires customization and tailoring to each institution's needs. All these factors makes very challenging the operation and maintenance of a college or university campuses facilities.

The operation and maintenance of a college or university campus is a complex process that requires a series of trained professionals from sanitation specialists to project managers. The overall goal of managing the actual buildings themselves is charged to the Facilities Management department on a campus, possibly called Physical Plant Services. The specific goal of this department is to ensure the safe and efficient operation of the buildings in support of the mission of the college or university. The below excerpt is a mission statement that is typical of Facilities Management departments;

"*The mission of the Facilities Department is to provide a safe, clean, properly maintained environment for the WPI community, in support of academic and social activities. Facilities staff will furnish the highest quality service, with the highest level of professionalism.*"

http://www.wpi.edu/Admin/Facilities/

Beyond the Facilities Management department there are many individuals involved in overseeing the operation and maintenance, ranging from the Chief Financial Officer (CFO) that deals with the budgetary restrictions and Master Plan of the college down to the individuals that clean the buildings on a day to day basis and the input of the students and faculty that use the building on a day to day basis. A typical organizational chart of a Facilities Management department can be seen in Figure 3. Below the CFO is an individual who acts as the assistant to the CFO, whose day to day activities include managing the flow of the whole Facilities Management department. Below this individual are several key members who control very specific aspects of the Facilities Management day to day tasks.

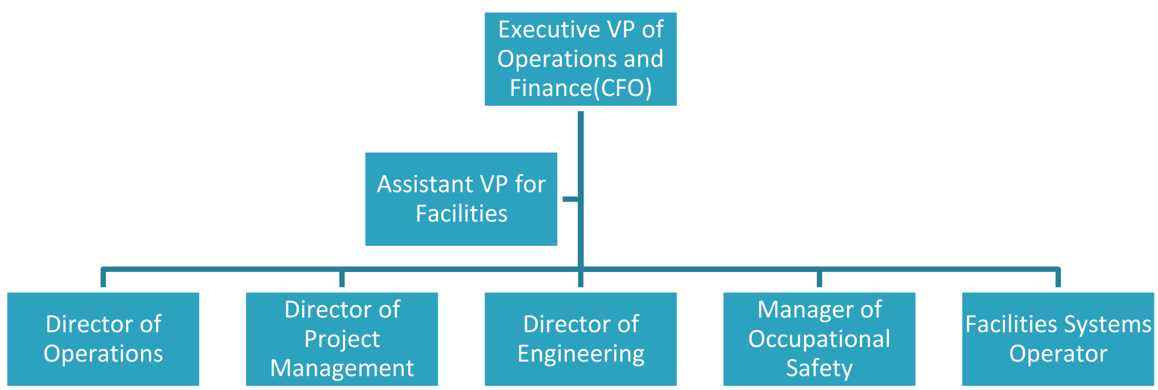


Figure 3: Organizational Breakdown of FM Department

Beyond the Facilities Management team and their task of ensuring the efficient and safe operation of the campus buildings is the department responsible for ensuring the space inside the buildings is being used for its intended purpose. This department could consist of several committees but is generally a part of the Provost or Academic Affairs department. The Space Planning Committee includes faculty, staff, and administrators who are charged with ensuring the proper and efficient utilization of space and assets for the benefit of the academic and social mission on the campus. This includes assigning space for each class in the proper location, and coordinating with other groups on campus to maintain the proper level of equipment in each room, and ensuring an efficient flow throughout the campus.

2.3 Space Planning

The management of the utilization of the space contained within the buildings on a college campus is governed by the function of that college or university. That purpose extends its control to the amount of space given to each department, staff member, and student. It also determines when the space is used, what is contained within the space, and who owns, uses, and operates that space. Given that a college or university is an academically based institution, this purpose is generally controlled by the department for academic affairs. The act of managing the utilization of this space, or space planning, takes precedence over all the daily operations and maintenance of those buildings. Figure 4 shows a basic relationship chart for information flow at a typical college or university campus.

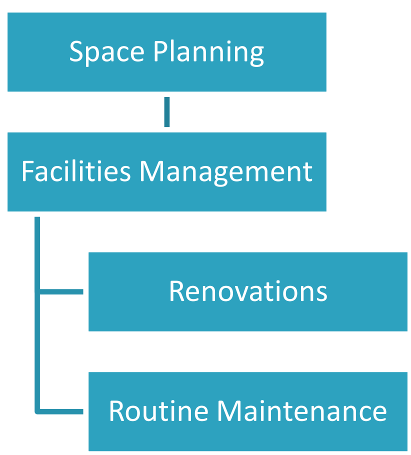


Figure 4: Information Flow at College or University

With the constant technological advances that experienced year after year, and with the increase in the availability of a college education (through student loans and government aid), the demand for space and campus facilities has been increasing dramatically. In the UK alone the attendance rate at colleges has increased by 100% in the past 20 years (Building, 2009). This increase in demand and the competition among colleges for better students has resulted in an academic environment that needs to be pliable in nature in order to maintain pace. And a space planning process must be in place at a college or university to meet the ever changing demand imposed by all these factors.

The combination of working to maintain an efficient and effective flow and adaptability of sources on the campus demands information to make decisions. For example, perform space utilization surveys to ensure the proper space per occupant and that the proper equipment is contained within the space. There are several more advanced needs for information to support the needs of the university to make space use related decisions on an almost continuous basis. Such as determination of occupant use and assets contained within a space when it needs to be changed. There are also complications encountered when it becomes necessary to move utility infrastructure or alter the use of this infrastructure within a building.

A space utilization survey may determine the amount of space per occupant, amount of space per work station, etc. Normally conducting these surveys is done by a consulting firm such, i.e. Rickes Associates. These surveys are generated for the purpose of maintaining a standardized environment, thus more efficient. The cost of these is dependent upon the size of the institution and the complexity of the survey. The issue with these surveys is the static nature of the data generated. In order to keep it up to date the spreadsheets generated by the utilization survey need to be hand updated with real-time accurate data. As number of computers in a laboratory change or the number of students using the space changes, the spreadsheets need to be updated to reflect current conditions. The step beyond that process is entering the data into a space planning software such as Resource 25® (R25) or FAMIS® from FAMIS Computer Corporation©. These programs are a utility that campuses can utilize to manage the space and get real time data about their space. But, again the data needs to be entered manually every time the situation changes, and is only utilized by this one department for the sole purpose of managing the space in the building. Figure 5 below shows an example of the capabilities of this type of software; example is Resource 25® from Worcester Polytechnic Institute. The software acts as a database for information about the space on campus such as occupancy load, time occupied, and equipment content. The end use of the software is to manage the space on the campus, the equipment in that space, and operation and maintenance of that space.

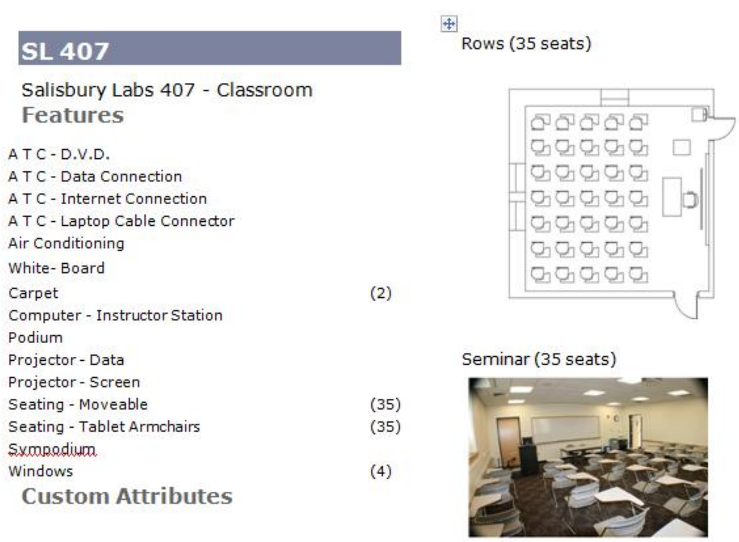


Figure 5: Resource 25 Software Database Example

The next set of issues is part of the process in dealing with changes in needs and requirements on a campus. These issues have to do with the logistics of making changes in the utilization of space on a campus, which is inevitable. When a change in space utilization is required within a building for some reason the assets contained within that space presumably need to move, depending on the change in utilization. The occupants of that space will also need to be relocated or dismissed. This management of assets and occupants is not easy to track with conventional systems previously noted.

Another way that has been developed to deal with this is by bar-coding all of the assets and having the physical scanning of the equipment populate a database that can be viewed electronically. By changing the status of the asset in this database the institution would be able to accurately track and manage the logistics of their assets. Of course this is assuming there was adequate interoperability between the database software and the space planning software in use by the institution. Even with those assumptions made, the act of tracking assets for this purpose only results in this data being input into a system used specifically for the management of the space on the campus. At this point it is important to determine how the change in the utilization of the space is being made. It is a simple task to change the utilization of an office from an adjunct professor to a pair of teaching assistants. It is not a simple task on the other hand to change the utilization of the space from a chemistry laboratory to a series of tenured professor's offices. The latter requires physical changes in the composition of the room. The change in a physical composition of a building results in a whole new series of issues, including the infrastructure of the building. Some parts of a building, depending on age and certain other characteristics, cannot be changed or altered so easily.

2.4 Renovations

Renovation work, along with the rest of the construction industry lately, is feeling the effects of the failing economy. The construction industry saw a decrease from 974 Billion dollars (Seasonally adjusted annual rate) to 884 Billion dollars this January, a drop by nearly 10 percent (Census, 2010). Though this number indicates a drop in the money being spent on construction across all types, from green field development to Rehabilitation projects, it doesn't tell the whole story. The fact of the matter is that the major players in the construction and development industry are starting to see the benefits in renovating an existing building versus developing a new green field project. There are now government incentives coming to redevelop older buildings, or adapt and reuse existing structures. The General Services Administration, the owner/operator of a vast majority of government buildings, is leaning towards renovations in all the money they allocate to construction. A Gilbane, Rhode Island based Construction Management firm, representative was quoted in a recent article by Debrah Wood in _*Southwest Contractor,*_ February 2009, that, "Nationally, in every sector, we have renovation work"(Wood, 2009). The reasons for this constant increase in renovations can be attributed to the sustainability forces in the market today. Investing money up front to increase the energy efficiency of an older building seems to be the wave the construction industry is riding on. There is also evidence that the increase in renovation projects is occurring in more densely populated areas, perhaps an indication that the actual land to start new construction just doesn't exist. With evidence of several large projects, and major companies being involved in renovating older buildings, this is something that will become a much more integral part of the construction industry moving into the future (Wood, 2009).

This increase in renovation work extends to the education sector as well, which saw an average of 12% decrease in spending over the last year (public and private) (Census, 2010). Colleges and universities are also feeling the effects of the failing economy, between the private institutions losing endowments and the public institutions losing funding. These conditions create an environment that requires institutions to search beyond the typical means of building a new building to satisfy the growing requirements of the institution. This means satisfying those space requirements by maximizing the efficiency of the buildings they already own, or building additions onto those buildings to save green field sites.

Renovating a building on a college campus is not an easy alternative for the space planning committee to implement. This is due to the many complications that are involved with performing a renovation. But there are several reasons that a space planning committee would deem necessary for the renovation of an existing building. Among these reasons are ensuring the life safety of the building and those inside of it, fulfilling code requirements, satisfying use requirements, and executive orders.

A successful college or university institution typically develops a "Master Plan" to project all the investments to be made on their buildings, as well as other capital investments. This plan usually employs a series of criteria that breaks down the whole into what work will get done when and in what order. This plan dictates when and why a building gets renovated, or if at all. Different institutions have differing priority levels for each of the factors listed above. Most often the life safety of the occupants and building will take precedence. This category of renovations includes work that ensures the safe occupation of the building such as fire safety system upgrades or installations. This may also include building envelope improvements, energy efficiency upgrades, or structural integrity issues.

Another important factor included in this plan addresses compliance with code requirements. These renovations and upgrades are necessary due to constantly changing requirements of building occupancy. The American Disability Act (ADA) is one set of upgrades that falls into this category, or the removal of environmentally hazardous materials. Another set of upgrades that may be necessary for a building is related to the occupancy of older buildings. It may be deemed necessary to bring up to the most recent building code, all of the infrastructure in the building (electrical, plumbing, etc). Two additional factors driving renovation projects fall into the space planning category and are used to fulfill the constantly changing needs of the institution. Some renovations that may fall into this category are those that add additional laboratory space onto a building or create offices for new faculty members out of unused classroom space. Also included in this category are the renovations requested by the committee of department members, updates and rehabilitating space in buildings for instance.

Renovation projects impact campus life in many different ways. There are issues that affect the college campus environment and then there are issues that plague all renovation projects. The main issues surrounding renovations on the college campus are the relocation of the assets and occupants currently occupying the space to be renovated, the scheduling and phasing of projects that are occurring in buildings that need to remain in use, and the obvious difficulty in dealing with the constant change in space requirements. The critical issues when performing a renovation on any building are the unknown existing conditions, cost implications of seemingly minor changes, structural stability, safety considerations, and inaccurate dimensioning of existing documentation.

Those issues that are particular to college campus renovations are derivative of the relationship between the space planning process and renovations for the purpose of changing the utilization of space. A major cause of the issues is the lack of coordination between space planning process and the facilities management department, who manages the delivery of the renovation project from the owner's side. This lack of coordination produces information gaps adding uncertainty to the renovation process and poor system interoperability. For example the FM department uses a work order system such as Maximo that operates totally independently from the space planning software used by the space planning committee. These two separate software systems are not interoperable, that is, they do not directly exchange electronic information. Figure 6 is an example of a workflow environment utilizing Maximo. This workflow does not allow interoperability with other software types that may be used on the campus.

Figure 6: Workflow Diagram Utilizing Maximo

The issues associated with all renovation work, regardless of the institution in which they are being performed, are a result of inefficient practices throughout the industry. The largest of the problems are due in part to the lack of proper communication in the construction industry, which results in inferior data transference. This results in poor quality of data obtained by the FM department on the campus, or no data at all.

When it comes time for a renovation to be performed it is likely that the only set of plans that the FM department has are inaccurate or do not reflect as-built conditions. This would result in poor reflection of existing conditions, causing problems with cost estimates and designs for the renovation. For example, if electrical service was updated or positions of electrical fixtures was moved this wouldn't be reflected on the plans, and the information would have to be hand collected or provisions would have to be made after construction began to adjust for the incorrect data.

Other issues with renovations are relative to the age of the building and the type of construction. As mentioned previously there are many concerns with the documentation actually possessed by the FM department. Depending on the age of the building the drawings may have been drawn by hand or more likely they were designed to a different construction standard than we currently adhere to. This raises questions about the structural stability of the building and its capability of withstanding new loads placed upon it. It also raises many questions about the accuracy of the drawings, as many changes may have occurred since they were originally designed.

All of these issues make extremely small changes that may be necessary in some buildings much more expensive than they should cost. The last set of issues is related to the safety of the occupants and construction workers that will be moving through a building being renovated, assuming parts of it will be available for occupancy. It is extremely difficult to prepare safety plans for emergency situations while parts, possibly critical, of a building are under construction. There is also issues that are raised when discussing noise levels, construction debris, vibrations from construction equipment, and stability of the building if the structural system is being augmented. All of these issues are the result of improper preparation which is, in turn, the result of improper tools to prepare for the phasing and organization of general conditions (lay down and set up areas).

All of this leads to the point that the current methods we use to deliver renovation projects, although effective on the surface, is causing inefficiencies in the industry and costing owners more. There is much room for improvement in this process and renovations are, and will only continue to grow as, an important aspect of operating and maintaining a college or university campus built environment. Which makes the necessity for finding an efficient process for the delivery of renovation projects all the more important.

2.5 Building Information Modeling

Building Information Modeling is a technology based delivery process which is gradually becoming more recognizable in the construction industry. The benefits of BIM have been extolled in some form or another by software vendors, enthusiastic supporters, or success stories from firms who are currently utilizing in some form or another. The benefits of BIM range from simply providing 3-Dimensional visualizations and supporting an energy analysis all the way to a tool that can catalyze the integration of the project delivery team from start to finish. BIM is being used by 43 percent of architects, 35 percent of engineers and 23 percent of contractors on more than 60 percent of projects, according to a 2008 SmartMarket Report (Leybovich, 2010). The reason for architect, engineer, and contractor adoption has to do with increases in efficiency and cost reductions over the long run. Specific benefits that can be seen with the implementation of BIM enabled delivery systems are reductions in paper use, coordination of team members and trades, phasing, and estimating.

The most well documented set of benefits being seen throughout the industry is a reduction in coordination related Requests for Information (RFI). Companies throughout the industry have cited cases where they have saved over 50% in coordination related RFI's and 50% in Coordination related Change Orders over an almost exact duplicate project that did not utilize BIM (Leybovich, 2010). Another major benefit is the reduction in schedule length due to a more accurately planned construction phase. Evidence from the same project report shows that the construction schedule was reduced by 6 months on the project utilizing BIM over the one that did not. These benefits are a result of more accurate clash detection through the 3-Dimensional modeling of BIM and better team coordination utilizing the 3-Dimensional model as a common language through which communication is achieved.

These benefits are very well documented and although adoption of BIM has slowed recently due to the economic downturn, it is still increasing in adoption. The GSA, as of 2006, requires the utilization BIM on all construction projects, the state of Wisconsin, as of July 2009, now requires all projects over $2.5 Million to utilize BIM (Leybovich, 2010). The use of BIM across the construction industry will continue to increase as the benefits of the system start to become reality. One of the areas in the construction industry that is starting to become a focus, because of its importance in the life-cycle of a building, is the facilities management sector. The widespread use of BIM to design and construct buildings has cast a light on the inefficiencies in the traditional processes that owners use to operate and maintain their buildings. The idea to use BIM to reform the methods by which owners manage information to operate their buildings, or at least increase the efficiency, is one that has been the subject of serious study recently (Autodesk BIM and FM, 2007). There have been studies done on initial benefits of a BIM enabled system, such as space visualization, asset tracking/management, and MEP infrastructure maintenance.

Ideally the owner receives the Building Information Model after the construction phase and utilizes the model as a source of information for the O&M of the building. With the building model in the owners possession there are several areas that have been identified as possibly providing benefit to owners in the operation and maintenance of their facility. Such as visualization, building element quantification, asset tracking, and more accurate building documentation (Autodesk BIM and FM, 2007). Due to legal issues, the free transference of the 3-Dimensional Model is slow in coming to the industry though. There is also the issue with the interoperability of the 3-Dimensional model information and whatever software is being utilized by the Space Planning Committee and FM departments already.

Chapter 3 Methodology

It is the objective of this study to explore the benefits of using Building Information Modeling (BIM) in the delivery of renovation projects as well as its possible utilization in space utilization management. This study attempted to identify opportunities for BIM to improve upon the process that universities and institutions, in particular, currently use for their renovations and space utilization management.

The methods used in this study to collect and analyze data included a literature review, a review of the current state of the industry through interviews and a survey, and two case studies. The literature review was used to compile data on the background of renovations and space planning as well as the existence of data related to BIM in this respect, or lack thereof. The interviews were composed of questions tailored to collect data pertaining to the current methods utilized for renovations and space utilization management at colleges and universities. The answers to these questions were then used to compose a survey that would reach a larger responding audience, to try and ascertain the current state of BIM in renovations and space planning across the college and university sector of the industry. A case study was performed on the Salisbury Laboratories building on the WPI campus in an attempt to ascertain possible benefits of BIM in space planning and renovations. The results from this case study were then applied to a series of recommendations that were tailored to a second building on the WPI campus, the Lee

Street school building, in an attempt to give the FM department at WPI a recommended future use.

3.1 Literature Review

As part of this study a literature review was performed including white papers, past research papers, scientific articles, industry publications, and government agency publications. The review of literature for this study revealed several interesting points; mainly that Building Information Modeling is not being widely used at this point in the support of facilities management, although the idea has been talked about by many including the General Services Administration.

3.2 Review of Current State of Colleges and Universities

This research project collected information from the WPI facilities management department and from surrounding colleges and universities in the Worcester-Boston area to better understand the current practices in facilities management with relation to renovations and space planning, and to try to ascertain the level of knowledge and use of BIM in this respect. Through this research the study attempted to identify if the need for the use of Building Information Modeling is a viable alternative to support space planning and renovations. It was also an attempt to determine the potential use of BIM by WPI for this purpose.

In order to determine these needs the study collected information from several key members of the WPI facilities management department. A committee was formed on the WPI campus in order to facilitate the possible implementation of BIM based management software. The committee was formed to attempt to determine possible benefits and costs of implementing building management software that is based off of a BIM platform. The information gleaned from these meetings was a source of data for the study to generate direction. In addition to this committee, interviews were performed with 5 different key members of other college and university facility management departments.

After conducting the interviews, a survey was generated using the information collected and compiled. The survey contained questions pertaining to the level of knowledge and use of Building Information Modeling on college and university campuses, as well as questions regarding the current state of delivering renovation projects and handling space planning. The survey provided information to meet the objectives of this study.

3.3 Case Studies

In an attempt to conduct this study in more detail, two case studies were performed: the first of which involved the use of a preliminary Revit® model of Salisbury Laboratories which was previously created by WPI graduate students Zijia Liu and Christopher Keegan. The second case study was performed utilizing the information obtained from the first case study on the Lee Street school building.

3.3.1 Salisbury Laboratories

The model was updated to more accurately show the existing conditions of the Salisbury Laboratories building. The BIM was updated by adding information to reflect information requested by the Space Planning Committee at WPI. After the model was updated several tests were performed on the model to indicate its possible usefulness in the support of the delivery of renovation projects and space planning. For example, quantity takeoffs were pulled from the model as well as space utilization surveys. This analysis of the Salisbury Laboratories Revit® model was able to validate that a BIM enabled management system would be a valid solution to increasing the efficiency and sustainability of space planning and renovation practices in the Facilities Management department for colleges and universities.

3.3.2 Lee Street School Building

The data gleaned from the Salisbury Laboratories building model will be incorporated and applied to a second building on the WPI campus, the Lee Street School building, which comprises the study's second case study. By utilizing the lessons learned from the Salisbury Laboratories case study, the FM department at WPI can apply the information to maximize the benefit of BIM on a project that is set for major renovations in the near future. In order to facilitate this process a building model shell was created with a table of recommendations for data to be added into the model. This will create a real application for the study and allow the possible benefits of BIM to be realized right away.

Chapter 4 Review of Current Practices of Colleges and Universities

Several data collection methods were employed in order to obtain a more clear understanding of the current practices utilized to deliver renovation projects and perform space planning processes. Among those methods were meetings with key personnel on the Worcester Polytechnic Institute (WPI) Facilities Management Department staff, interviews with key personnel at other local colleges and universities, and a survey of Facilities Management departments at college and universities across the country. The purpose of this method was to first obtain information about the methods employed by the FM department at WPI (campus location of case study). Once information was obtained the study then investigated methods and critical issues at other Colleges and Universities in that geographic location. The study then consolidated the information about methods and issues and conducted an electronic survey among Facility Managers at various campuses across the country.

4.1 WPI Meetings

4.1.1 WPI-BIM Committee

In order to explore the possibility of deploying a BIM enabled FM system WPI set up a committee composed of students, faculty, and an outside consultant. This committee, the WPI-BIM group, was focused on reviewing current practices and information needs and on exploring the possible benefits of using BIM for WPI. There are several important pieces of information that came out of these meetings that are pertinent to this study including specific details on the kind of information the FM department upper management identified as potential areas for immediate benefit derived from this system. Other information obtained from these meetings was a list of concerns on the adoption of this system. Also gleaned from these meetings was information about how WPI performs space planning management and global Facilities Management tasks.

Other sets of meetings were performed with the head project manager for the WPI FM department. At these meetings information about how WPI delivers renovation projects was revealed. The Space Planning committee on the WPI campus was also engaged and voiced opinions on what information they would like to see in the building model.

Many of the benefits they identified as part of using this system coincide with the benefits this study identified through the literature review; such as space utilization surveys, quantification of building elements, centralized location for accurate building plans, and Infrastructure diagrams. The concerns voiced by WPI are also of no surprise, they see the transference of data into this system as possibly problematic. They also have concerns about the sustainability of this type of system, of whether or not it could provide continuous value. There is also the concern that the use of the system will require too much training.

The main focus of the meetings was on the purpose of trying to use Building Information Modeling as a tool to increase the efficiency of the Facilities Management practices at WPI. The main ideas that were brought up by the members of the committee were using the model as a means by which to store data in a centralized location through a building model. This data would be accessed by the FM department and space planning committee for different purposes. Some ideas as to these purposes were for planning space, archival, and keeping building data current. Another major focus was on the capital budget, and how this would help capital expenditure projects and project planning (See appendix B for meeting minutes).

The main benefits they saw for space planning purposes was for space utilization surveys. While the major benefit they saw throughout the whole process was having a completely accurate set of floor plans for every building that were current and easily accessible. Several items were discussed about the capabilities of Revit® to export in different file formats, such as DWF and XLS. With the capability of being able to quantify building elements and export to a spreadsheet that could be easily updated, the possibility of a more seamless conversion was possible. There is also the possibility of using a 3rd party building model viewing software, such as Navisworks®, to view the content of the 3D model, which would require less training. There is also the option of exporting the building model into a .dwf file format to be viewed in Autodesk® Design Review for model viewing as well. Therefore only the people who would be updating the model would need to be trained in building model authoring, the users could still utilize common file formats in readily known programs. Figure 7 shows an overview of the knowledge and training required to utilize different software and the file formats associated with them.

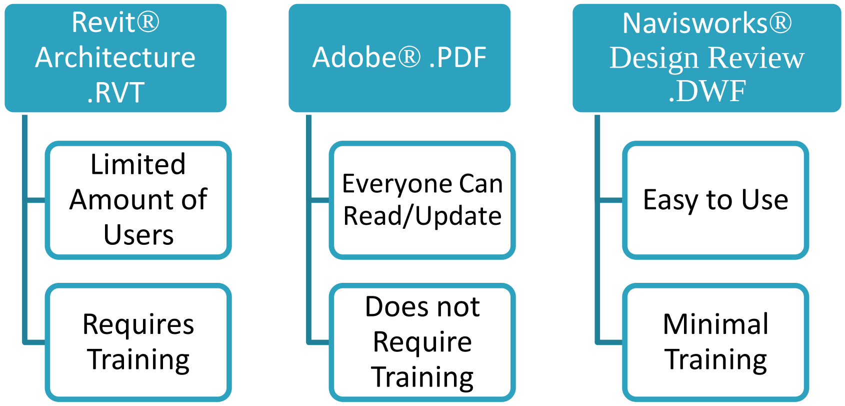


Figure 7: Software Training Requirement Breakdown

The biggest concerns that WPI had were very similar to the ones the industry sees as barriers to adoption as well. They voiced concerns about the interoperability of their current work order and preventative maintenance system, Maximo, and the Revit model information. They are concerned that they will not be able to access the information from the Revit model due to the complex nature of the system and the amount of time and money necessary to train employees in the use of the program. There is also concern about the amount of time and money needed to maintain the system, and whether or not the return on the investment into the system will be worth it.

The last part of information obtained was about current practices and programs used by WPI to perform the delivery of renovation projects and details about their space planning practices. WPI utilizes a traditional process for the delivery of renovation projects, constrained by the lack of accurate information about the building existing conditions and by the lack of interoperability between the information systems used by the space planning groups and FM department. The FM department utilizes Maximo for tracking of work orders and maintenance schedules, while a program called Resource 25 is utilized by the

Space Planning committee. The two programs do not interoperate with one another and thus there is a data transfer gap.

4.1.2 Facilities Management Meetings

Several meetings were performed with the head of facilities project management at WPI to ascertain details about the specifics behind the delivery of renovation projects and what information the FM department specifically, would like to see included in the Building Models. The importance of these meetings lies in the practicality of the responses, and the accuracy of the information provided by an individual immersed in these practices on a day to day basis. Some important information obtained in these meetings were details about the actual process used to generate a working set of documents for renovations, in particular for the case study in this research. It was found that the original paper drawings possessed by WPI for the majority of their buildings have been converted electronically into a 2-Dimensional PDF or DWG format and even fewer (10%) in 3-Dimensional building models. On several occasions the individual mentioned the drawings they possessed as “dimensionally challenged”. With drawings such as these when it comes time to perform renovations, it is up to the architect designing the renovation to use his best judgment or to verify dimensions in the field when laying out floor plans which may bring out numerous change orders during construction. What is important for this individual to include in the model are the locations of MEP infrastructure connections and main equipment items such as water, electric, storm sewer, steam, sanitary line, and fire protection standpipe locations are important. Their main objective is to be able to convey this information to maintenance personnel prior to sending them out to perform maintenance or a repair.

4.1.3 Space Planning Committee

The last meeting in which information for this study was obtained from at WPI was with the Space Planning committee. The meeting was attended by key members from the provost office, academic affairs, and facilities management. The concept of using BIM to facilitate their activities was presented to this committee and afterwards they were asked for comments and ideas. They were interested in the idea of using the model for space utilization surveys but were concerned about the usefulness of the DWF format in Autodesk® Design Review. After the presentation the committee proceeded to discuss the renovation plans for the 2nd and 3rd floors of Salisbury Laboratories. To support their discussion they used a colored 2-Dimensional CAD produced floor plan which can be seen in figure 8 below. They used this floor plan to decide what they were going to do with the final renovation and made decisions based upon the look of this layout. The proposed modifications on the use of the floor space needed to be sent back to the architect to update the 2-Dimensional floor plan and possibly have another meeting to decide again if it met their requirements. This process could have been easily improved with the support of a 3-Dimensional digital building model and the direct participation of the architect at the meeting.

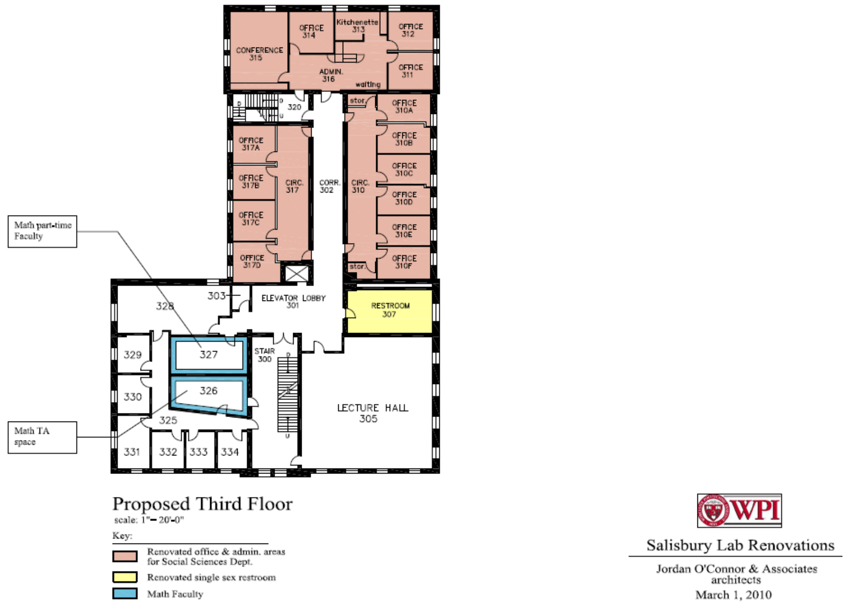


Figure 8: Architect Generated Floor Plan

4.2 Other College and University Interviews

As part of the study, interviews with key personnel at other colleges and universities were performed. The purpose of these interviews was to assess that the benefits and methods that the background research uncovered as well as those that WPI identified were viable across the rest of the educational institutions in that geographic area.

4.2.1 Worcester State College

The first interview was related to a campus of approximately 5,000 Full-time students with 12 buildings housing approximately 1.2Million SF. This institution is governed by state agencies, Massachusetts State College Building Association and the Division of Capital Asset Management. This makes their situation different from a private institution, because their funding process is highly regulated and once approved it can only be applied towards specific items. The main use of Building Information Modeling on this campus is geared towards sustainability and energy analysis. Another benefit from the use of BIM seen by this institution was with space utilization surveys, a quantification and classification of space in the buildings. There were several barriers to the use of BIM, namely the cost of training employees and lack of knowledge of capabilities of BIM.

Because of state regulations mandating the use of BIM, Executive Order 484 by Governor Swift, any new construction on this campus requires the use of a 3-Dimensional building model. The rest of the buildings on the campus are in 2-Dimensional DWG format. They have a space utilization survey recently completed by a third party consultant. This all amounts to a well documented campus and coupled with state procurement guidelines, MGL 149, a standardized delivery process for any renovation work. The space planning process is governed by a committee composed of heads of departments on the campus and the Vice President of Academic Affairs. A big focus on the campus is on standardization of space for faculty and students, which is extremely hard to do with 2D floor plans and spreadsheet surveys. All estimates and schedules are generated by the contractor, with a third party consultant hired as an owner's representative performing a reconciliation of these for the college.

There were several barriers to the adoption of a BIM enabled system; most are an effect of government guidelines. The biggest barrier was the cost of training employees in the use of the system, unless the state mandates it or assigns an individual to this position, it will not happen. The individual interviewed was also doubtful of the actual benefit of the program, mentioning that BIM does not get to the core of how individual occupants react with one another, quoting this as a large drawback to the system.

4.2.2 Assumption College

This institution is a campus of approximately 2,100 Full time students with 40 buildings. The Facilities Management department on this campus manages approximately $1 million in renovation work a year. The knowledge of BIM at this institution was minimal, and was unaware of the benefits of the system. The process involved in the delivery of renovation projects is typical of a private institution. They contract an architect and a general contractor for capital asset renovation projects, any smaller projects they self perform. They hire architects and contractors with whom they have developed a strong relationship and therefore use the architect as the owners representative as well for reconciliation of contractor generated estimates and schedules. Their building drawings for 60-80% of the campus are stored in electronic CAD format (actual amount unknown), the rest of this information is in paper format.

The individual interviewed was the head of the FM department at the college and did not participate much in the space planning process. The registrar governs the use of space on the college campus, and all assets within. This process is completely separate from the renovation delivery process. The institution saw benefit, though in 2-Dimensional, in the use of computer generated space utilization plans that could be automatically updated.

4.2.3 Harvard – Allston Development Group

The Allston development group is charged with the growth of Harvard into Allston, and controls approximately $500 million in work on an annual basis. The main focus of BIM for this particular institution was as an asset management tool. The main barrier commented on by this individual was the economy and the owner reluctance to spend "extraneous" money. At the development group the gears are being set in motion for the coming of BIM by developing programmatic tools for the implementation of its use on new construction projects, standardization for the information to be input into the models. The individual commented on the main barrier at great length, mentioning the fact that the use of BIM is "owner-controlled" and that until the owner demands it all we will see is "AD-HOC" BIM. There is no conversation ongoing for the modeling of existing buildings, or its use in Facilities Management.

The delivery process for renovation projects is typical for private institutions. The Architect is contracted to design the renovation and generate a conceptual cost estimate with the construction manager generating the detailed estimate and schedule. Reconciliations of these is charged to the owners representative, third party consultant.

4.2.4 Harvard- FAS Undergraduate

This institution is a large private institution with over 200 buildings housing approximately 10 million SF. The Facilities Management department performs $30-75 million/annually in renovation and renewal projects. Current use of BIM on the campus is for special data and visual renderings only, used solely for reference purposes. Although they do use BIM for space surveys it only extends to computing volume of the space. According to this institution the main barrier for the use of BIM is the special skills required to create and update the model and the resources required to keep the model up to date and accurate. The interviewee mentioned that it was even hard to properly maintain and update a 2-Dimensional set of building documents. Their building drawings for 90% of the campus are stored in 2-Dimensional Electronic format and no full 3-Dimensional building models. The interviewee saw the potential benefit of BIM in the direct transference of the model from contractor to owner post construction phase to assist in the O&M process.

4.2.5 Harvard- School of Public Health

This institution consists of a campus of 24 buildings and a Facilities Management department that performs $4 Million in renovation work annually. This institution sees the main benefits of BIM in the coordination and integration it offers during and after the construction phase. The largest barrier to the adoption of BIM is the political environment, with executives perceiving a high risk in the contract terms and intellectual property issues.

Some issues related to performing a renovation include the coordination of involved parties, change orders due to improper designs and unknown existing conditions, and schedule inaccuracies. Issues they see with the space planning process are difficulties with coordinating changes to the utility infrastructure and finding and allocating swing space. They currently use Capital Asset Facilities Management Software (CAFMS) to assign space allocations, but is a completely separate process from the actual renovation. All work is done with 2-Dimensional CAD building plans.

4.2.6 Summary

The use of BIM across other academic institutions is varied, but the use of BIM in the support of FM is almost non-existent. Even the knowledge of BIM and its benefits and drawbacks was extremely varied among this small sample group. The processes by which renovation projects are delivered is fairly systematic and standardized with an architect being contracted and given whatever 2D building plans the college possesses to update and design the renovation off of. The estimates and schedule were then generated by third party consultants with reconciliation of these being done either in house or by a consultant, both of which cost money and time. None of the interviewees mentioned anything about the inefficiencies in the current process used for delivering renovations, although none rejected the idea of a more efficient process. Across all the universities interviewed the space planning process was separate from the renovation process, making clear the existence of the data transfer gap in institutions.

Interview Summary

School	Knowledge of BIM	Use of BIM	Observed Benefits	Observed Drawbacks	Notes
Worcester State College	Yes	Mandated by state regulations for use in obtaining LEED certification	Sustainability and Space Utilization Surveys	State funding preventing generation of models and staffing to maintain	State Regulations govern all projects
Assumption College	No	None	Space Classification and Quantification	Knowledge of Benefits and system specifics	Lack of knowledge of BIM in general
Harvard Undergraduate	Yes	Graphic Visualization and quantification of space volume	Direct transfer of model for accurate O&M data as well as a more accurate set of plans to build off of	Specialty training required to generate and update Models	
Harvard School of Public Health	Yes	None	Integration and Coordination of Construction process and beyond	Political resistance, contract terms, and lack of knowledge	High profile politcally charged environment is the driving factor
Harvard Alston Development Group	Yes	Ad-hoc BIM (random models for random purposes)	Asset-Management	Economy and lack of Owner support	Currently generating a BIM standardization in an attempt to increase efficiency when starting to utilize BIM

Figure 9: Interview Summary Chart

4.3 Survey

What was previously learned from reviewing the literature and conducting interviews was consolidated in a survey that comprised of a set of questions created from the data collected from the previously described interviews and meetings. Commercially available internet based software was used for the compilation and distribution of the survey. It was then sent out using several different methods; including the Society for College and University Planners (SCUP) distribution lists and known contacts from the interviews and meetings. The survey generated a mildly sized response group of 23 respondents which limits its statistical significance. The survey was addressed to individuals holding key roles in Facilities Management departments at colleges and universities.

The focus of the survey was to gain a clearer understanding of the current situation across colleges and universities in terms of BIM and renovations and space planning. Among the information the survey was able to elucidate was the level of knowledge and use of BIM, what BIM is being used for, and also why it is not being used. Another part of the survey addressed the identification of issues common to renovation projects and space planning management as well any software programs currently being utilized to support these efforts.

The results from the survey were, in some ways, surprising and, in other ways, expected due to knowledge acquired from previous research. Previous research showed that Facilities Management is an important part of the construction process, the survey solidifies the fact that space planning and renovations are an important portion of that process. With campuses spending approximately $12 per Square Foot[Note 1] on capital asset renovations annually and changing approximately 3.5% of gross building area annually[Note 2]. There were some interesting, though inconclusive, findings resulting from cross-tabulations of the profiling data showing that the level of BIM use does not depend on size, money spent, or number of persons employed.

Through information from the interviews and meetings it was evident that general knowledge of BIM and its benefits was not common knowledge as the industry

Note 1: Data generated from survey respondents of total Square footage of buildings over total amount of money spent on capital asset renovations annually. Range of accuracy is +/- 1.5%

Note 2: Data generated from survey respondent answers to total square footage over square footage of space reassigned on an annual basis. Range of accuracy is $12.43-$26.97/Ft^2

documentation states. The survey solidified that fact with 0% of respondents being involved with BIM on a regular basis and approximately 11% being involved with it in some capacity as seen in Figure 10. Another interesting statistic is that among respondents approximately 80% have developed little to no building models for buildings on their campuses as seen in Figure 11.

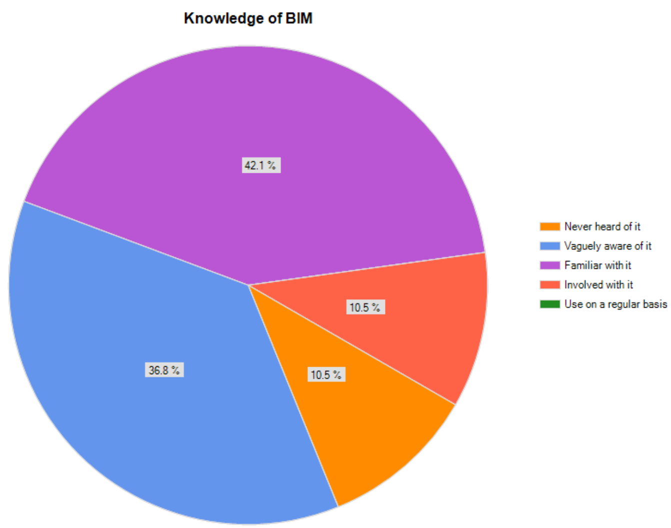


Figure 10: Survey Results of BIM Knowledge

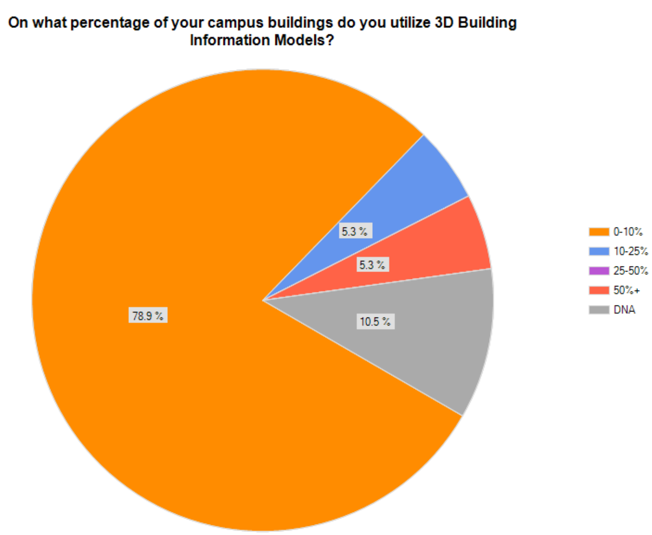


Figure 11: Survey Results on BIM Utilization

The survey also questioned respondents as to the status of their software systems utilized for the support of space planning and the delivery of renovation projects. As seen in Figure 12, the results showed that 50% of respondents used no software to support either process, while the majority of the other 50% used a variety of software types; no respondents used the same program in the support of both processes[Note 3]. As seen in Figure 13, the large variety in software used to support these processes exemplifies the data generated by the NIST study on inadequate interoperability, and shows that the data transfer inside of a single institution is not unlike data transfer between two completely separate institutions.

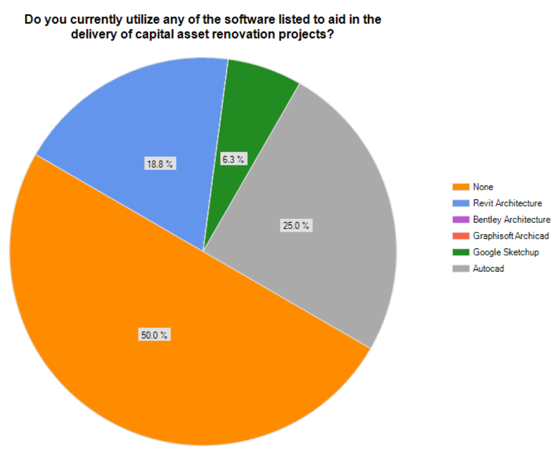


Figure 12: Survey Results on BIM Software Use

Do you currently utilize any software to aid in the management of Space Planning?

Answer Options	Answer Options	Response Percent	Response Count
Yes	Yes	52.6%	10
No	No	47.4%	9
If Yes Please Specify:			
Resource 25			
Autocad			
AutoCADExcel			
Drawbase			
FAMIS			
FacilitiesLink			
own written software and Excel			
ArchiBus Strategic Master Planning module			
FAMIS			
Manhattan Centerstone			

Figure 13: Survey Results on Utilization of Space Planning Software

Note 3: Cross-tabulation of both responses

The next set of data generated by the survey is in regards to common issues with renovations and space planning processes, a list developed by previous research and meetings. As seen in Figure 14, the survey respondents confirmed that the largest issues with performing renovations were finding swing space to put assets in during renovations, coordination of parties, and scheduling/phasing. As seen in Figure 15, respondents again confirmed that finding swing space was also the largest issue with performing any space utilization change.

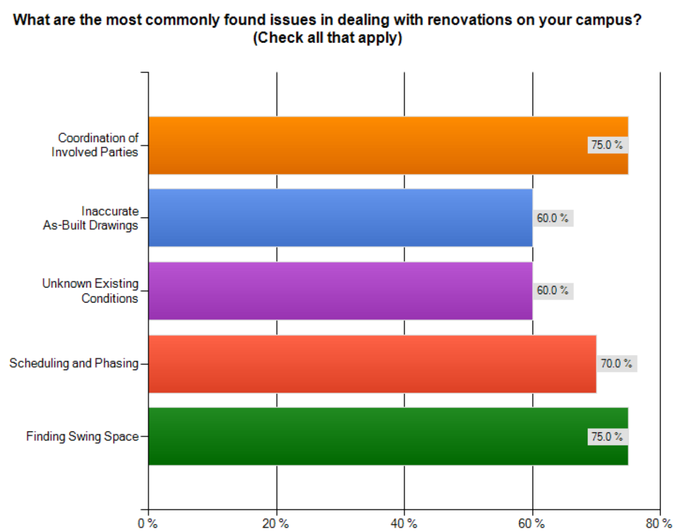


Figure 14: Survey Results on Common Issues with Renovations

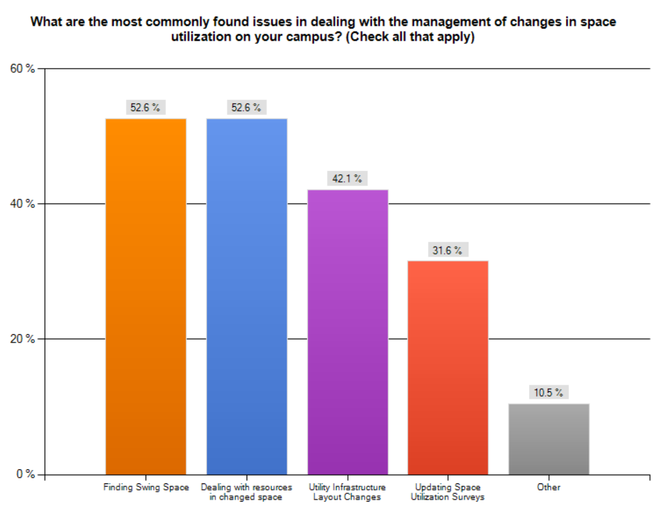


Figure 15: Survey Results on Common Issues with Space Planning

The respondent group that claimed to be involved with BIM in some capacity on their campuses were asked to identify what they saw as benefits of using BIM and also what they used BIM for in terms of Facilities Management. As seen in Figure 16, the survey group indicated that visualization of space was the principal use of BIM with only one respondent claiming to use BIM in support of delivery of renovation projects. As seen in Figure 17, the primary benefits seen by this respondent group were a reduction in paper use while benefit was also seen in more accurate as-built drawings.

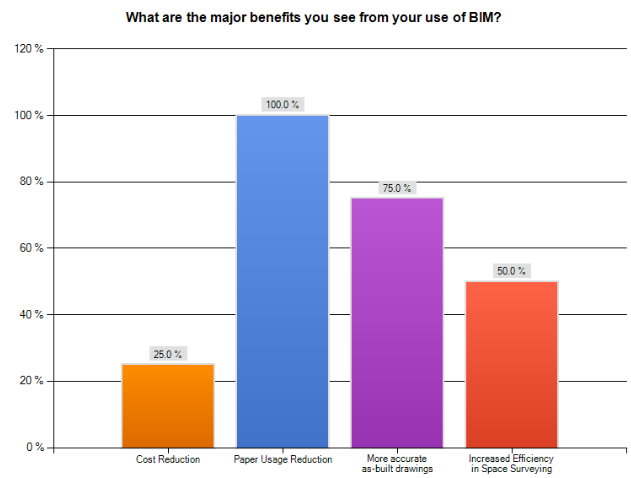


Figure 16: Survey Results on Benefits of BIM Use

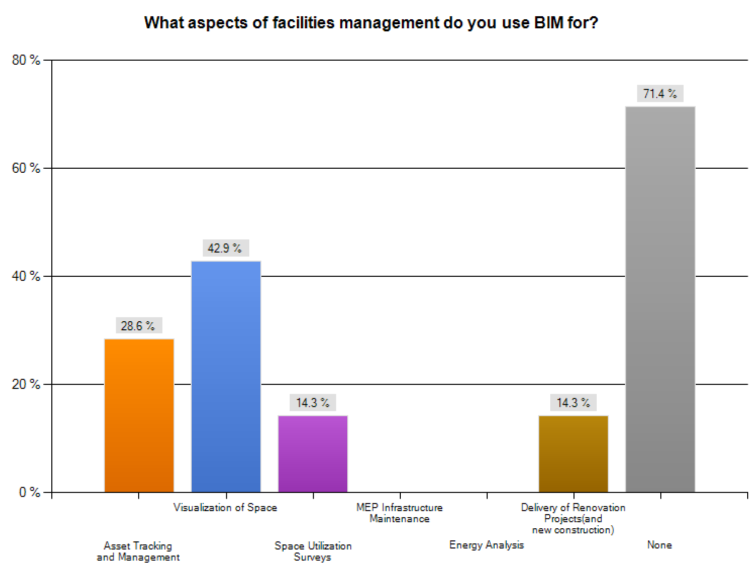


Figure 17: Survey Results on Aspects of BIM Use

Possibly the most important set of data generated by this survey was a result of questions asked to those who did not use BIM. Specifically they were asked what they saw as specific barriers to the adoption of BIM as well as what they saw as immediate benefits if they could implement BIM. Among the respondent group the largest barrier to the implementation of BIM was the cost of employing or training personnel in the use of the system as indicated in Figure 18 below. Among the respondent group that said they were familiar with BIM, 100% saw the largest barrier to be the cost of training and employing personnel to utilize BIM as indicated by Figure 19 below. They were then asked to rate on a scale of 1-5 what they would be likely to implement a BIM system for with energy analysis coming in as the most likely benefit and asset management next.

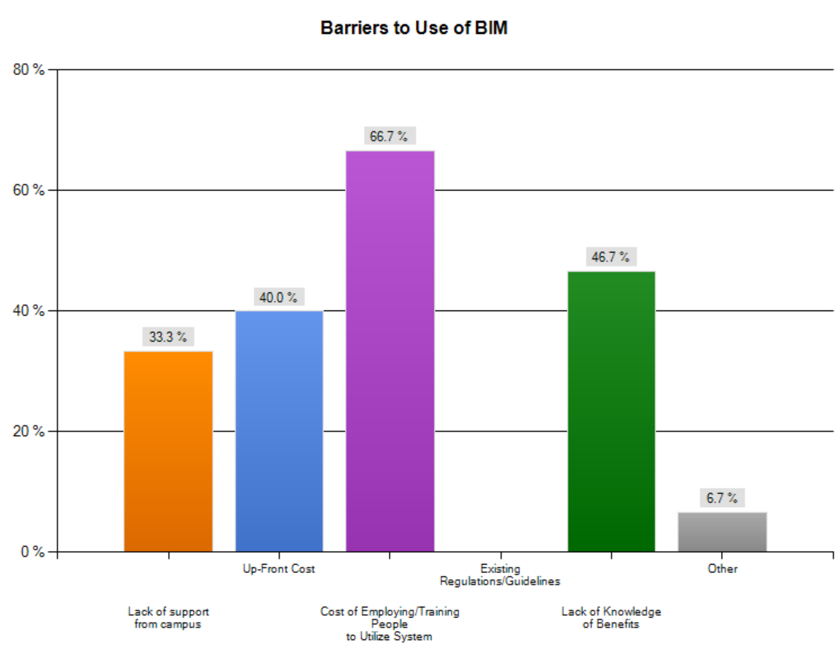


Figure 18: Survey Results on Barriers to Use of BIM

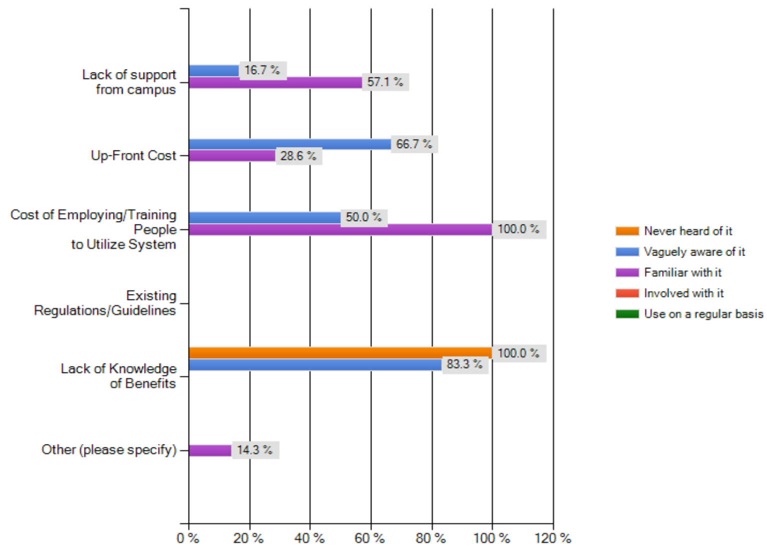


Figure 19: Barriers to Use of BIM according to BIM Knowledge

For a process that is so widely used throughout the construction industry, with clearly realized benefits, the data shown in this survey is alarming at points. The lack of knowledge of BIM is most likely the cause of the lack of use and the perception that it is too expensive to implement. With the amount of money spent on renovations annually on college campuses in the United States, there needs to be a focus on dealing with the inefficiency of the process, with the same being said about Space planning. Most respondent colleges seem to think that BIM is a process that is far into the future for Facilities Management, the documentation being published in the construction industry would argue otherwise.

Chapter 5 Case Study – Salisbury Laboratories

The Salisbury Laboratories building on WPI's campus has undergone several major renovations since its original completion in 1898. WPI FM department has just completed a renovation of approximately 1100 SF on the 4th floor of the building and the building work is underway for similar renovations on the 2nd and 3rd floors for completion in the spring or summer of 2010. The purpose of these renovations is to facilitate the change of the use of the building from Biology and Biotechnology to Humanities and Social Sciences, as a new development of buildings has been constructed for the Biology and Biomedical Engineering Departments. The fact that the building is an older building and has had several major renovations makes it a great subject for a case study on the possible benefits of Building Information Modeling to perform renovations and space planning management.

Salisbury Laboratories presents many common issues, which were uncovered during earlier stages of research in this study, in terms of performing a renovation and space planning management. Among these issues are unknown existing conditions, coordination of parties, and scheduling/phasing conflicts. These topics of concern include the process of locating swing space, asset management, and phasing for the use of the building. The presence of these complications makes this an ideal case study for the use of BIM in support of renovations and Space Planning Management. This chapter will analyze the creation of the building model and its possible uses for Salisbury Laboratories.

5.1 Building Model Creation – Revit® Architecture

The 3D building model for Salisbury Laboratories was first created in the fall of 2009 by several WPI students. The model was created to generate space utilization surveys from a set of 2D CAD created building documents and therefore the actual utility of the model was fairly limited (Keegan/Liu, 2009). There were also several issues with file size, file sharing, and compatibility that needed to be dealt with as well. The model could not be worked with effectively due to its 50+ MB size, and there were issues when trying to model elements in the model. So a member of the virtual construction staff at Tocci © Building Companies was contacted to assist with some of the file sizing and sharing issues.

The consultant was able to discern that the issues were the cause of the creation of a central file, in creating a central file version; the model can be shared by more than one party. The central file was created originally to facilitate the editing of the model by all of the members of the original model creation team. The model must be "checked out" and then checked back in by each party, but several problems are encountered with this, including increased file size and ensuring the model is always centrally located for access, if two users access the central file and then save over it on different occasions, compatibility issues will arise when the model attempts to auto-save from inside of Revit®. These problems all result in a slow-running model that is essentially useless. To solve these problems the model information needed to be migrated to a whole new file and all of the associated plan views, quantity takeoffs, and any 3D renderings needed to be re-generated. The result was a cleaner and much smoother running model.

After these problems were fixed, the model needed to be updated to show actual conditions of the building with field-verified locations of windows, doors, and other building elements. The actual dimensions of the model were taken from the 2-Dimensional building documents they were created from. With the information collected from meetings with the WPI FM department and Space Planning Committee staff members the model was populated with information that they requested, refer to appendix B1.4 for complete list. A site plan was then attached to the building model using the Google® Earth Image Import tool and was then populated with site plan data from field verified measurements.

5.2 Model Use

5.2.1 Proposed Renovation Uses

Information was received from the WPI FM department about the ongoing renovations, floor plans and cost information specifically. This information was used to implement phasing within the model for the ongoing renovations. In addition to the phasing, quantity takeoffs for the proposed renovations were also generated, and by exporting the takeoffs into Microsoft® Excel® and applying R.S. Means® assembly costs to them, a conceptual estimate was generated for the demolition of existing conditions and reconstruction of the space. Views were rendered from the model to show the space before and after the proposed renovation as well.

By creating separate phases within a model, it is possible to view the same model with different parameters for each phase by changing a setting within the program. For example, by entering phasing for this renovation it is possible to see the floor plan as it

Figure 20: Existing 2nd Floor Layout Salisbury

Figure 21: Proposed 2nd Floor Layout Salisbury

existed prior to the start of the renovation, and as it will exist after the renovation (See Figures 20-21).

Views of the space can then be rendered from these phases to show how the space will look (See Figures 22-23). It is possible from these phases to create a phasing plan for the construction process. For example, if remediation processes are necessary, areas can be identified as quarantined, or staging areas can be identified inside of the spaces to be renovated to maximize efficiency. There is also the opportunity to create phasing for lay-down and setup areas outside of the building as well (See Figures 24-27). This allows for the involved parties to create a plan for general conditions, setup of a construction trailer, dumpster, staging if necessary, or parking for workers.

Figure 22: Rendering Before Proposed Renovation

Figure 23: Rendering of Proposed Renovation

Figure 24: Rendering Before General Conditions Setup

Figure 25: Rendering of General Conditions Setup

Figure 26: Actual General Conditions Setup Area

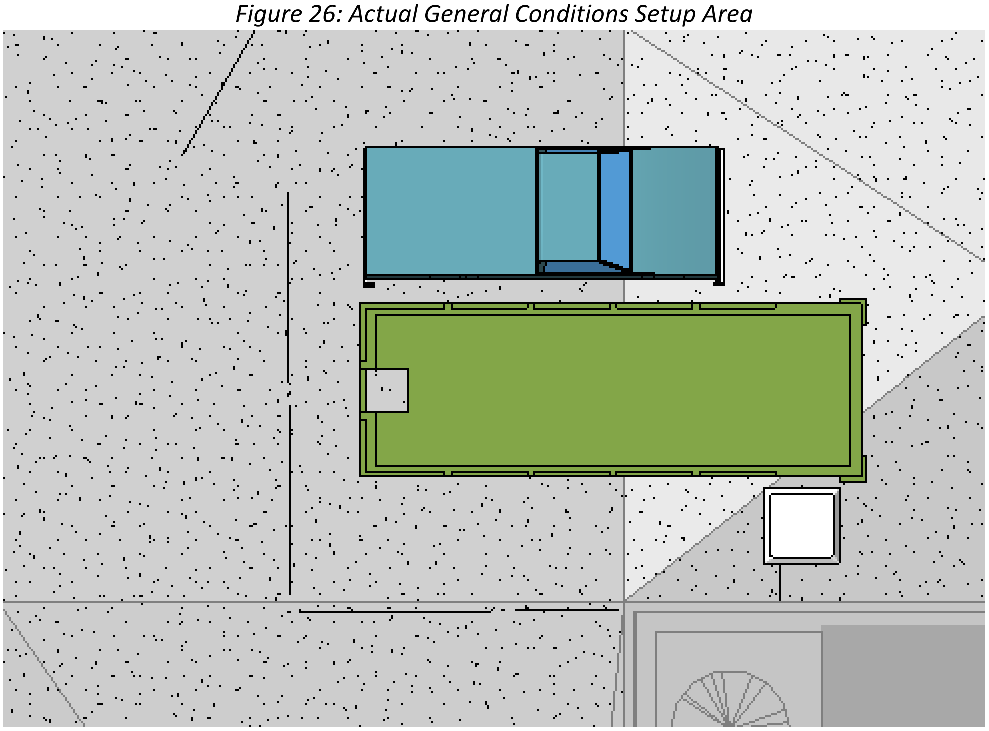


Figure 27: Floor Plan of General Conditions

It is also possible to use previous or proposed phases as an underlay of another phase to predict problem areas. For instance it is possible that a partition wall scheduled to be removed could potentially be partially saved, or that a door might need to be moved to accommodate for a partition wall to be added. It is also a huge benefit to owners to visually see the space prior to being constructed to know if that is what they actually want; it prevents huge change orders at the end of the project.

According to WPI FM the total cost of the Salisbury Laboratories renovations will be approximately $1.5 million, this number is conceptual and includes other minor items beyond the renovation. There are approximately 9400 SF being renovated in Salisbury Laboratories, at a cost of approximately $159.60 per SF according to this conceptual number, which includes MEP work and several inspections of building conditions. The building model was used as a source for quantity takeoffs, and the quantities were exported via delimited text format and then imported into Microsoft® Excel®. Once in Excel® costs were associated with each item and a total was drawn from this to generate a conceptual estimate. The estimate generated from the model was for the second floor renovation only, 3700 SF.

Conceptual Estimate (Excluding MEP)	Description	2	Ext	Each	Extende
Item		Quantity	Quantity Type		Total
Demolition					
	Commercial Building	3700	Ft^2	$8.20	$30,340.00
Wall Construction		3230	Ft^2	$4.96	$16,020.80
Interior Finishes		3700	Ft^2	$1.96	$7,252.00
Doors		11	Each	$790.00	$8,690.00
Floor Finishes		3700	Ft^2	$14.66	$54,242.00
Ceiling Finishes		3565	Ft^2	$4.61	$16,434.65
Subtotal					$132,979.45
General Conditions					
	Dust Control	2%			$2,659.59
	Match Existing Construction	3%			$3,989.38
	Design Fees	5%			$6,648.97
	Construction Manager Fees	7%			$9,308.56
Subtotal					$22,606.51
Contingency		10%			$13,297.95
Total					$168,883.90
Cost Per Ft^2		3700			$45.64

Figure 28: Summary of Estimate Generated from Model

The total cost for this renovation according to the estimate was 45.64/Ft2[See Note 4]. This cost is obviously much lower, because it does not include costs of upgrading the mechanical, electrical, and plumbing. These elements can be incorporated into the model using Revit® MEP.

The next observed benefit of utilizing a building model is the opportunity the model presents in maximizing the energy efficiency of the building. Building modeling software allows the export of a certain file type, called gbXML, and this file type is able to be analyzed by energy analysis software such as Green Building Studio®. When the gbXML file is run through Autodesk's® Green Building Studio® Software, it produces a complete building energy analysis. If the owner were to run the existing building through the energy analysis software, they would get a report showing the annual energy uses of the building, water, electricity, sewer etc (Figure 29).

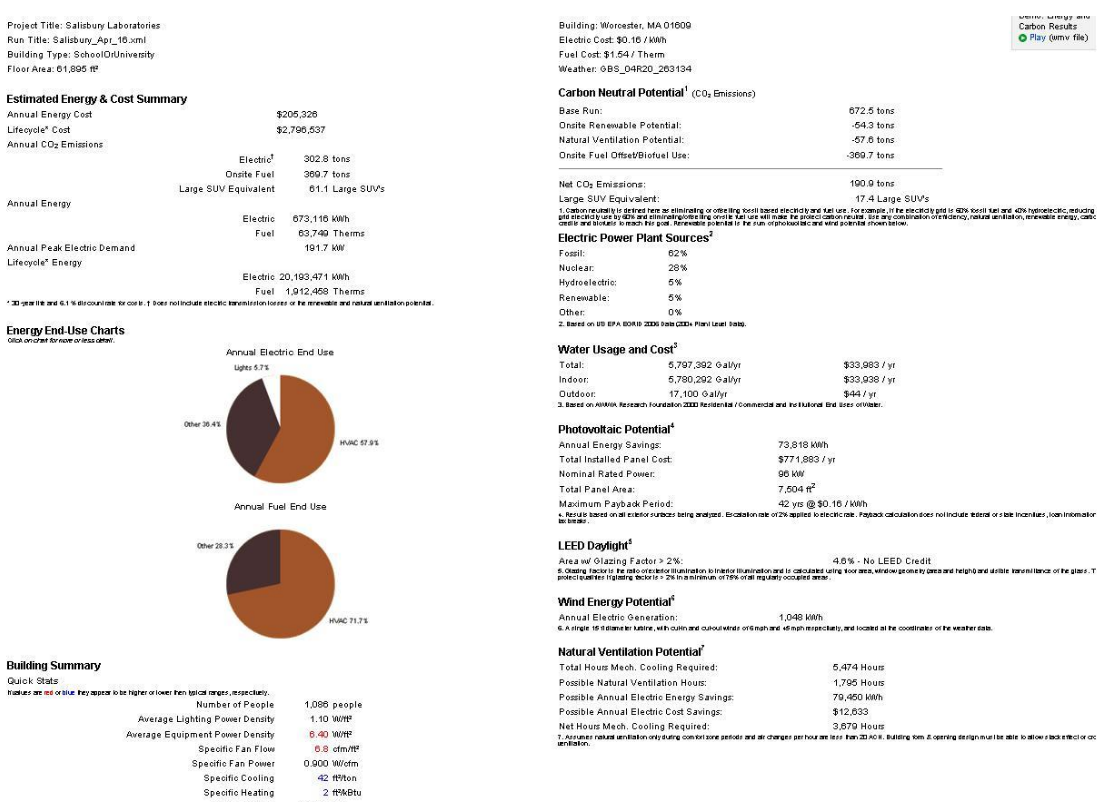


Figure 29: Energy Analysis Example

Note 4: Estimate generated using costs from RS Means® 2009 Assemblies and Interior Costs Data. For full details refer to Appendix D

The model could be exported in two different phases, existing and proposed for example, in this format and then run through the analysis software. This would produce two runs of the same building, showing a difference in energy use between the two phases. This allows the owner the opportunity to maximize the energy efficiency of their building. This particular software also provides comparison standards as well, so the building performance can be matched against the standard building for its size and type. Full results of the energy analysis are made available for all project members via a web site, https://gbs.autodesk.com/gbs/Scheme.mvc/EnergyAndCarbonResults?RunID=MmAFOFZUsB4%3d&AltRunID=cJfGmxrUVvo%3dfor , Salisbury Laboratories results can be found in Appendix E.

5.2.2 Proposed Space Planning Uses

The information that was collected from the Space Planning Committee (See chapter 4) and the meetings with the WPI-BIM Committee was used to populate the building model. Items that the committees found relevant were placed in the building model to demonstrate the capability of a building model to act as a centralized, accessible, location for building information. The highest priority item that the space planning committee and WPIBIM committee identified was an accurate set of floor plans and space utilization surveys. With this in mind the ongoing renovation at Salisbury Laboratories, due to the change in use of space, was setup to show space utilization for before and after renovation (Refer to Figures 30-31).

Other information the committees saw as relevant was entered into the building model as well; including locations of Fire Extinguishers, locations of Electronic Card Access doors, Egress Routes, and locations for inter-building mechanical connections.

The physical locations and all data that could be hand collected about these items was put into the model. Tags were created and placed next to each of these items to identify what it was and some important data about it. For example, for a fire extinguisher the last date it was serviced, and whether it was recharged or just serviced (Refer to Figure 32).

Figure 30: Model Generated Space Utilization Survey

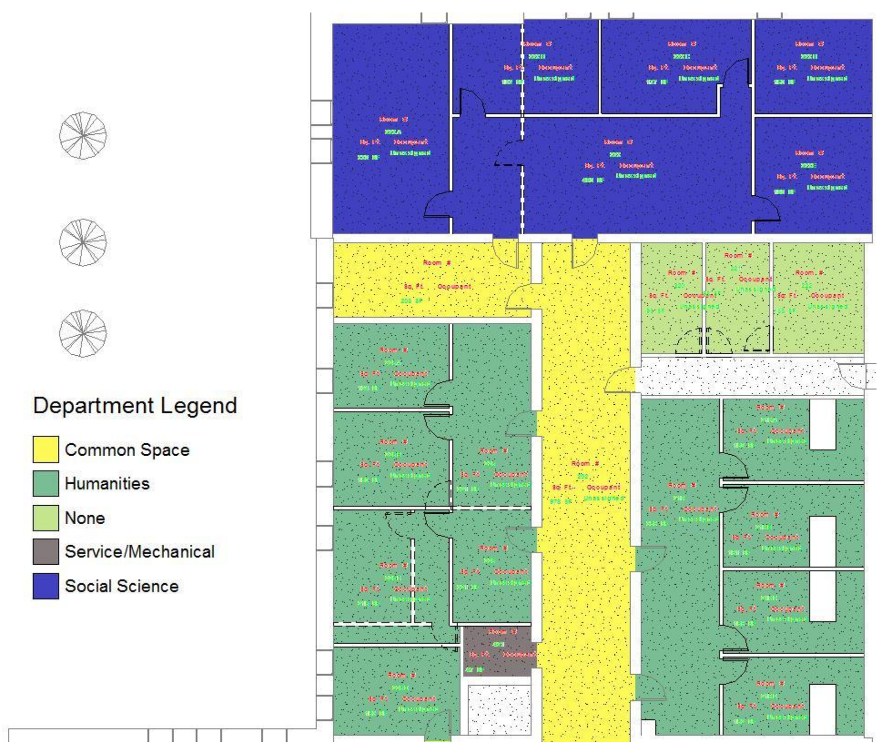


Figure 31: Proposed Space Utilization Survey

For card access doors, a tag was placed on the door that is equipped with an electronic card swipe for access (Refer to Figure 33). Egress routes were mapped for each floor and colored to indicate where the exits where (Refer to Figure 34).

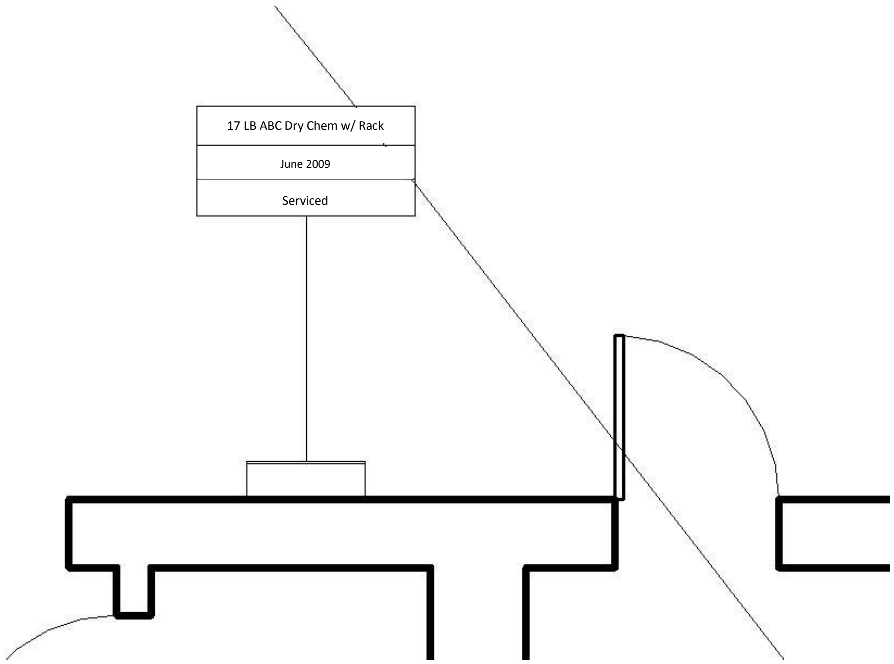


Figure 32: Fire Extinguisher Location Tag

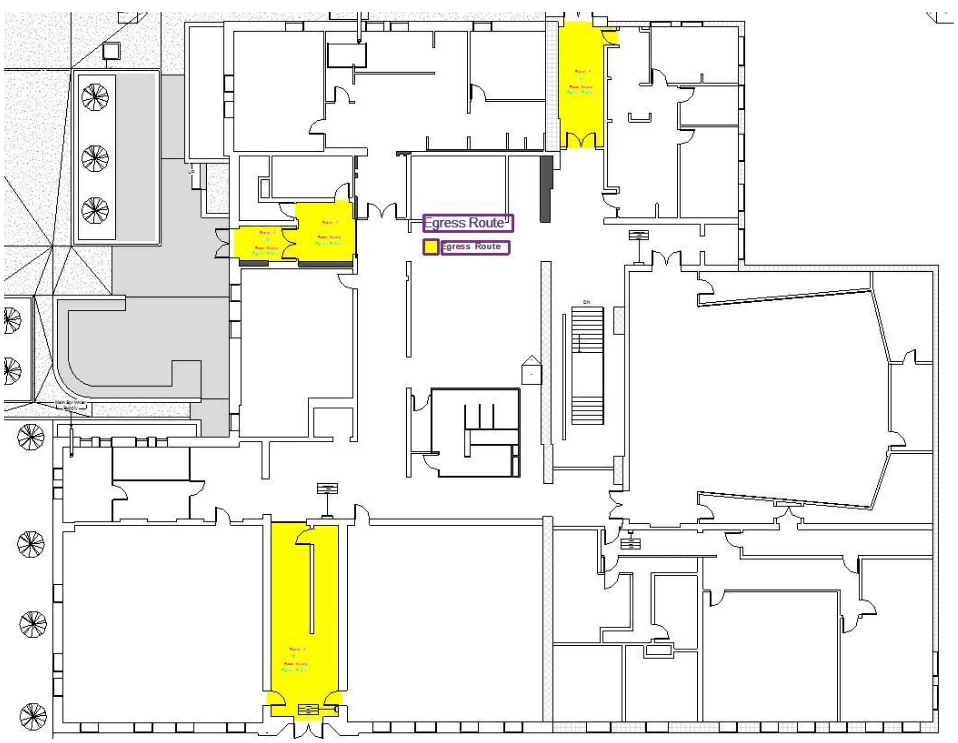


Figure 33: Egress Route Location Plan

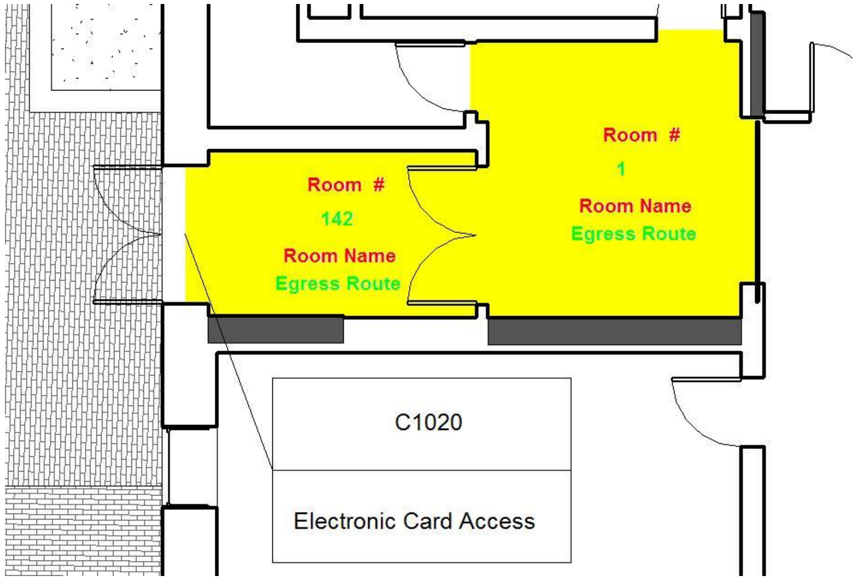


Figure 34: Card Access Door Location Tag

5.3 Conclusions

Using Salisbury Laboratories as a case study for the use of Building Information Modeling in support of Renovations and Space Planning has uncovered several interesting points. First of all the capabilities of the program for the visualization of spaces and floor plans, coupled with the ease of updating those, make it a great tool to support owner's decision making prior to contracting for the renovation. The capability of Revit to export to several different file types makes generating quantity takeoffs and schedules of materials, extremely streamlined, for examples of quantity takeoffs generated from Revit® model see Appendix D. The main obstacle of this is that the information that is pulled out of the model is only as accurate as the information put into the model. This makes the job of model creation, as well as the job of updating the model very important, both of which are time intensive processes. The model detail can only be brought to a certain level, which results in a low level of detail takeoff, and as a result a lower level detail estimate. This level of detail for an estimate works well for owners at early stages, for planning and budgeting purposes. For instance if the owner wanted to know how much it would cost to rearrange a floor, they could do that in just a couple of hours at most (Refer to Figure 28).

The capability of the building model to be set up in stages allows the project team to visualize, prior to the start of construction, how the building and the people around it will react to the work. This allows the team to properly set up and prepare for the construction, which makes the 3D building model a great asset. Even with a low level of detail model, the realization of benefits from a 3D building model can be seen through visualization of space and phasing. This is also true for the ability to coordinate the project team throughout the construction process, if all team members have access to the model; there is a common language that is established between project team members and a point of reference for everyone that is easily understood.

With the capabilities of the building model in terms of visualization, probably the principal benefit is in the generation of space utilization surveys and conceptual floor plans prior to renovations or prior to changing the utilization of space in a building. Actual benefit in terms of efficiency can be seen by comparing the floor plans created by the building model (Figures 19-20) and the one created by WPI contracted architect (Figure 35). The building document created by the building model can be populated with information about the room itself, including assets inside and occupancy loads and the model could reflect these. Whereas the information on the 2-Dimensional document exists only on the piece of paper or as annotation (DWG form) and BIM allows the extraction of data and production of reports; floor plans, elevations, sections, and renderings.

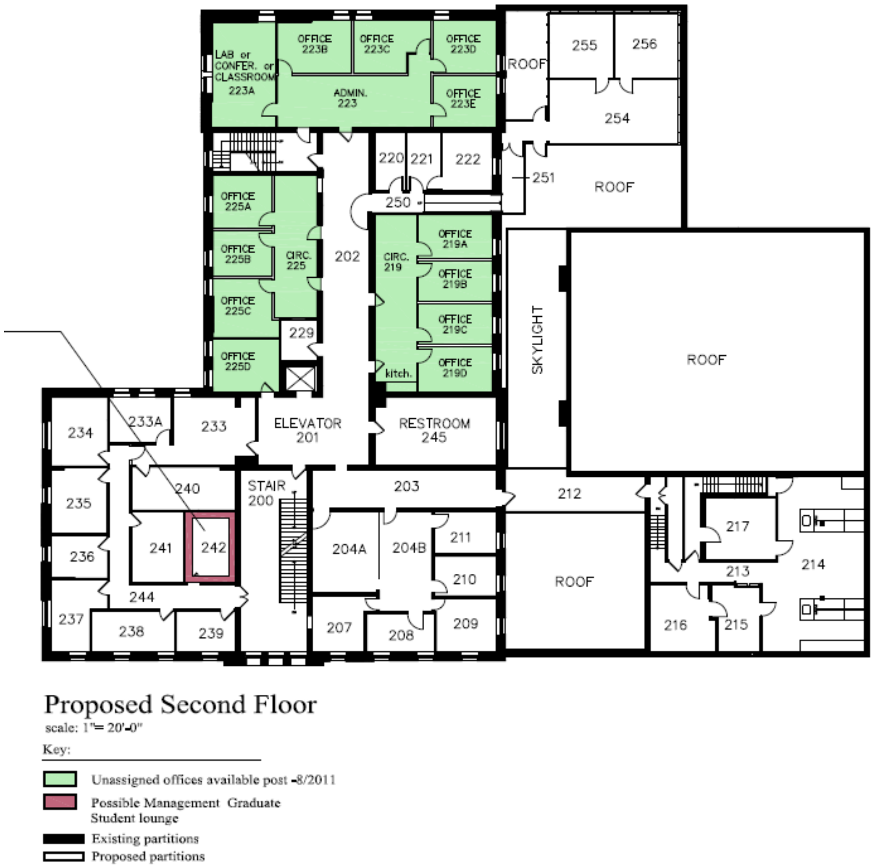


Figure 35: Architect Generated Floor Plan

The Salisbury Laboratories case study showed several other fascinating points as well. The capability for the entry of all types of building information into a model could make it extremely useful for Facilities Management and Space Planning. With a centralized and easily accessible location for all building information there is no confusion about where anything is, and what they will find when they get there. The personnel being sent on a work order will be prepared prior to commencing work, thus making the process more efficient. With the advent of the use of tablet PC's the maintenance personnel could access building information while they are performing tasks at the building, reducing redundancy in labor, with multiple trips to gather information from a centralized geographic location. However, accessing and updating the model does require training, making the process of maintaining this type of system costly. Through the use of DWF file formats in Design Review or Navisworks® the viewing of the model does not require training, however, which means only certain personnel, would need to be trained to use the Modeling software while others could receive a “crash course” in viewing software, which is recommended to maximize the efficiency of the process. The personnel authoring, or creating the models would be required to have a knowledge of building codes and in the use of the modeling software.

The most apparent benefit of building information modeling in this respect is its ability to coordinate two previously separated parties in facilities management, those that manage the building space and those that manage the building itself. With a common language between them and a means of transferring common information, the costs of inadequate interoperability could start to decline. The time for decision making could be reduced through the use of BIM as well as the room for misinterpretation for the data, thus reducing errors by all parties.

Chapter 6 Conclusions and Recommendations

6.1 Conclusions

The use of Building Information Modeling in the support of space planning processes and renovation project delivery has many benefits, but they come at a cost. There is a great possibility in the use of this system to redefine the way renovation projects are delivered, not only on college campuses but across the whole construction industry. With the status of the current economy and the recent surge in efforts to decrease human impact on the environment, the amount of renovation projects will only increase. This will force the hand of the construction industry to improve the efficiency of its delivery of renovation projects, and BIM has the capacity to aid in this.

6.1.1 Benefits

The capacity of BIM to act as a centralized database for building information is one of the major benefits of having building models. The ability to access information from a single location about the building provides many benefits. Information about assets inside of the building and locations of equipment and mechanical system connections can allow for more efficient building maintenance, as well as more efficient planning when it comes time to perform updates and renovations. Autodesk®, FM Desktop®, and several other companies are working on systems to provide a link between 3D building models and Facilities Management software, which will capitalize, in a big way, on these possible benefits. Autodesk® also offers a program that will analyze Building Models for energy use and efficiency, Green Building Studio®, utilizing a gbXML file type export. This will allow owners a tool to detect possible effects of renovations on energy use in the building, an opportunity to maximize efficiency.

The possibilities of BIM in terms of its visualization opportunities pose enough benefit to desire the implementation of the system. Even the savviest of owners have a hard time visualizing a building before it's constructed, the visualization of a space within a building is even harder to visualize. Building Information allows this visualization and also allows the owner to redefine the space to fit their needs before any money is invested in that project. The utilization reports that are generated from the model for this purpose are of more value than the typical report due to the link they possess with the building model information. The benefit of being able to visually detect clashes in building systems, and design errors, is also a major benefit.

The possibility of generating conceptual estimates to generate a master plan for capital asset work on the campus is a great tool as well. The capability of exporting to Microsoft Project® and Primavera® programs is starting to achieve a high level of utility as well, allowing the generation of phasing plans and more accurate estimates inside of those programs. Programs such as BIMJet® and Autodesk® consulting provide direct links to MS Project® that are bi-directional, which allows the altering of the estimate or schedule inside of the Project file to update the model parameters as well.

The possession of a building model would also provide the owner with an easily updateable and accurate set of building documents. The benefit of this in performing renovations would be the availability to provide possible architects with this model, which would expedite the design process considerably, saving the owner money and preventing redundant data creation, in re-creating floor plans or hand collecting data if none is available. After the architect designs the renovation inside of the building model, the model is updated and phased to show all information about what the renovation effected and changes that were made, as well as when, versus the typical addition of new building documents to existing sets. Beyond this is the ability to update the building model as changes are made during the construction process allowing an “as-built” model at the end of the construction phase, and by proxy, allowing the creation of 2-Dimensional as-built building documents for owner reference.

6.1.2 Barriers

This all assumes the owner possesses a building model, or the capacity to create one, for their building already and that the building model is accurate and updated enough to generate this data, wherein lies the quandary of BIM. Although the benefits seem to be so apparent that adopting the system would make perfect business sense, the costs need to be taken into account, and there are several. Among the barriers to the adoption of BIM is the obvious, monetary cost of the programs involved and that of training individuals in the use. The benefits of BIM cannot be realized if the owner doesn’t have a Building Model.

And the cost of the proper creation of a building model is not cheap; the creation of the case study building model took 90 hours originally, 10 hours to enter special room data, 10 hours to fix compatibility issues with central filing. After that the data entry for accurate information took another 80 hours, while the hand collection of data took another 20. The creation of the model, in total, took approximately 210 man hours, before any reports were generated or renderings completed. Knowledge of building codes and of the model creation software is required for this process, with proper training reducing these times slightly. Salisbury Laboratories is approximately 62,000 SF which means the model creation task entails approximately .0035 hours SF.

The system needs to be kept up to date after this, reflecting any and all changes that are made after model creation and the utility of the model is reliant upon the quality of the data entered into it. This model does not take into account the lack of accuracy that may be likely in the existing floor plans. Technologies are being leveraged to account for this lack of accuracy, in Laser scanning and 3D Photographic Scanning for example. These technologies have been used in manufacturing, to model complex shapes, but can be used to collect digital information about a building and then through a multi-step process, create a digital representation of the existing building to a high level of accuracy, and from there the building model can be created. Beyond this, there is the possibility of utilizing tablet PC's to access building model data while physically working in the building, allowing for a more streamlined process.

It seems from the study results that the more important barrier is the lack of owner knowledge in the possible benefits and uses of the system. This lack of knowledge by owners is a huge deterrent to the wide spread use of BIM in Facilities Management. The hierarchy of the construction industry lends to the owner the largest amount of influence in the methods of project delivery, being the source of payment for those delivery methods. Building Information Modeling as a tool to design and deliver construction projects will only continue to grow in its utilization. It would be wise for owners and facility managers to educate themselves in the use of the system and its benefits before they are forced to. If the owners start seeing possible benefits beyond the construction of the building in BIM, it will make coordination among members of the construction industry increase in leaps and bounds.

6.2 Recommendations

With the information learned through this research study, a few confident recommendations can be made for the use of BIM in future building renovations and space planning management. As mentioned previously, the creation of building models is time intensive but this should be commensurate with the objectives in the use of the model and resulting level of detail, and the usefulness of the model is completely reliant upon the quality of the information entered into it. This makes the creation of the model the ultimate driver to the usefulness of the system, with the entry data selection process being equally important. Therefore it is highly suggested that any institution looking to implement a Facilities Management system based off of Building Information Modeling, creates a BIM standardization and BIM project execution plan. There are several institutions that have examples of these including an Autodesk® white paper, Transition to BIM, and Penn State University, BIM Execution. This will ensure the quality of data being entered into the models is what is needed, no more and no less, and will maximize the efficiency of data entry.

Using the data collected from the case study at Salisbury Laboratories and the previous research, several pieces of information have been identified as being of use in future Building Models. The Lee Street school building is slated for a renovation next year at WPI, and this presents a perfect opportunity for this study to lay a framework for the possible use of Building Information Modeling to support the delivery of that renovation project. A building model file was created with floor plans as the framework, obtained from the WPI Facilities Management department. This will allow the creation of an accurate building model along with field identified and collected information. A List of this information can be seen in figure 36, which details a list of information necessary to create a building model that will benefit the FM department with the delivery of the renovation and subsequent planning of the currently unoccupied space. Using the information obtained from the study, it is known that the development of the model will take approximately .0035 hours SF. The FM department should also take into account the necessity to have someone on task to update the model, but the physical viewing of the model should take place in a viewing system such as Autodesk® Design Review® or Navisworks®. Since very little training is required in these systems the staff personnel, excepting of course the one person trained to update the system, will not be required to learn details of building model creation.

Recommended Data for Entry in Future Building Models		
Data	**Details**	**Notes**
Accurate Dimensions		From Existing Building Documents
Electrical Connection and Panel Locations		Field Collected
	Panel Load and Details	Information from Building documents
	Link to Panel Schematic	Inside Element Parameters
Water Connection Location		Field Collected
	Pipe Size	Information from Building Documents
	Meter Location	Information from Building Documents
	Pressure Details	Information from Building Documents
Sanitary connections		Field Collected
	Flow Capacity	Information from Building Documents
	Pipe Size	Information from Building Documents
Card Access Door Locations		Campus Police Card Access Management
	Time Schedule	
	Model and Maintenance Information	
Fire Extinguisher Locations		
	Sevice type/date	Field Collected
	Model Number and Type details	
Spatial/Room Information		
	Department	
	Occupant	
	Occupancy Load	Use Resource 25 Space Planning software as a database to access this information
	Asset/Equipment Contained	
	Room Use	
	Link to Schedule	

Figure 36: Recommended Data for Entry into Future Building Models

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Appendix A Interview Data

A.1 Questionnaire for Interviews

- What Organization are you from?
- How many buildings do you maintain on your campus?
- How many students attend your school full-time?
    - How much renovation work, in number of projects, do you complete on an annual basis?
    - How many FTE's do you employ in your facilities management (including project management, plant services, and facilities management)?
    - How much space, approximately, do you reassign or determine a change in utilization is necessary on an annual basis, in square footage?
- To what capacity (if any) are you utilizing Building Information Modeling on your campus?
    - To what extent does any of this use apply to Renovations and Space Utilization Management?
- What Government procurement policies are in place that governs the selection of parties involved, and steps taken, in renovation projects on your campus?
- Do Government Policies allow, or require, the use of BIM in the design, procurement, and construction of projects?
- What steps do you take to determine that a renovation is to be performed? Do you utilize a Master Plan? (how do you determine the needs for space renovation in your campus)
- What information/measures/procedures do you use to manage changes in Space Utilization?
    - Are there any State policies directly related to change in space utilization?
- What procedures do you employ to estimate cost?
- What procedures do you employ to establish a schedule?
- What methods do you use to establish a phasing plan?
- Are you familiar with the concept of Building Information Modeling?
- If possible gauge your level of knowledge of Building Information Modeling and its uses in facilities management.
    - For what specific purposes do you use BIM in this process?
    - How do you develop your BIM models?
    - What software do you use?
    - Based on that level of knowledge what benefits could you see in using Building information modeling on your campus?
        - In relation to Renovation and Space utilization Management what benefit could BIM be to you on your campus?

A.2 Interview Meeting Minutes

A2.1 Sandra Olson

Director of Facilities Management
Worcester State College
December 8th, 2009

- State Procurement Guidelines Governed by Governors Swifts Executive order 484
  - States that some form of electronic building documentation and design be used in all New construction and Renovation projects
    - The end of this means is to ensure that a LEED Certification is attained for corresponding projects (Minimum LEED cert.)
- 2 agencies govern these policies
  - MSCBA – Massachusetts State College Building Authority
    - Can float their own bonds
    - Governs all projects that generate a revenue
- DCAM – Division of Capital Asset Management
  - Govern all state owned building projects
- Target of these governing agencies in using BIM seems to be for sustainability and energy analysis purposes with a focus on LEED at this point
- Commissioning programs undertaken on all projects for energy analysis
- Andleman-Lelack Modeled all of lower campus
  - Also obtain models of all new Construction and Major renovations on campus after project completion
- Biggest paybacks (low hanging fruit) seems to be energy analysis and effects on MEP
  - >1 ½ Years - A Project
  - 1 ½ to 3 Years – B Project etc…
  - Mentioned how important it was that you know how your building performs before you do a renovation
    - Model is of utmost importance in this respect
- Another low hanging fruit would be how the renovation effects spaces and departments
  - Mentions how BIM does not get how a department functions as a unit, which offices should be together, etc and therefore loses some functionality as a cause of this
    - Core mission – Never given to you by a model
  - Although did see a correlation to the usefulness of BIM in planning for swing spaces during renovations
    - Once you obtain the core mission and determine what needs are in terms of space quantity and space requirements – Model is useful
    - Duration – Model useful in determining how long space is good for, how long space will be occupied?
- State regulations govern uniformity of space requirements in colleges
  - Regulations just starting to come into effect in State Institutions

  - Mentions importance of maintaining uniformity among faculty spaces
    - Same equipment, same amount of space etc.
      - How many SF, Desk, Computer, etc..
  - Research needs to be done before space requirements are set, and space requirements need to be set before building model can be generated and used in all kinds of projects
- Believes BIM information is for conceptual use only
  - Schedules, Estimates, Cost, even design, etc
  - Preset Schedule Jobs – i.e. "Summer Slam"
    - Believes Models may not help that
      - BIM has capability to tell you How much SF needs to be done per day?
      - Can BIM phase different contractors? Activities?
      - Can BIM tell you occupancy load for workers?
- Government regulations and procurement guidelines
- State Law governs that 5% of operating lines has to be reinvested in deferred maintenance (all state buildings)
  - Whole 5% at WSC goes to deferred maintenance
    - Life Safety Comes first
    - Code Requirements
    - Executive Requests and requirements
    - Master Plan comes last
    - Next 5 years are firmly planned out, 6-10 are hazy but laid out indefinitely, and 10+ has a conceptual plan.
- Customers know best, how can facilities help you, once a year these questions are asked of department heads.
- Department chairs submit 5 year plans of things they need.
- VP of Academic Affairs
  - Get together and make a prioritization list of things that need to be done.
- Student affairs can submit projects they would like to be reviewed on an annual basis
- Ricks Associates
  - SF per computer Station
  - Hours classroom is used
  - Loading of classrooms
  - Average of everything about every room
  - %of seats filled and hours used
- Submit to department of higher education as part of funding process
  - Codes to classify space in higher education
- BIM used to classify space per these guidelines
  - And then quantify
    - Who owns it, what's in it, etc
  - Only mentions usefulness of BIM in terms of quantifying SF of space
- Does see usefulness of possibly using REVIT and Maximo to interoperate

- "Dead Sea Scrolls" (Olson Wording) to digital format recently done.

Profiling

- Maintain 1.2 Million SF in 12 buildings
- 4800 Full-Time Students
- 16.7 Million annually (Projects over 10k Capital asset work)
- 61 FTE's employed in Facilities Management department
- Approximately 40,000 SF of space re-designated/annually

BIM

- Revit only program used on campus and only on new construction projects
    - 100% of campus in 2D CAD format
    - 10% in 3D Revit
- Potential uses of BIM seen in Sustainability mostly
    - Envelope analysis
    - Energy Analysis
- Potential use hindered by state funding guidelines and lack of personnel to implement and operate system utilizing BIM

A2.2 Todd Derderian

Director of Facilities
Assumption College
Worcester, Ma
December, 10th 2009

- Maintain 40 buildings on main campus containing 940,000 SF (appr)
  - 2100 fulltime students
  - 1 Million Dollars in Capital improvements and renovations/Annually
    - 4.5 Million in capital gains/annually on average
  - 62 Full time employees in facilities management (no Project Managers on staff) They act as owners reps
- Any current buildings, some buildings in 2D Electronic Format, and some have no documentation at all
  - No 3-D Building Models for any projects at all
- Director of Facilities Management Operations at Assumption College in Worcester, Ma
- Utilize a master Plan for Capital Asset Projects
  - Condition, Change of use, Change of Program (Determinations of need for renovation)
    - Department heads complete forms for changes/needs that they want to request
      - Life Safety comes first
      - Health of Building next
      - Everything gets prioritized by executive committee with input from all departments after
- Project Manage all projects under 3 Independent contractors, anything over 3 a CM is hired
- Architect designs, schedules, and estimates all projects for owner
  - some estimates done in house by using historical cost averages
  - schedule done by architect for preliminary purposes and final schedule done by CM or independent contractor
- Schedule determined by project
  - Most renos done in summer time to avoid conflicts with classes
    - Due to small amount of capital asset work done this works well for them
  - Any major renovations or work done during school year is phased by the registrar for use of space issues

        - All use of space done by registrar in conjunction with departments affected by changes of space utilization
            - No programs he knows of used in the aid of these decisions
            - Registrar also deals with assets inside of space
- Standardization of spaces (i.e. Classrooms, offices, etc) are dealt with on a singular basis
    - No standardization guidelines to follow
- Knowledge of Building Information Modeling is very limited
    - No use of 3-D Building Models on campus
        - Not even in the sight for the future
- Use of electronic formatting for building delivery is only standard if that's what the architect who is designing the building is using
    - Have a portion of their campus in electronic format, some have just Blueprnits, others have no documentation at all
- He believes they rely too heavily upon the architect for their information regarding building design and O & M
    - Would like to see an in-house professional trained in reading, updating, and commenting on building documentation(floor plans etc)
        - For planning purposes for everyday use would like to hire a draftsmen
            - BIM-aided planning?

A2.3 Maureen McDonough

Director of Alston Development Group
Harvard University
February 2nd, 2010

- In charge of Alston Development group
  - Charged with growth fo Harvard across Charles River into Alston
    - 2Billion Dollar organization
      - Prior to endowment difficulties
      - 500 Million/ Annually
- Prior to that worked with Massport at Logan Airport
  - No BIM used on project
- Hasn't seen a consistent flow of BIM into any project Delivery
  - Likes to say that she sees "Ad-Hoc BIM" because she only sees it in bits and pieces when people decide they want to use it
  - BIM is definitely coming and she wants to ensure that her organization is prepared for it
    - Wants to design an improved Project Delivery Standardization that asks for specific aspects in terms of BIM
- With decrease in funds the number of projects is decreasing which is good and bad
  - Good – Can slow down and improve project standards and owner requirements
  - Bad for progress
- Would like to see BIM focus on the management of assets
  - Asset Tracking and Management of those assets
    - What do we have who owns it etc
  - Need to focus on what you want out of BIM before you can move forward with
    - You need to put into the model what you want to get out of it
      - Don't do unnecessary work
        - Who does that work?
          - Responsibility of Owner to demand it though
- Universities such as Yale, Penn State, and others are setting in motion the programmatic tools to start using BIM
  - BIM as a useful model for Facilities managements starts with a programmatic knowledge of what you want/need
  - Could include cost/schedule information
- Not currently using BIM for New Construction or Capital Asset Renovations
  - No discussions currently going on to use BIM in Renovations either
- Made a point to mention here that use of BIM comes from Owner side
  - Owner needs to be "BIM-enabled" and to request it before it will be used on a regular basis

- Estimating Cost?
  - Architect responsible for baseline cost estimates
  - CM for high detail cost estimates as part of CM services
  - Owners representative used to reconcile the cost estimates from owners side
- Scheduling Projects
  - CM develops baseline schedule from designs by architect (typical)
  - In-house expertise on scheduling to reconcile the CM schedule
  - Owners rep also reviews schedule
- Very excited about the advent of BIM in facilities Management
  - The integration of Construction process with O & M of buildings is exciting
    - Definitely coming and wants to be on the front end of it to ensure that they know what to ask for when it does

A2.4 Jay Philips

Director of Facilities Management
Harvard College FAS (Undergraduate)
February 10th, 2010

- Director of Infrastructure in the Facilities Management department at Harvard College FAS, which is the equivalent to their Undergraduate School
  - Includes MEPS, Telecom, etc
- 239 Buildings consisting of 10 Million SF
  - 30-75 Million in Renovation work on Capital Assets annually
- 60 Members in the facilities management department in operations
  - Separated into Operations, Planning, and Capital Project Management
- Only use he sees currently for BIM is in Spatial data management
  - Space utilization surveys and volume calculations
- Defined BIM as "a graphic representation of a building…3-Dimensional Modeling of a building"
- No real use of BIM on campus but is familiar with the concept
  - Use 3D models and renderings for reference purpose only
    - For graphic representation of a space to see how the space works
    - Also for fly-throughs and renderings of a space
  - They do use Autocad 2D Plans for Specialty Space utilization surveys and for Reference
    - Have 90%(Approximate) of campus in 2D CAD Electronic Format
      - The rest don't have any, or just paper blueprints
- Would like to see BIM used for Maintainability and constructability of building projects
  - See's special use for BIM in detecting Spatial conflicts with MEP Infrastructure
    - Would like to see the model post construction for reference
  - Would also like to see the model used for asset management
    - Tracking quantities, location, condition, and detailed information about all assets
- Sees the specialty skill necessary to create, update, and maintain a BIM system as the main hindrance to the implementation and use of a Building Information Model in O&M
  - Updating the model being the major player in his eyes due to the necessity that the model be as accurate on a day to day basis as the building itself is
    - This requires a major staffing upgrade in this area and is in turn a major turnoff for the implementation
    - Mentions that they have a hard time keeping accurate 2-Dimensional As-builts and believes the 3D as-builts would be even more work to keep accurate and up-to-date

A2.5 Danny Beaudoin

Director of Facilities Management
Harvard College of Public Health
February 10th, 2010

- Manager of Facilities at the Harvard School of Public Health
  - Manages 9 owned and 15 Leased buildings
    - Leases are full, so they maintain everything to do with building
  - Perform 4 Million Annually in Capital Asset Renovations/Rehabilitations
  - 33 People on staff in the Facilities Management Department
- Utilize Master Plan of campus to determine necessity of Renovations
  - Executive committee consisting of heads of departments decide on project order
    - Space Allocation is major determining factor due to wooing of prodigious staff
      - Very politically charged high profile environment
        - Due to this condition assessments and improvements fall to back of list
- Knowledge of BIM is limited to information obtained from 4 presentations by Tocci Construction Co.
- Not currently utilizing BIM for project Delivery on Campus
  - All buildings in 2D CAD
    - If renovated they have updated as-built drawings in electronic format
    - If not renovated the blueprints are not up-to-date but are in Electronic Format
- Biggest reason behind non-utilization of BIM is cultural/political
  - Contract terms scare the executives making the decisions
  - Use of vendors with relationships
    - i.e. the architect they have been using has been doing work with them for 25 years
      - the architect is not BIM-Enabled so neither are they
  - Also no evidence of people using BIM in this environment to prove usefulness
    - Not exposed to the BIM Enabled environment
- Would like to implement a pilot program to show the executives the potential benefits of BIM
  - Is sold on the usefulness of BIM but understands that cultural and political blockades will not allow the implementation of a BIM driven approach to project delivery
- Due to constant research nature of facilities the need for swing space is extremely important
  - Space allocation and utilization surveys are done through a capital asset facilities management program called Ecenter 21

- In his view BIM offers an integration from the construction process
  - A direct turnover from construction to operation and Maintenance with no lag in information or time
    - Truly turnkey projects
- Biggest issues with Renovations
  - Coordination of involved parties
    - Change Orders due to lack of coordination
  - Commissioning and schedule creep are also huge problems
- Biggest issue with Space utilization Management as he sees it is the effect on MEP Infrastructure

Appendix B Meeting Information

B.1 WPI-BIM Committee

B1.1 September 28th, 2009

WPI Kaven Hall, Worcester, Ma
Alfredo DiMauro, Liz Tomaszewski, Laura Handler, Chris Keegan, Zijia Liu, Guillermo Salazar

Immediate and Long Term Goals

1. Staying current
   a. Current Plans
      i. Updates from small renovations etc.
2. Archival organization
   a. What was done/When it was done
3. Planning Purposes
   a. Space Usage/type of space
      i. Owner of space
      ii. Whats in the space
   b. Capital budget
      i. Quantify amount of materials
         1. Carpet needing to be replaced, roofing, etc
            a. Estimate approximate cost etc
4. Dashboard system to track building performance?

Summer Actions: Develop WPI-BIM Standard

- Conduct Charrette to identify WPI Campus-wide Information Needs
- Define Model Requirements (object definition, attributes, scale, accuracy, tolerances etc.)
- Future Contractual BIM requirements for renovation and new construction
- BIM Tools and related software
- BIM-Maximo-Resource25? Interoperability
- Data Entry procedures and tools (tablets, bar-coding, photogrammetric, etc..)\
- Extend BIM to 3D campus-wide layout including topographic surfacing and GIS elements
- Identify and coordinate future actions to be performed by students and/or consultants

List of current Revit Models

Developed by students through, Projects and Theses work or by consultants

Kaven Hall (	Salisbury
Campus Center	Bartlett Center
East Hall	Schussler Street
Goddard Hall (old layout before renovation)	Atwater Kent
Olin Hall	Stratton
Washburn	Higgins Labs
New Recreation Center (Cannon Design)	Goddard Hall (renovated, Consigli Construction?)

B1.2 October 28th, 2009

WPI Kaven Hall, Worcester, Ma

Alfredo DiMauro, Liz Tomaszewski, Laura Handler, Chris Keegan, Zijia Liu, Guillermo Salazar

Meeting Minutes

- Autodesk to combine Navisworks and DWF file formats to increase interoperability
    - Navisworks as a platform for FM system?
- Model Authoring is Revit
    - Site layout and planning
- Model viewing is Navisworks?
    - Freedom is free and readily available to public
    - Other versions are by license only
- Maximo and Autodesk in talks now about possible interoperability
    - Likelihood of success?

Areas of concern for entry into system

- Safety Related and hazardous Materials content
    - What's stored in room
    - Who is responsible
    - Contact information
- First responders
    - Entry and exit points
    - Flammable and explosives
    - Campus police to run this part of system to prep for Fire/EMT/police
- Preventative Maintenance
    - Prev. Maint. On Maximo not on-line
    - Embedded within main Maximo work order system
    - 30/60/90 day PM filters on model?
        - Yellow/Orange/Red?

B1.3 February 8th, 2010

WPI-BIM Group Meeting
WPI Facilities Department, Lee Street, Worcester MA
February 8, 2010

Alfredo DiMauro, Liz Tomaszewski, Laura Handler, Chris Keegan, Zijia Liu, Guillermo Salazar

Short Term Actions (C & D Term):
1. Review existing Revit Models for Accuracy (nearer square foot) in terms of floor layouts and space allocations. Identify Emergency Egress routes and Fire Extinguisher Location and possibly Card Access:

- Chris Keegan: Salisbury, Lee Street
- Zijia Liu, Kaven Hall
- CE590-A student term project: Atwater Kent, Washburn Shops, Bartlett Center, East Hall (to be confirmed depending on students choosing these as term projects).

2. Complete Thesis by Zijia Liu (Strategic BIM Execution Plan, Support for Space Planning and Renovation)

Summer Actions: Develop WPI-BIM Standard
- Conduct Charrette to identify WPI Campus-wide Information Needs
- Define Model Requirements (object definition, attributes, scale, accuracy, tolerances etc.)
- Future Contractual BIM requirements for renovation and new construction
- BIM Tools and related software
- BIM-Maximo-Resource25? Interoperability
- Data Entry procedures and tools (tablets, bar-coding, photogrammetric, etc..)\
- Extend BIM to 3D campus-wide layout including topographic surfacing and GIS elements
- Identify and coordinate future actions to be performed by students and/or consultants

List of current Revit Models

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Kaven Hall (	Salisbury
Campus Center	Bartlett Center
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Olin Hall	Stratton
Washburn	Higgins Labs
New Recreation Center (Cannon Design)	Goddard Hall (renovated, Consigli Construction?)

B1.4 February 8th, 2010 – Reference Sheet

BIM

Buildings to Prioritize:

Maintenance and Operations	Space Planning
East Hall	Atwater Kent
Gateway Park	Washburn Shops
Goddard Hall	Alumni Gym
Bartlett Center	Salisbury Labs
Campus Center	

Specific Deliverables:

Highest Priority: Accurate Floor Layouts and Space Allocations

Next Priorities: Mechanical

Emergency/Egress

Fire Extinguishers

Card Access Locations

Strategy:

Continuity of Students/student group progress

Format of files/filenames

Access

Appendix C Survey Information

C.1 Survey Questionnaire

BIM in Facilities Management

General Information

The purpose of this survey is to gauge the level of knowledge and use of Building Information Modeling (BIM) in the management of facilities at Colleges and Universities, with a particular focus on Space Planning and Renovations.

There are three parts to this survey and it should not take more than 10-15 minutes to complete. Any comments you may have regarding BIM in this respect please feel free to write in on the last part of the survey.

Part one will collect some general information about your specific campus with particular regard to the facilities management department.

1. How many full-time students attend your institution?

- <1000
- 1001-5000
- 5001+
- Other (please specify)

2. How many Full Time Employees are staffed by your facilities management department?

- 0-25
- 25-50
- 50-100
- 100+
- Other (please specify)

Page 1

BIM in Facilities Management

3. How many buildings on your campus are maintained by the institution?

- 0-10
- 11-25
- 25-50
- 50-100
- 100+
- Other (please specify)

4. Approximately how many total square feet is contained in those buildings?

- <10,000
- 10,001-100,000
- 100,001-500,000
- 500,001-1,000,000
- >1,000,000
- Other (please specify)

5. Approximately how many square feet of space do you change the utilization of on an annual basis, on average?

- 0-10,000 Square Feet
- 10,001-25,000 Square Feet
- 25,001-50,000 Square Feet
- 50,001-100,000 Square Feet
- 100,000+ Square Feet
- Other (please specify)

BIM in Facilities Management

6. How much do you spend on an annual basis on capital asset renovations?

- $0-$5 Million
- $5-$10 Million
- $10-$25 Million
- $25-$50 Million
- $50+ Million
- Other (please specify)

Renovation and Space Utilization Management

Part two consists of a series of questions devoted to determining what the current state of performing Renovations and the Management of Space Planning in your Facilities Management department is.

7. What are the most commonly found issues in dealing with renovations on your campus? (Check all that apply)

- Coordination of Involved Parties
- Inaccurate As-Built Drawings
- Unknown Existing Conditions
- Scheduling and Phasing
- Finding Swing Space
- Other (please specify)

BIM in Facilities Management

8. What are the most commonly found issues in dealing with the management of changes in space utilization on your campus? (Check all that apply)

- [ ] Finding Swing Space
- [ ] Dealing with resources in changed space
- [ ] Utility Infrastructure Layout Changes
- [ ] Updating Space Utilization Surveys
- [ ] Other (please specify)

9. Do you currently utilize any of the software listed to aid in the delivery of capital asset renovation projects?

- [ ] Revit Architecture
- [ ] Google Sketchup
- [ ] Bentley Architecture
- [ ] None
- [ ] Graphisoft Archicad
- [ ] Other (please specify)

10. Do you currently utilize any software to aid in the management of Space Planning?

- ( ) Yes
- ( ) No

If Yes Please Specify:

BIM in Facilities Management

11. Have you heard or know of the concept behind Building Information Modeling?

- Never heard of it
- Vaguely aware of it
- Familiar with it
- Involved with it
- Use on a regular basis

Comment on knowledge of BIM:

12. On what percentage of your campus buildings do you utilize 3D Building Information Models?

- 0-10%
- 10-25%
- 25-50%
- 50%+
- Other (please specify)

13. If you have been directly involved with BIM once or more have you used it in support of space planning or renovations?

- Yes
- No
- Does Not Apply

Please Explain:

Benefits and Drawbacks of using BIM

The last part of this survey contains a series of questions that is designed for those Facilities Management departments that are currently not utilizing BIM. The questions are geared towards determining why you are not using BIM and what you see as possible benefits of using BIM.

BIM in Facilities Management

14. What is the largest contributing factor as to why you don't use BIM?

- [ ] Lack of support from campus
- [ ] Up-Front Cost
- [ ] Cost of Employing/Training People to Utilize System
- [ ] Existing Regulations/Guidelines
- [ ] Lack of Knowledge of Benefits
- [ ] Other (please specify)

15. What areas of facilities management would be your top priority in implementing a Building Information Model enabled system? (Rate from 1 to 5 with 1 being the lowest, if you have a higher priority item or items not available please provide in comment box)

	1	2	3	4	5
Asset Tracking and Management	○	○	○	○	○
MEP Infrastructure Maintenance	○	○	○	○	○
Delivery of Renovation Projects(and new construction)	○	○	○	○	○
Space Utilization Surveys	○	○	○	○	○
Energy Analysis	○	○	○	○	○

Other (please specify)

Benefits and Drawbacks of using BIM

The last part of this survey contains a series of questions that is designed for those Facilities Management departments that are currently utilizing BIM on some level. The questions are geared towards determining what you are using BIM for and what you see as benefits from the use of BIM.

BIM in Facilities Management

16. What aspects of facilities management do you use BIM for?

- [ ] Energy Analysis
- [ ] Delivery of Renovation Projects(and new construction)
- [ ] Asset Tracking and Management
- [ ] Space Utilization Surveys
- [ ] Visualization of Space
- [ ] MEP Infrastructure Maintenance
- [ ] Other (please specify)

17. What are the major benefits you see from your use of BIM?

- [ ] More accurate as-built drawings
- [ ] Increased Efficiency in Space Surveying
- [ ] Paper Usage Reduction
- [ ] Cost Reduction

Other (please specify)

C.2 Survey Responses

RespondentID	CollectorID	StartDate	EndDate	IP Address	How many full-time students attend your institution?	Other	How many Full Time Employees are staffed by your facilities management department?
					Response	Other (please specify)	Response
992214882	12366614	3/9/2010 15:15	3/9/2010 15:19	192.80.61.76	1001-5000		50-100
991483444	12366614	3/8/2010 20:15	3/8/2010 20:21	155.37.164.141	<1000		100+
991481810	12366614	3/8/2010 20:16	3/8/2010 20:21	156.12.25.63	5001+		100+
991322374	12366614	3/8/2010 18:10	3/8/2010 18:11	170.140.192.236	5001+		100+
991308153	12366614	3/8/2010 17:56	3/8/2010 18:15	198.200.181.208	5001+		50-100
991220637	12366614	3/8/2010 16:48	3/8/2010 16:54	143.236.34.54	5001+		100+
991211916	12366614	3/8/2010 16:41	3/8/2010 16:44	128.32.76.166	5001+		100+
989798728	12366614	3/5/2010 22:44	3/5/2010 22:48	68.116.176.4	1001-5000		25-50
986731497	12366614	3/3/2010 2:21	3/3/2010 2:23	76.121.168.121	5001+		0-25
986713805	12366614	3/3/2010 1:57	3/3/2010 2:02	71.235.38.54	Other (please specify)	22,000 or so	50-100
985934856	12366614	3/2/2010 15:53	3/2/2010 15:58	38.111.224.18	1001-5000		100+
985891907	12366614	3/2/2010 15:18	3/2/2010 15:22	149.130.138.107	1001-5000		100+
985891672	12366614	3/2/2010 15:18	3/2/2010 15:25	141.222.58.145	1001-5000		0-25
985786887	12366614	3/2/2010 13:44	3/2/2010 13:55	130.64.248.20	<1000		0-25
985751742	12366614	3/2/2010 13:02	3/2/2010 13:11	148.85.210.195	1001-5000		50-100
985750947	12366614	3/2/2010 13:04	3/2/2010 13:08	140.232.206.133	1001-5000		50-100
985745217	12366614	3/2/2010 12:54	3/2/2010 13:02	155.48.62.98	1001-5000		50-100
985721060	12366614	3/2/2010 12:09	3/2/2010 12:14	136.167.28.131	5001+		100+
985092445	12366614	3/1/2010 20:03	3/1/2010 20:11	130.215.142.213	1001-5000		50-100
978888393	12366614	2/22/2010 20:08	2/22/2010 20:19	130.215.80.82	1001-5000		50-100

How many buildings on your campus are maintained by the institution?	Approximately how many total square feet is contained in those buildings?	Approximately how many square feet of space do you change the utilization of on an annual basis, on average?	How much do you spend on an annual basis on capital asset renovations?
Response	Response	Response	Response
25-50	500,001-1,000,000	0-10,000 Square Feet	$0-$5 Million
25-50	>1,000,000	0-10,000 Square Feet	$10-$25 Million
50-100	>1,000,000	0-10,000 Square Feet	$5-$10 Million
100+	>1,000,000	100,000+ Square Feet	$25-$50 Million
25-50	>1,000,000	0-10,000 Square Feet	$0-$5 Million
50-100	>1,000,000	0-10,000 Square Feet	$5-$10 Million
100+	>1,000,000	50,001-100,000 Square Feet	$50+ Million
25-50	100,001-500,000	0-10,000 Square Feet	$0-$5 Million
50-100	>1,000,000	10,001-25,000 Square Feet	$5-$10 Million
100+	>1,000,000	0-10,000 Square Feet	$5-$10 Million
25-50	>1,000,000	0-10,000 Square Feet	$5-$10 Million
100+	>1,000,000	0-10,000 Square Feet	$0-$5 Million
100+	>1,000,000	10,001-25,000 Square Feet	$0-$5 Million
25-50	100,001-500,000	0-10,000 Square Feet	$0-$5 Million
100+	>1,000,000	10,001-25,000 Square Feet	
50-100	>1,000,000	10,001-25,000 Square Feet	$0-$5 Million
50-100	>1,000,000	0-10,000 Square Feet	$5-$10 Million
100+	>1,000,000		
50-100	>1,000,000	25,001-50,000 Square Feet	$10-$25 Million
25-Nov	500,001-1,000,000	25,001-50,000 Square Feet	$10-$25 Million

What are the most commonly found issues in dealing with renovations on your campus? (Check all that apply)	A	B	C	D
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions	Scheduling and Phasing	Finding Swing Space
Coordination of Involved Parties			Scheduling and Phasing	
Coordination of Involved Parties	Inaccurate As-Built Drawings		Scheduling and Phasing	
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions	Scheduling and Phasing	Finding Swing Space
Coordination of Involved Parties			Scheduling and Phasing	Finding Swing Space
Coordination of Involved Parties				Finding Swing Space
Coordination of Involved Parties		Unknown Existing Conditions	Scheduling and Phasing	Finding Swing Space
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions		Finding Swing Space
			Scheduling and Phasing	
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions		Finding Swing Space
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions	Scheduling and Phasing	Finding Swing Space
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions	Scheduling and Phasing	Finding Swing Space
		Unknown Existing Conditions		Finding Swing Space
Coordination of Involved Parties			Scheduling and Phasing	Finding Swing Space
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions	Scheduling and Phasing	
Coordination of Involved Parties			Scheduling and Phasing	Finding Swing Space
	Inaccurate As-Built Drawings	Unknown Existing Conditions	Scheduling and Phasing	Finding Swing Space
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions	Scheduling and Phasing	Finding Swing Space
Coordination of Involved Parties	Inaccurate As-Built Drawings	Unknown Existing Conditions	Scheduling and Phasing	Finding Swing Space

Other2	What are the most commonly found issues in dealing with the management of changes in space utilization on your campus? (Check all that apply)	A2	B2
Other (please specify)	Finding Swing Space	Dealing with resources in changed space	Utility Infrastructure Layout Changes
	Finding Swing Space		
			Utility Infrastructure Layout Changes
expectations exceeding funding		Dealing with resources in changed space	
	Finding Swing Space	Dealing with resources in changed space	
	Finding Swing Space		
		Dealing with resources in changed space	
	Finding Swing Space		
	Finding Swing Space	Dealing with resources in changed space	Utility Infrastructure Layout Changes
	Finding Swing Space	Dealing with resources in changed space	Utility Infrastructure Layout Changes
		Dealing with resources in changed space	Utility Infrastructure Layout Changes
		Dealing with resources in changed space	Utility Infrastructure Layout Changes
	Finding Swing Space		
		Dealing with resources in changed space	Utility Infrastructure Layout Changes
	Finding Swing Space		
something else	Finding Swing Space	Dealing with resources in changed space	Utility Infrastructure Layout Changes

C2	Other3	Do you currently utilize any of the software listed to aid in the delivery of capital asset renovation projects?	A3	B3	C3
Updating Space Utilization Surveys	Other (please specify)	Revit Architecture	Bentley Architecture	Graphisoft Archicad	Google Sketchup
Updating Space Utilization Surveys					
Updating Space Utilization Surveys					
Updating Space Utilization Surveys					
Updating Space Utilization Surveys					
					Google Sketchup
		Revit Architecture			
	Question is confusing, not answerable.				
Updating Space Utilization Surveys	addressing expectations	Revit Architecture			
Updating Space Utilization Surveys					
		Revit Architecture			

D2	Other4	Do you currently utilize any software to aid in the management of Space Planning?	Response	Have you heard or know of the concept behind Building Information Modeling?
None	Other (please specify)	Response	If Yes Please Specify:	Response
None		No		Vaguely aware of it
None		Yes	FAMIS	Familiar with it
None		No		Vaguely aware of it
	Auto CAD 2008	Yes	ArchiBus Strategic Master Planning module	Familiar with it
	AutoCAD	Yes	own written software and Excel	Familiar with it
		Yes	FacilitiesLink	Familiar with it
		No		Vaguely aware of it
		No		Familiar with it
		Yes	FAMIS	Involved with it
None		No		Never heard of it
None		No		Vaguely aware of it
None		No		Familiar with it
	None	Yes	Drawbase	Never heard of it
		Yes	AutoCAD Excel	Vaguely aware of it
None		No		Vaguely aware of it
		Yes	Autocad	Involved with it
None		No		Familiar with it
		Yes	Resource 25	Vaguely aware of it

Comments	On what percentage of your campus buildings do you utilize 3D Building Information Models?
Comment on knowledge of BIM:	Response
	0-10%
Know that it exists and the basic concept behind it	0-10%
	0-10%
	0-10%
oversold to administrators who have no concept of the time required for keeping it current	50%+
	0-10%
	0-10%
	0-10%
We've just started using it for MEP modeling in particular. Excellent tool for existing science building renovation projects.	Other (please specify)
	0-10%
	0-10%
Works only if all the players are integrated with the software, many smaller contractors are not there yet along with many smaller colleges	0-10%
	Other (please specify)
	0-10%
	0-10%
	0-10%
	10-25%
	0-10%

Other5	If you have been directly involved with BIM once or more have you used it in support of space planning or renovations?	Comments2
Other (please specify)	Response	Please Explain:
	No	
	No	
	No	
	Does Not Apply	
	Does Not Apply	
	No	
	Does Not Apply	
	Yes	
We are using it on 5 major projects - planning stages only at this time.	Yes	
	Does Not Apply	
	Does Not Apply	
	Does Not Apply	
None	Does Not Apply	
	Does Not Apply	
	Does Not Apply	
	Yes	using it for renovation of older building
	No	just getting familiar with it.
	No	

What is the largest contributing factor as to why you don't use BIM?	A4	B4	C4	D3
Lack of support from campus	Up-Front Cost	Cost of Employing/Training People to Utilize System	Existing Regulations/Guidelines	Lack of Knowledge of Benefits
Lack of support from campus	Up-Front Cost			
Lack of support from campus	Up-Front Cost	Cost of Employing/Training People to Utilize System		
		Cost of Employing/Training People to Utilize System		Lack of Knowledge of Benefits
		Cost of Employing/Training People to Utilize System		
Lack of support from campus	Up-Front Cost	Cost of Employing/Training People to Utilize System		
		Cost of Employing/Training People to Utilize System		
	Up-Front Cost			Lack of Knowledge of Benefits
				Lack of Knowledge of Benefits
	Up-Front Cost	Cost of Employing/Training People to Utilize System		Lack of Knowledge of Benefits
		Cost of Employing/Training People to Utilize System		
				Lack of Knowledge of Benefits
				Lack of Knowledge of Benefits
	Up-Front Cost	Cost of Employing/Training People to Utilize System		Lack of Knowledge of Benefits
Lack of support from campus		Cost of Employing/Training People to Utilize System		

What areas of facilities management would be your top priority in implementing a Building Information Model enabled system? (Rate from 1 to 5)	A5	B5	C5	D4
Space Utilization Surveys	MEP Infrastructure Maintenance	Energy Analysis	Asset Tracking and Management	Delivery of Renovation Projects
2	3	2	1	1
2	5	4	3	4
3	1	5	4	2
5	2	4	3	1
5	5	3	2	3
4	3	2	3	5
3	5	5	3	3
5	5	5	5	5
2	4	4	1	4
2	5	5	4	5
3	3	3	3	3
2	2	5	4	3
5	3	3	4	4

Other6	What aspects of facilities management do you use BIM for?	A6	B6
Other (please specify)	Asset Tracking and Management	Visualization of Space	Space Utilization Surveys
I can not answer this question, because I know nothing about BIM			
		Visualization of Space	
	Asset Tracking and Management	Visualization of Space	Space Utilization Surveys
	Asset Tracking and Management	Visualization of Space	

C6	D5	E	Other7	What are the major benefits you see from your use of BIM?	A7
MEP Infrastructure Maintenance	Energy Analysis	Delivery of Renovation Projects	Other (please specify)	Cost Reduction	Paper Usage Reduction
			we do not use BIM		
			Do not use		
					Paper Usage Reduction
			not using		
			None		
		Delivery of Renovation Projects	still in very early stages		Paper Usage Reduction
					Paper Usage Reduction
				Cost Reduction	Paper Usage Reduction

B7	C7	Other8
More accurate as-built drawings	Increased Efficiency in Space Surveying	Other (please specify)
		Do not use
More accurate as-built drawings		
		na
		None
More accurate as-built drawings	Increased Efficiency in Space Surveying	better coordination of MEP
More accurate as-built drawings	Increased Efficiency in Space Surveying	overall acuracy of utilization information and ability to generate reports and graphic representations.

Appendix D Cost Estimate Details

Wall Construction and Finishes								
Assembly Code	Assembly Description	Cost/Ft^2	Cost/Ft^22	Area in Ft^2	Wall Type	Column2	Comments	Extended
		Wall Finish	Construction		Finishes	Construction Type		
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	361	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$1,790.56
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	110	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$545.60
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	177	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$877.92
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	163	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$808.48
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	163	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$808.48
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	275	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$1,364.00
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	355	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$1,760.80
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	281	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$1,393.76
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	27	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$133.92
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	37	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$183.52
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	165	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$818.40
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	133	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$659.68
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	389	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$1,929.44
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	198	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$982.08
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	198	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$982.08
C1010145	Partitions - Drywall w/ Metal Stud	$1.03	$3.93	198	Painted - 2 Coats and Primer	Basic Wall - 5/8" FR Both Sides 3 5/8" Studs	Proposed Wall	$982.08
	Total			3230				$16,020.80

Floor Material Takeoff 2							
Material: Area (Ft^2)	**Assembly Code**	**Assembly Description**	**Material: Cost**	**Material: Name**	**Level**	**Comments**	**Extended**
1031	B1010	Floor Construction	$14.66	Carpet - 42 Oz with Padding	2nd Floor Existing	Proposed Floor Finish	$15,114.46
1114	B1010	Floor Construction	$14.66	Carpet - 42 Oz With Padding	2nd Floor Existing	Proposed Floor Finish	$16,331.24
1555	B1010	Floor Construction	$14.66	Carpet - 42 Oz with Padding	2nd Floor Existing	Proposed Floor Finish	$22,796.30
Total							$54,242.00

Ceiling Schedule						
Assembly Code	**Assembly Description**	**Cost per Ft^2**	**Area (Ft^2)**	**Level**	**Type Comments**	**Extended**
C3030210	Suspended Ceilings - Acoustical	$4.61	156	2nd Floor Existing	Proposed Ceiling Finish	$719.16
C3030210	Suspended Ceilings - Acoustical	$4.61	158	2nd Floor Existing	Proposed Ceiling Finish	$728.38
C3030210	Suspended Ceilings - Acoustical	$4.61	157	2nd Floor Existing	Proposed Ceiling Finish	$723.77
C3030210	Suspended Ceilings - Acoustical	$4.61	150	2nd Floor Existing	Proposed Ceiling Finish	$691.50
C3030210	Suspended Ceilings - Acoustical	$4.61	354	2nd Floor Existing	Proposed Ceiling Finish	$1,631.94
C3030210	Suspended Ceilings - Acoustical	$4.61	132	2nd Floor Existing	Proposed Ceiling Finish	$608.52
C3030210	Suspended Ceilings - Acoustical	$4.61	321	2nd Floor Existing	Proposed Ceiling Finish	$1,479.81
C3030210	Suspended Ceilings - Acoustical	$4.61	148	2nd Floor Existing	Proposed Ceiling Finish	$682.28
C3030210	Suspended Ceilings - Acoustical	$4.61	215	2nd Floor Existing	Proposed Ceiling Finish	$991.15
C3030210	Suspended Ceilings - Acoustical	$4.61	47	2nd Floor Existing	Proposed Ceiling Finish	$216.67
C3030210	Suspended Ceilings - Acoustical	$4.61	44	2nd Floor Existing	Proposed Ceiling Finish	$202.84
C3030210	Suspended Ceilings - Acoustical	$4.61	153	2nd Floor Existing	Proposed Ceiling Finish	$705.33
C3030210	Suspended Ceilings - Acoustical	$4.61	338	2nd Floor Existing	Proposed Ceiling Finish	$1,558.18
C3030210	Suspended Ceilings - Acoustical	$4.61	183	2nd Floor Existing	Proposed Ceiling Finish	$843.63
C3030210	Suspended Ceilings - Acoustical	$4.61	179	2nd Floor Existing	Proposed Ceiling Finish	$825.19
C3030210	Suspended Ceilings - Acoustical	$4.61	490	2nd Floor Existing	Proposed Ceiling Finish	$2,258.90
C3030210	Suspended Ceilings - Acoustical	$4.61	188	2nd Floor Existing	Proposed Ceiling Finish	$866.68
C3030210	Suspended Ceilings - Acoustical	$4.61	152	2nd Floor Existing	Proposed Ceiling Finish	$700.72
Total			3565			$16,434.65

Door Schedule							
Assembly Code	**Assembly Description**	**Cost/Ea.**	**Thickness**	**Family**	**Type**	**Comments**	**Extended**
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
C1020	Interior Doors	$790.00	0' - 2"	Single-Flush Vision	36" x 84"	Proposed Doors	$790.00
Total							$8,690.00

Note: All costs taken from RS Means© 2009 Interior Cost and Assemblies Cost Data

Appendix E Energy Analysis Details

Project Title: Salisbury Laboratories
Run Title: Salisbury_Apr_16.xml
Building Type: SchoolOrUniversity
Floor Area: 61,895 ft²

Estimated Energy & Cost Summary

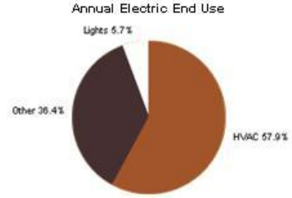
Annual Energy Cost		$205,326
Lifecycle* Cost		$2,796,537
Annual CO_2 Emissions		
	Electric†	302.8 tons
	Onsite Fuel	369.7 tons
	Large SUV Equivalent	61.1 Large SUV's
Annual Energy		
	Electric	673,116 kWh
	Fuel	63,749 Therms
Annual Peak Electric Demand		191.7 kW
Lifecycle* Energy		
	Electric	20,193,471 kWh
	Fuel	1,912,458 Therms

* 30-year life and 6.1 % discount rate for costs. † Does not include electric transmission losses or the renewable and natural ventilation potential.

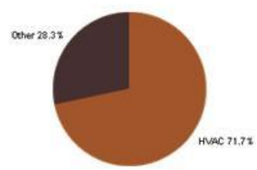
Energy End-Use Charts

Click on chart for more or less detail.

Annual Electric End Use



Annual Fuel End Use



Building Summary

Quick Stats

%values are red or blue they appear to be higher or lower than typical ranges, respectively.

Number of People	1,086 people
Average Lighting Power Density	1.10 W/ft²
Average Equipment Power Density	6.40 W/ft²
Specific Fan Flow	6.8 cfm/ft²
Specific Fan Power	0.900 W/cfm
Specific Cooling	42 ft²/ton
Specific Heating	2 ft²/kBtu
Total Fan Flow	49,677 cfm

Building: Worcester, MA 01609
Electric Cost: $0.16 / kWh
Fuel Cost: $1.54 / Therm
Weather: GBS_04R20_263134

Demo: Energy and Carbon Results
Play (wmv file)

Carbon Neutral Potential[1] (CO_2 Emissions)

Base Run:	672.5 tons
Onsite Renewable Potential:	-54.3 tons
Natural Ventilation Potential:	-57.6 tons
Onsite Fuel Offset/Biofuel Use:	-369.7 tons
Net CO_2 Emissions:	190.9 tons
Large SUV Equivalent:	17.4 Large SUV's

1. Carbon neutrality is defined here as eliminating or offsetting fossil based electricity and fuel use. For example, if the electricity grid is 60% fossil fuel and 40% hydroelectric, reducing grid electricity use by 60% and eliminating/offsetting on-site fuel use will make the project carbon neutral. Use any combination of efficiency, natural ventilation, renewable energy, carbon credits and biofuels to reach this goal. Renewable potential is the sum of photovoltaic and wind potential shown below.

Electric Power Plant Sources[2]

Fossil:	62%
Nuclear:	28%
Hydroelectric:	5%
Renewable:	5%
Other:	0%

2. Based on US EPA EGRID 2006 Data (2004 Plant Level Data).

Water Usage and Cost[3]

Total:	5,797,392 Gal/yr	$33,983 / yr
Indoor:	5,780,292 Gal/yr	$33,938 / yr
Outdoor:	17,100 Gal/yr	$44 / yr

3. Based on AWWA Research Foundation 2000 Residential / Commercial and Institutional End Uses of Water.

Photovoltaic Potential[4]

Annual Energy Savings:	73,818 kWh
Total Installed Panel Cost:	$771,883 / yr
Nominal Rated Power:	96 kW
Total Panel Area:	7,504 ft²
Maximum Payback Period:	42 yrs @ $0.16 / kWh

4. Results based on all exterior surfaces being analyzed. Escalation rate of 2% applied to electric rate. Payback calculation does not include federal or state incentives, loan information tax breaks.

LEED Daylight[5]

Area w/ Glazing Factor > 2%:	4.6% - No LEED Credit

5. Glazing factor is the ratio of exterior illumination to interior illumination and is calculated using floor area, window geometry (area and height) and visible transmittance of the glass. T project qualifies if glazing factor is > 2% in a minimum of 75% of all regularly occupied areas.

Wind Energy Potential[6]

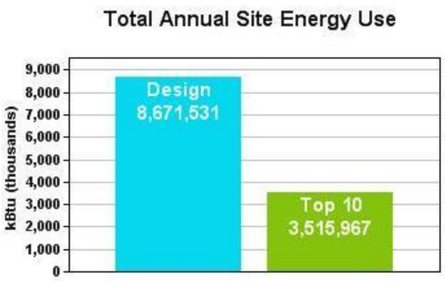
Annual Electric Generation:	1,048 kWh

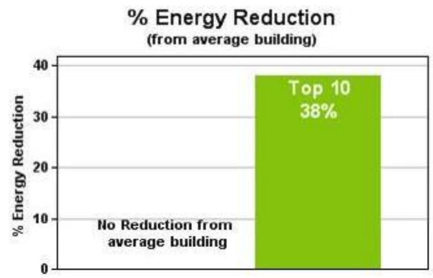
6. A single 15 ft diameter turbine, with cut-in and cut-out winds of 6 mph and 45 mph respectively, and located at the coordinates of the weather data.

Natural Ventilation Potential[7]

Total Hours Mech. Cooling Required:	5,474 Hours
Possible Natural Ventilation Hours:	1,795 Hours
Possible Annual Electric Energy Savings:	79,450 kWh
Possible Annual Electric Cost Savings:	$12,633
Net Hours Mech. Cooling Required:	3,679 Hours

7. Assumes natural ventilation only during comfort zone periods and air changes per hour are less than 20 ACH. Building form & opening design must be able to allow stack effect or cro ventilation.





Target Finder Energy Performance Results (estimated)

Space Type: K-12 School **Sub Space Type:** None

Energy	Design	Top 10% of Buildings
Energy Performance Rating (1-100)	10	90
Energy Reduction (%)	No Reduction	38
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	140.1	56.81
Total Annual Site Energy (kBtu)	8,671,531	3,515,967
Total Annual Energy Cost ($)	107,025	43,395
CO2 Emissions (tons/year)	625	253
CO2 Emissions Reduction (%)	-53	38

LEED® Water Efficiency Help

Water Usage and Costs

Total:	**5,797,392 Gal/yr**	**$33,982/yr**
Indoor:	5,780,292 Gal/yr	$33,938/yr
Outdoor:	17,100 Gal/yr	$44/yr
Net Utility:	**5,797,392 Gal/yr**	$33,982/yr

Source: AWWA Research Foundation 2000 Residential / Commercial and Institutional End Uses of Water.

General Information

Project Title: Salisbury Laboratories
Run Title: Salisbury_Apr_16.xml
Building Type: SchoolOrUniversity
Floor Area: 61,895 ft²

Water Usage Estimator

Change inputs and click "Estimate" to update Water Usage and Costs.

Estimate Save Reset

- Invalid Catchment Area

Unit Water Prices

Water: 2.60 $/kgal Sewer: 3.48 $/kgal

Indoor Water Factors

Number of People: 1086
(Typical people for this building type/size: 1548)
Percent of Time Occupied (%): 49

Outdoor Water Factors

Irrigated Area* (ft²): 1000
Timed Sprinklers: Yes
Pool: No
Other Equipment/Fixtures: No Usage: 25 Gal/day

*Irrigated area is a placeholder. Site data from Building Information Model is not incorporated.

Building Summary / **Efficiency Savings**

	Total	Male	Female	Employee Only	Efficiency	Percent of Indoor Usage (%)	Gallons per Year	Annual Cost Savings ($)
Toilets:	29	10	19	0	Standard	0	0	0
Urinals:	21	21		0	Standard	0	0	0
Sinks:	28	14	14	0	Standard	0	0	0
Showers:	0	0	0		Standard	0	0	0
Clothes Washers:	0				Standard	0	0	0
Dishwashers:	0				Standard	0	0	0
Cooling Towers:	1				Standard	0	0	0
☑Include cooling tower blowdown in sewer costs					**Total Efficiency Savings:**	**0%**	**0**	**$0**

Source: 2000 Uniform Plumbing Code of the IAPMO, Tables 4-1 and 4-3.

LEED Daylight (?)

* Update your glass performance using Design Alternatives.

Percentage of building area with glazing factor over 2%: **4.6% - No LEED Credit**

LEED requires your project achieve a minimum glazing factor (?) of 2% in a minimum of 75% of all regularly occupied areas.

LEED Daylight Space Analysis

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			Sidelighting Vision Glazing (?)		Sidelighting Daylight Glazing (?)		Toplighting Sawtooth Monitor (?)		Toplighting Vertical Monitor (?)		Toplighting Horizontal Skylight (?)		
Space ID	Space Type (?)	Space Area (ft²)	Area (ft²)	VT (?)	Area (ft²)	VT (?)	Area (ft²)	VT (?)	Area (ft²)	VT (?)	Area (ft²)	VT (?)	Glazing Factor
sp-138-CorridorHall	Unspecified	3,819	38	0.44	3	0.44	0	N/A	0	N/A	0	N/A	0.1%
sp-115-Kinicut_Hall	Unspecified	2,295	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0%
sp-305-Classroom	Unspecified	1,713	106	0.44	0	N/A	0	N/A	0	N/A	0	N/A	0.5%
sp-104-Coghlin_Lecture_hall	Unspecified	1,653	131	0.44	13	0.44	0	N/A	0	N/A	0	N/A	0.8%
sp-105-Gordon_Lecture_Hall	Unspecified	1,605	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0%
sp-041-Mechanical	Unspecified	1,575	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0%
sp-302-Hallway	Unspecified	1,119	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0%
sp-219-Bio_Teaching_Lab	Unspecified	1,029	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0%
sp-223-Teaching_Lab	Unspecified	1,018	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0%
sp-045-CorridorHall	Unspecified	987	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0%
sp-125-Department_Office	Unspecified	980	38	0.44	4	0.44	0	N/A	0	N/A	0	N/A	0.4%
sp-400A-Hallway	Unspecified	978	76	0.44	6	0.44	0	N/A	0	N/A	0	N/A	0.7%
sp-202-Corridor	Unspecified	978	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0%
sp-406-Classroom	Unspecified	949	73	0.44	0	N/A	0	N/A	0	N/A	0	N/A	0.7%
sp-214-Research_Lab	Unspecified	824	92	0.44	0	N/A	0	N/A	0	N/A	0	N/A	1%
sp-114-None	Unspecified	734	67	0.44	7	0.44	0	N/A	0	N/A	0	N/A	0.9%
sp-413-MQP_Project_Lab	Unspecified	733	78	0.44	0	N/A	0	N/A	0	N/A	0	N/A	0.9%
sp-402-Wet_Lab	Unspecified	714	53	0.44	0	N/A	0	N/A	0	N/A	0	N/A	0.7%
sp-101-Computer_Lab	Unspecified	713	53	0.44	5	0.44	0	N/A	0	N/A	0	N/A	0.7%
sp-407-Seminar	Unspecified	680	40	0.44	0	N/A	0	N/A	0	N/A	0	N/A	0.5%

Note: Please refer to U.S. Green Building Council LEED Credit 8.1 documentation for more information (www.usgbc.org).