BUILDING INFORMATION MODELING FOR MEP

by

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Abstract

Building Information Modeling (BIM) is a new way of approaching the design, construction, and management of a building. It is an innovative method that bridges the communication gap between the architects, engineers, and contractors. By definition Building Information Modeling is a model-based technology linked with a database of project information. BIM builds a virtual model of the building so that architects, engineers, and contractors can all access at anytime. With BIM, architects and engineers are able to efficiently generate and exchange information, create digital representations of all stages of the building process, and simulate real-world performance. By doing this, many errors are eliminated in the field which increases productivity and improves quality. This report defines what BIM actually is and discusses the benefits and challenges that are associated with this new method of design and construction. Specifically, this report will take an in depth look at how BIM affects MEP design.

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Dedication

I dedicate this report to my parents Jay and Jennifer McFarland for inspiring me to become an engineer and supporting me throughout my studies.

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CHAPTER 1 - Introduction to Building Information Modeling

In the building construction and design industry today, there are many people that are starting to talk about a new technology that could reshape the culture and image of the industry. The technology is Building Information Modeling, BIM, and it is becoming a very useful tool to architects, engineers, and contractors in the working force and those soon to be. BIM is new, innovative, and something that most design and construction professionals do not use on a regular basis. However, as those professionals have learned more and more about BIM the closer it is becoming to being adopted as a common practice. In the past BIM has mainly been utilized by architects and structural engineers, but it is recently being used by mechanical, electrical, and plumbing designers and engineers as well. Overall, BIM is being used throughout the entire building process, from contractors to architects. Therefore, with the industry becoming more and more focused on "Green" design; BIM is beginning to offer many benefits to aid in sustainable design. After taking into account all of the areas of the industry that BIM affects, it is obvious why this technology is taking the industry by storm.

Building Information Modeling is a new way of approaching the design, construction, and management of a building. If used correctly it saves money, time, and materials while producing fewer errors and enhancing productivity resulting in a higher-quality work making it a sustainable and practical tool. BIM utilizes the most advanced technology and software in industry to effectively build a virtual model of the building. This helps in many phases of the design and construction process including coordination between disciplines by making critical information available to everyone involved (Zigo, 2005). By making sure everyone is up to date and informed, architects, engineers, builders, and owners have a clear vision and are able to make better decisions faster. Many times because of lack of communication between architects, engineers, and contractors; owners are often bombarded with unnecessary expenses and time delays. By implementing BIM, these negatives are reduced and firms are able to increase the level of service, quality, and performance that they provide to their clients according to a study by Dr. Lachmi Khemlani; College of Architecture, UC Berkeley.

Many in design and construction believe that BIM is where the industry is headed. Many firms are indeed moving toward BIM according to a statistical analysis performed on nine consulting firms throughout the country (Appendix A). The majorities of these firms currently know about BIM, on some level, and have an implementation process already started. Those firms that do not already have a process started for BIM think that they will have to implement it eventually, but they would rather wait until the software and technology are more user friendly to their needs.

Building Information Modeling offers a magnitude of advantages and rewards for firms willing to utilize this method of design, but as with any new technology there are challenges as well. The goal of this paper is to explain what BIM is and identify its advantages through the entire life-cycle of a building, identify how it is used in sustainable design, and discuss where the industry currently is concerning BIM. Lastly, the strengths and challenges of implementing BIM in mechanical, electrical, and plumbing (MEP) design will be looked at in depth, and a recommendation will be made to implement it for MEP.

CHAPTER 2 - What is Building Information Modeling, and What Are the Key Benefits?

Building Information Modeling (BIM) has been around since the 1990's. It is a new way of approaching the design, construction, and management of the life-cycle of a building. BIM has changed the way in which professionals all over the world apply technology to the many phases of design and construction. This chapter will further describe what BIM actually is, and it will explain the key benefits to the building design, construction, and management phases.

2.1 Definition

The American Institute of Architects has defined BIM as "a model-based technology linked with a database of project information" (Wikipedia, 2007). Basically, BIM is similar to a mathematical or physical representation of a system with known properties. The building itself is the system in this case, and the physical representation is electronically developed based on the information the designers input. When using BIM, the digital model that the designers actually build can be used to ensure the continuous and immediate availability of information to any member of the design, construction, and management team (Wikipedia, 2007). The information is available because BIM allows the virtual information model to be handed from the design team to the contractor and then to the owner, with each adding their own discipline specific knowledge (Wikipedia, 2007). With all of the disciplines using the same model, there is access to all of the information by all members of building design, construction, and management teams. This allows an integrated approach in which architects, engineers, contractors, and owners are able to obtain a clearer vision of the overall project. All parties are able to stay up to date and can coordinate with the project design scope, schedule, and cost information (BIM Modeling in Practice, n.d.). This allows everyone to make better decisions based on all of the information that is available, not on estimations or assumptions. In turn, the projects become more profitable and the quality is increased.

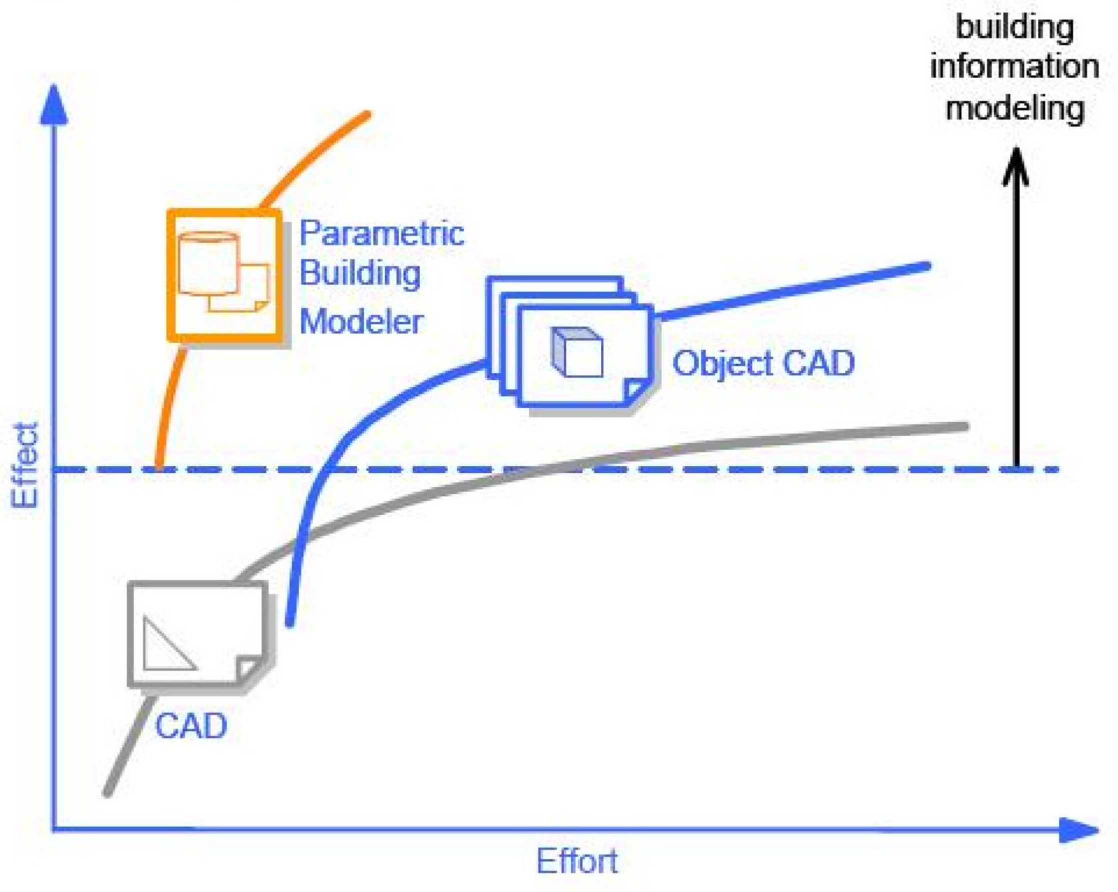
2.2 Technology Used

Although Building Information Modeling itself is actually an approach to building design, construction, and management, a suitable technology is required to effectively implement BIM (BIM Modeling in Practice, n.d.). A common misconception of BIM is that it is only used for 3D design because some of the technology does have the virtual modeling capabilities; however BIM can also be accomplished without the use of 3D modeling. The main difference in BIM is how the object is perceived after it is placed in the drawing. There are many technologies and software available that can be used by the BIM approach (BIM Modeling in Practice, n.d.):

- CAD
- Object CAD
- Parametric building modeling

CAD is the least effective technology to accomplish building information modeling because it takes a great amount of effort. Object CAD is more effective, but a parametric building modeling technology is by far the most effective way of using Building Information Modeling as shown by Figure 2.1 on the next page.

Figure 2.1: Effectiveness of BIM Technology (BIM Modeling in Practice, n.d.)



2.2.1 CAD

CAD technology is the least effective of all of the technologies used by Building Informational Modeling. At the same time, CAD is one of the easiest and oldest technologies used in industry today; however, this is because it is not applied in a BIM approach. When applied using BIM, CAD requires greater and greater levels of effort. To achieve the level of efficiency that BIM requires, CAD files must be layered and standards developed and maintained. Many times the quality of the information depends solely on the person inputting the data. Also, as updates and changes are made, CAD requires individuals to go back and modify every area affected by the design change. The most common practice of CAD with BIM is through programming and partner development of the individual firms. This allows firms to personalize CAD technologies and integrate many of the different design components. However, the level of effort becomes so high that CAD is usually not used in BIM applications. The most common software based on CAD technology is AutoCAD, but other software applications include Microstation and Solidworks (BIM Modeling in Practice, n.d.).

2.2.2 Object CAD

The next BIM compliant technology is Object CAD. Object CAD simulates building components from regular CAD and focuses on the 3D geometry of the drawings. This enables extraction of data of individual objects which provides information about the properties of objects throughout the building. This technology can effectively coordinate many representations of the building in documentation from one file. Also, because it contains so much data about the building in the object structure, it can be converted to BIM easier than typical CAD software. Since this technology is based off of CAD technology, it is easily implemented without much change, and the results are immediate. However, object CAD again relies heavily on the consistency and reliability of the user. It does not ensure high quality, reliable, and coordinated information that the higher level of BIM produces. This is because the software itself is not fully integrated. When a change is made, it is not implemented throughout the design. Many users of object CAD use it primarily for design and documentation tools instead of complete building information modeling. Autodesk has forms of object CAD technology in their Architectural Desktop and Building Systems software. There are other programs that incorporate object CAD as well (BIM Modeling in Practice, n.d.).

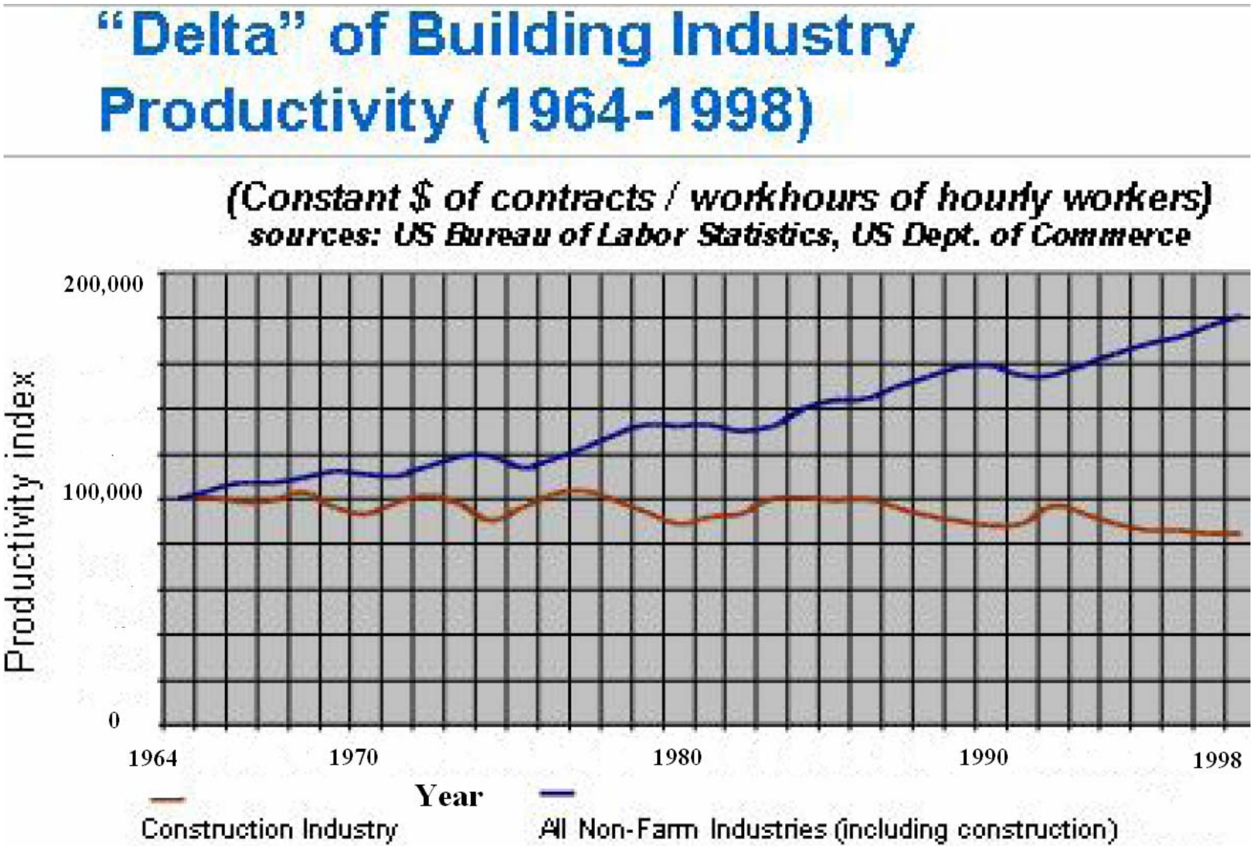
2.2.3 Parametric Building Modeling

The last and most effective technology that is used to implement BIM is Parametric Building Modeling. The basic difference of this technology compared to CAD and object CAD is the real-time self-coordination of the information in every view. The self-coordination is a very unique capability that parametric building modeling utilizes, and CAD and object CAD do not. It ensures that when a change is made in the design; it will be implemented throughout the entire project which gives assurance of the quality of information coming from the design. A complete set of design documents are stored in integrated databases that are completely interconnected within the drawing as well. This means that as one makes a change on the model, it is not only updated throughout the entire drawing, but all of the design documents and schedules are updated as well. This eliminates many errors and ensures a higher quality as well as saves time. This technology offers the highest effectiveness of building information modeling at the lowest level of effort. However, there is no way to use this technology in the traditional non building information modeling, and it requires wholesale adoption of BIM. Autodesk is leading the software design of parametric building technology with its Revit software, and it is assumed that Revit will be the technology discussed throughout this paper (BIM Modeling in Practice, n.d.).

2.3 Overall Benefits of Building Information Modeling

The benefits of building information modeling when it is applied in its full extent are numerous. The building industry is one of the last to implement computer model-based design resulting in the consumption of resources and numerous inefficiencies. The manufacturing industry has long ago been forced to realize model-based digital design due to global competitive pressures as shown on the next page in Figure 2.2. Every front of manufacturing: automobiles, airplanes, electronics, etc. has increased its productivity, while the construction industry has remained relatively the same. As globalization and economic integration continue to increase, the construction industry will be pressured to move forward with the model-based design (Bernstein and Pittman, 2007).

Figure 2.2: The difference in productivity between the construction industry and the manufacturing industry (Bernstein and Pittman, 2007).



The fully integrated technological approach of BIM can be applied to any phase of the project. This immediate and continuous availability of information allows better communication between architects, engineers, builders, and clients, which increases the quality and profitability of projects. Not only is there increased quality and profitability, but there are fewer errors, greater productivity, and opportunities for new revenue. This section will give a more detailed picture of the overall benefits that BIM offers the building design, construction, and management teams.

2.3.1 BIM in the Design Process

Building information modeling offers many advantages in the design phase of a building. This phase mainly deals with the architects, engineers, and other design team members that are involved in the design process. Because the BIM approach offers access to critical design, schedule, and budget information as well as the integrated automatic updates, there is multiple circumstances that create savings in time and money (BIM Modeling in Practice, n.d.).

During the course of design of a building, special attention must be brought to the project scope, schedule, and cost. When changes are made to any of these three areas, the project wastes time and money and many times creates a negative relationship between consultants, clients, and architects. Traditionally, the geometry and physical features of a project are fairly consistent and easily accessible. However, the cost and scheduling information, which are equally as important, are only occasionally available. With BIM, all of this design related information is immediately available so that the project-related decisions by the architect or owner can be made quickly and more effectively (BIM Modeling in Practice, n.d.).

BIM allows changes to be made to the design of a project at any time without any laborious re-coordination and manual checking. It is similar to an Excel spreadsheet in that as you change a value within the spreadsheet, any calculations are automatically recalculated without a person needing to go in and actually recalculate each equation by hand. The time that is saved by this function of BIM is invaluable. It allows the design team to focus on other significant architectural and engineering problems.

Similar to the Excel spreadsheet, whenever a change is made to the project, all the consequences of that change are updated throughout the entire project. This means that the design and documentation are captured at the point of creation and embedded throughout the project. This drastically saves the amount of time and effort taken to coordinate the project. The automatic coordination of changes offered by BIM also eliminates mistakes, improves the overall quality, and helps attain more repeat business (BIM Modeling in Practice, n.d.).

Lastly, BIM is extremely beneficial to designers that want to incorporate performance based design. Performance based design is when designers must prove that their design will meet certain codes and standards. Many times designers utilize performance based design for fire protection. For instance, if they are able to prove that they can provide coverage throughout a building without using the typical codes and standards, then their design can be accepted. The hard part is proving that the new design will work. Many times digital technology is the key enabler of performance based design. It is only used to graphically represent the design, but there is no way of analyzing or evaluating it. Because BIM is a fully integrated database of coordinated information, it is easier to evaluate performance based design. The integrated relationships of the design allow the design to be graphically represented and can be used to analyze the design. By using BIM the effort implementing a performance based design is much less and saves large amounts of time (BIM Performance Based Design, n.d.).

2.3.2 BIM in Construction

In the construction phase, BIM makes available information related to building quality, schedule, and cost. This increases productivity during construction due to easy retrieval of information. Because everything is available and current, contractors are able to quickly produce estimates and propose value-engineer items for projects. Contractors are also able to produce construction planning details more effectively, and they are able to quickly produce plans showing site use or renovation to the owner or client. Therefore, the impact of construction operation is minimized and the owner does not have to expend so much on operations and personnel because of the increased communication that BIM allows. Less time and money are spent on process and administration issues because documentation is higher in quality and easier to understand and the coordination of construction documents is increased. BIM offers even more advantages to the construction phase because of the increasingly competitive industry. Due to the industry's need for speedy construction, contractors are always looking for ways to do thing faster and more efficiently. When utilizing BIM, there is a definite increase in speed of delivery. This is because the embedding and linking of all vital information makes it easy to locate and produce estimations of material including vendor specific materials. BIM also allows for improved visualization of the project, which provides contractors with a better understanding of the project; therefore, they can better do their jobs while reducing costs (BIM Modeling in Practice, n.d.).

2.3.3 Managing the Building

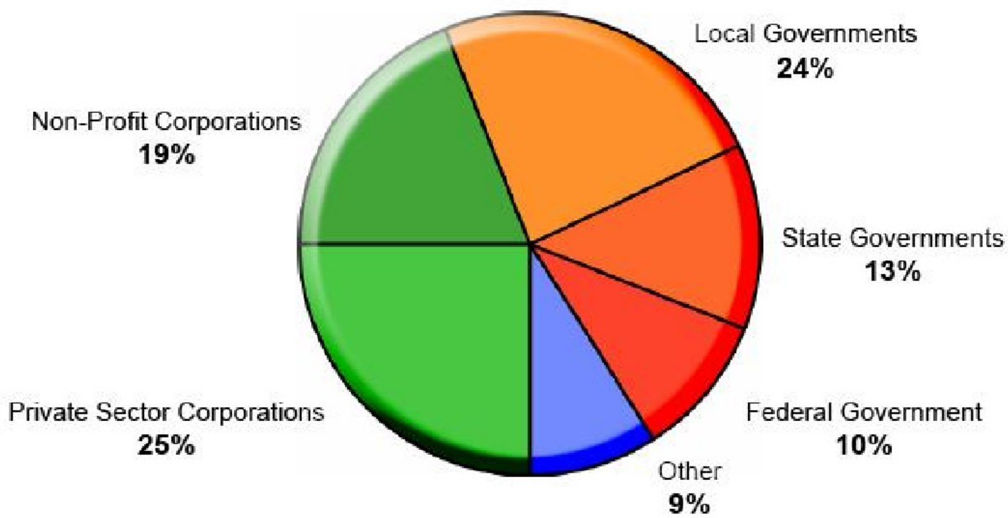
Lastly, building information modeling offers numerous benefits to the building management phase of the project. Similar to the way in which designers use BIM to do performance based designs, it can also be used to collect information on the use and performance of the actual building once it is built (BIM Performance Based Design, n.d.). Because BIM is a fully integrated database of coordinated information, it is easy to track and evaluate the performance of the building because the relationships are represented and can be used to analyze the design (BIM Performance Based Design, n.d.). Besides the performance of the building the main components that can also be monitored are the buildings occupants and contents, the life of the building over time, and the financial aspect of the building. BIM is able to do this because it provides a digital record of renovations and any changes to the building. Therefore, finishes, tenant assignments, furniture and equipment inventory, and financially important data about leasable areas and rental income are more easily managed and available. The access to this information improves both revenue and cost management of the building management phase. Building information modeling also allows easy building management programs to be implemented and utilized which includes energy analysis studies. By ensuring that all of the information about the building is available, the amount of time and money spent on managing the building is decreased considerably (BIM Modeling in Practice, 2007).

CHAPTER 3 - Building Information Modeling and Sustainable Design

Many people are startled by the environmental impact of buildings in the United States. It is far larger than any other industry in our country. The U.S. Department of Energy, Energy Efficiency and Renewable Energy Network (EREN) states that in the United States, commercial and residential buildings consume close to 40% of our total energy, 70% or our total electricity, 40% of our raw materials, and 12% of our fresh water while accounting for 30% of greenhouse gas emissions and 136 million tons of demolition waste (BIM Sustainable Design, 2007). National organizations such as the U.S. Green Building Council (USGBC) have brought attention to the detrimental affects that buildings have on the environment and have developed LEED (Leadership in Energy and Environmental Design) rating system. LEED certification is becoming increasingly popular in the building industry, and a variety of owners are pursuing

LEED accredited buildings as shown in Figure 3.1 below. The LEED rating system is nationally accepted as the national standard for sustainable design that seeks to overcome the negative impact of buildings through the use of environmentally sensitive design and construction practices (BIM Sustainable Design, 2007).

Figure 3.1: Different owners are pursuing LEED certification (BIM Sustainable Design, 2007).



By utilizing building information modeling, building performance analysis and evaluations can be done to effectively obtain sustainable design. Besides being able to graphically depict the building and allowing the owner/client to visualize the final product, the data needed to support sustainable design is obtained naturally as the project is designed. BIM is able to do this because it is able to link the building model directly to the commercially available analysis software thus greatly simplifying the design process. There are many areas that BIM can be used for sustainable design including (BIM Sustainable Design, 2007):

- Optimize design
- Daylighting

- Energy analysis
- Computation of materials
- Reducing waste and inefficiency

3.1 Optimize Design

By using building information modeling combined with numerous versions of analysis software, designers are able to track various design options until they are better equipped to make a decision. The designer, therefore, is able to develop multiple design alternatives within the same model. The different design options can be toggled on and off throughout the design process to compare the different aspects of the designs when needed. With this capability, sustainable design options for different LEED credit requirements can easily be examined and documented. This enables designers to keep varying types of good sustainable ideas on the table until they are evaluated and decided upon (BIM Sustainable Design, 2007).

3.2 Daylighting

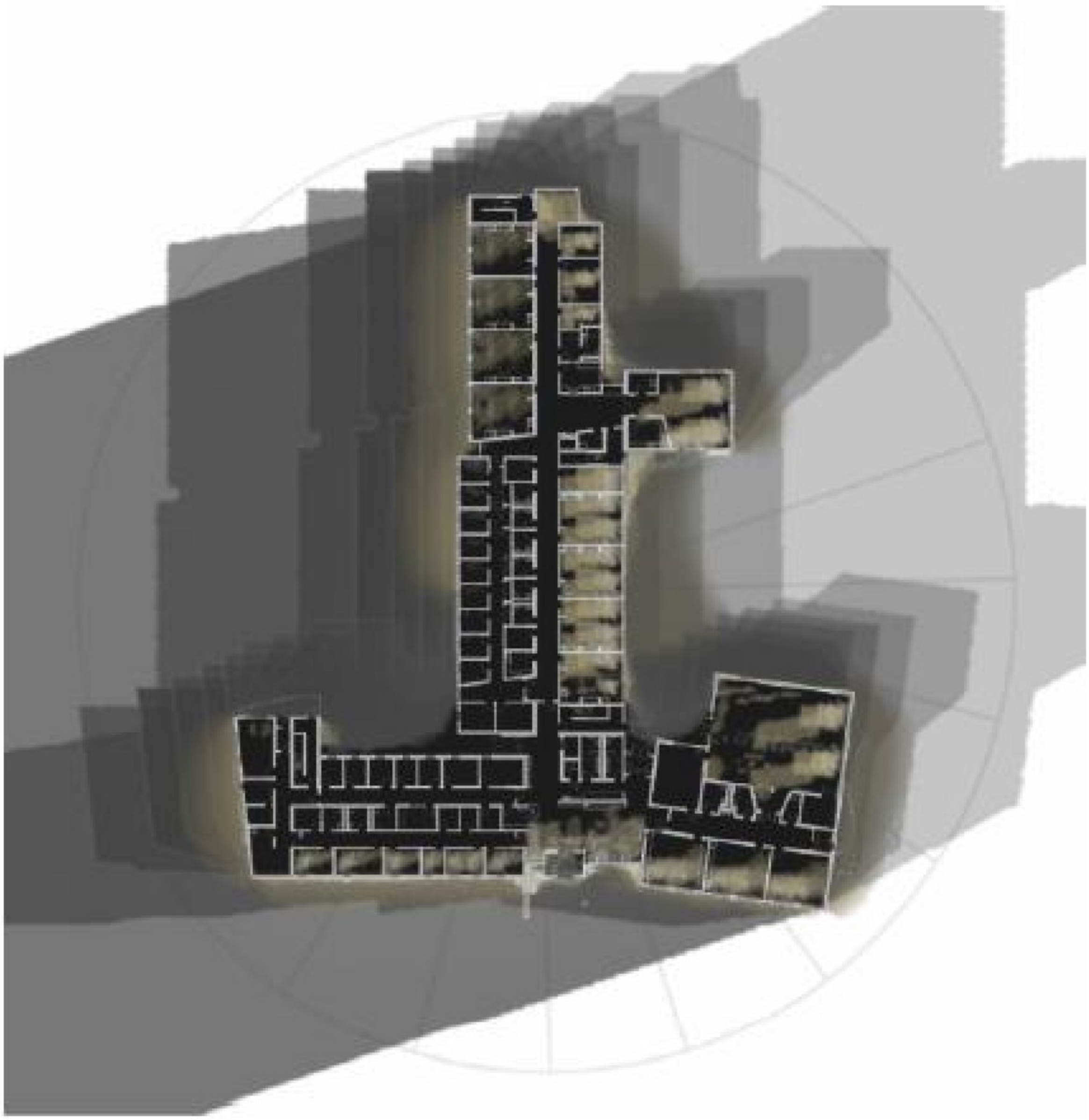
One of the sustainable designs utilized by building information modeling is the practice of using natural light to illuminate buildings. By using natural light, occupants are more comfortable and productive, and it can dramatically decrease the electrical lighting load associated with the building. Unfortunately, day lighting is rarely used because of the complicated formulas and cumbersome calculations. There is software available to accomplish the design, but they are very expensive and require large amounts of time. Many times because of the complexity of day light design, it is not used because the cost greatly outweighs the benefits. However, with the use of BIM and its capabilities of integrating the day lighting software, the design becomes feasible. BIM allows the design team to do the modeling, measurement, and documentation of complex interior day lighting designs within a reasonable amount of time and with relative ease. It also provides documentation needed to achieve a LEED rating. Figure 3.2 below is an example of how Revit can be used as a realistic rendering (left) and a quantifiable, color intensity model (right) (BIM Sustainable Design, 2007).

Figure 3.2: Using Revit as a daylight rendering (left). Using Revit as a numerically quantifiable model (right) (BIM Sustainable Design, 2007).

3.3 Energy Analysis

Another related sustainable aspect is design based on energy analysis. As described earlier, buildings consume large amounts of energy, and in order to reduce their affects on the environment studies need to be conducted. However, when designing a building it is difficult to conduct an energy analysis if the building is not built. Like day lighting software, programs have been developed to be used to evaluate buildings, but they are rarely used due to limits in time and costs. Many times firms contract out energy analysis, which results in extra expenses, time delays, and unavailability of information throughout the project. For these reasons energy analysis is not done often. However, with BIM an energy analysis can be utilized by the designer at any time during the design process if software such as Revit is used. It is convenient and does not take up large amounts of time. When using Revit, a variety of energy analyses can be preformed, including a solar/sun study shown on the next page in Figure 3.3 because the programs are integrated within the software. The true benefit comes from being able to apply the results of the energy analysis faster and make better, well informed decisions that save in energy use and give back to the environment (BIM Sustainable Design, 2007).

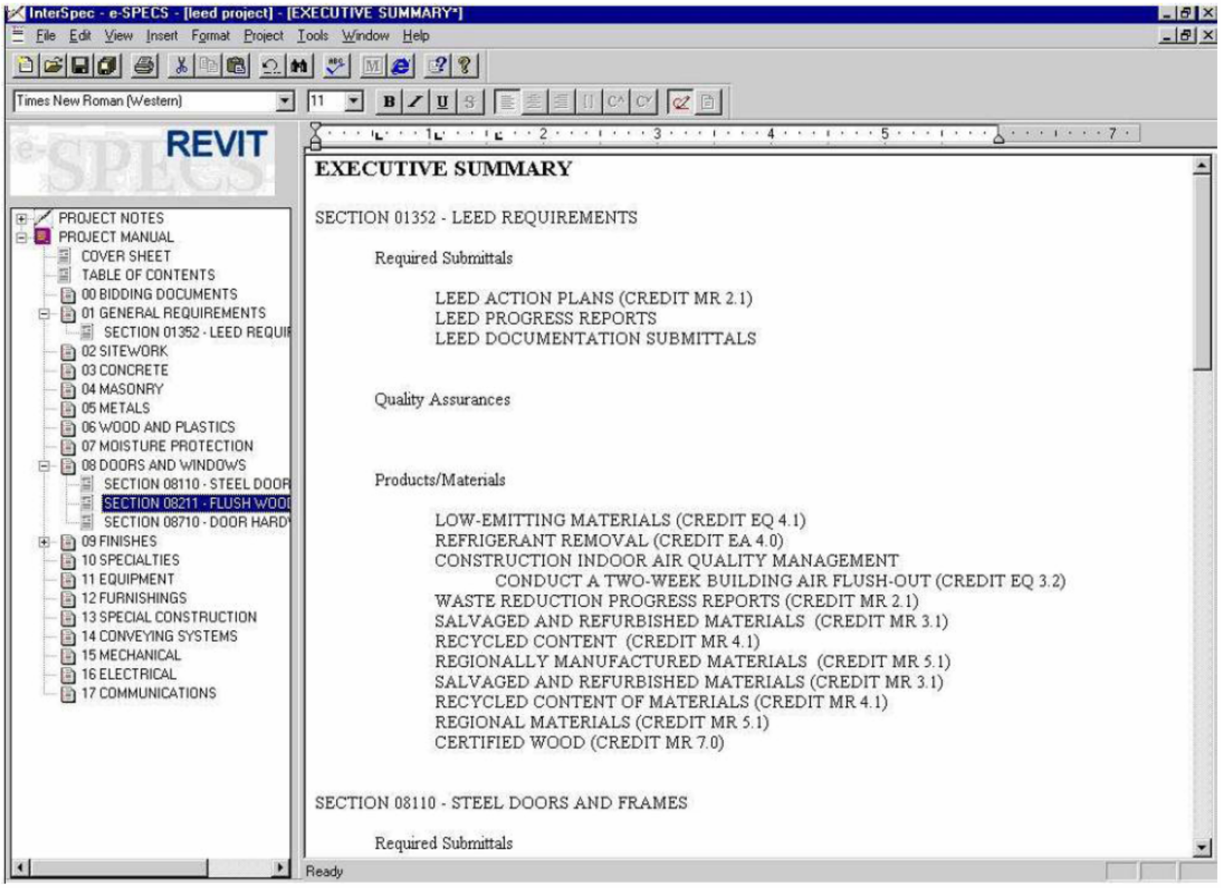
Figure 3.3: Solar/Sun study performed by Revit (BIM Sustainable Design, 2007).



3.4 Computation of Materials

The selection of building materials is important to sustainable design because it will reduce the impact on the consumption of raw materials. To ensure that there is no waste of materials, accurate computations must be done on the project's material quantities. This takes valuable time because the information must be found and processed. Usually, building information is scattered across multiple drawings, spread sheets, etc. Many times the information gathered from the project is unreliable and not worth taking the time to calculate the areas, volumes, and costs of materials needed to obtain LEED credit. Utilizing building information modeling, the building information needed is obtained effortlessly and accurately. Figure 3.4 on the next page is an example of a specification that can be generated automatically by Revit with LEED cross references to ensure certification. The calculations needed to obtain LEED credits can even be embedded into the schedules of the project which will be updated as the project is developed. This allows phasing of the project which is determines the extent of demolition and new construction on a project that is critical for green design (BIM Sustainable Design, 2007).

Figure 3.4: Material specification produced automatically by Revit (BIM Sustainable Design, 2007).



3.5 Reducing Waste and Inefficiency

Perhaps one of the most apparent problems in the construction industry is waste at the construction site. This is not only an environmental issue, but an economic issue as well. It was reported that in 2004 inefficiencies, mistakes, and delays in the construction phase accounted for $200 billion of the $650 billion spent on construction every year in the United States (Eastman, Lee, Sacks; 2006). Along with the loss of money is loss of materials and energy. There is one major cause of the inefficiency seen throughout the construction industry and that is poorly coordinated construction drawings. Millions are spent on change orders during construction that may not add value to the building. The source of the problem is addressed by utilizing building information modeling combined with the parametric building technology. This ensures that the entire building model, including documentation, is coordinated, consistent, and complete at all times. This ensures that there is a reduction in the amount of money, time, energy, and materials that are wasted during construction (BIM Sustainable Design, 2007).

CHAPTER 4 - Building Information Modeling in Industry

Currently the construction industry is extremely fragmented and needs to revolutionize the process by which it is conducted. Many in industry think that the answer is Building Information Modeling with its new approach to building design, construction, and management. This chapter will describe the status of the construction industry as it is currently, and it will discuss the reasons for the BIM movement.

4.1 Current Industry Standard

Many other industries throughout the nation have been able to utilize the advancement of technology that exists today. The manufacturing, agriculture, and finance industries are prime examples of the improved process presented when advanced technologies are applied. Each has been provided competitive gains, efficiencies, and new approaches by information technology.

The building industry is behind in its efforts to identify and utilize the advantages offered by technology due to the fragmented nature of the industry (Bernstein and Pittman, 2007).

The construction industry has traditionally been craftsman-oriented, with many individual participants working on a single project. All of these different disciplines are brought together to design, construct, and manage projects in a very competitive setting. The same participants of one project are hardly ever the same as the participants of another project. Many times all of the participants use their own type of technology that is personalized to their individual needs and is not compatible with other participants. This causes fragmentation throughout the construction industry. Each division is only responsible for their part in the design and construction of the building, and no one is concerned with the combined finished product. Typically, the architect designs the building with the help of engineering consultants, and then the construction documents are passed on to the contractor for bidding. Plans are also sent to subcontractors for bidding as well. The steel erector is interested in only steel, and the plumber is interested in only pipes, not wires and ducts (Eastman, Lee, Sacks; 2006). Because each party is looking out for their own interest, conflicts and disputes are often developed that cause the industry to be very inefficient and costly especially to the final project (Bernstein and Pittman, 2007).

Today's architects, engineers, and contractors are implementing information technologies very slowly. Since the building project teams rarely work together more than once, they are focused on a single, unique project that is only produced once. Therefore, it is difficult for an individual participant to really push for the overall use of the information models currently available. This is detrimental to the overall result, and owners and clients are usually the ones that suffer (Bernstein and Pittman, 2007).

4.2 Building Information Modeling Movement

Even though the building industry is a latecomer to incorporating informational technology into practice, there is a movement in that direction with building information modeling. The concept of BIM has revolutionary benefits that include: visualization of the end product in 3D, better quality plans, reduction in waste and errors, and easily accessible information that can be used for any phase of the buildings lifecycle. The benefits have been recognized, and now the industry is starting the BIM movement. There are many reasons that BIM is now becoming important to the industry (Revolution and Achievement, n.d.):

- Competitive construction market
- Client expectations
- Globalization
- Design-build
- Building life-cycle management

4.2.1 Competitive Construction Market

The construction industry is becoming increasingly competitive and complex compared to what it used to be. The business competition is resulting in a need of managerial innovation. Technology such as BIM is combing together with management concepts to transform processes and systems to become faster and more efficient. This productivity increase has become important. One result to this increasingly competitive environment is what is perceived to be an advanced “commoditization of services.” This means that clients are beginning to be offered a great deal of services by firms competently and profitably. Owners are expecting faster and better services no matter what the building type. Therefore, in response to the owner expectations, many design firms are using BIM and its related technology because it increases their efficiency and allows them to spend more time on important engineering designs (Revolution and Achievement, n.d.).

4.2.2 Client Expectations

Not only are clients expecting better buildings faster, but they are beginning to also expect "smart" buildings. Designers and contractors are required to produce far more sophisticated services and must be able to deliver them to the owner. With the increased attention to environmental effects, owners are requiring these smart buildings to have an increased amount of green design features including: security, audio/video automation, convenience devices, and advanced heating ventilating and air conditioning (HVAC) systems. All of these designs need the highest level design performance while still remaining practical to utilize. The data driven building information modeling systems allow a firm to do building performance and sustainability analysis in-house thus saving time, effort, and money while keeping the owner happy (Revolution and Achievement, n.d.).

4.2.3 Globalization

Globalization of the building industry is also forcing increased efficiency among professionals. With the ability of companies to outsource their services to professional centers in China and India, the service fee for professionals in America is being adversely affected. A $100,000 per year annual income professional with comparable experience in the United States is only making $30,000 per year annual income or less in India. To keep owners from out sourcing production to achieve cost savings and keep projects moving, professionals must offer newer and better services. By utilizing BIM, designers can do just that. They can offer better quality of work while still offering the owner cost savings. Outsourcing would not be necessary using BIM technology because there are too many design decisions that are made concurrently during production that India or China would not be able to make (Revolution and Achievement, n.d.).

4.2.4 Design Build

A growing trend in the building industry is the various forms of design-build. It is increasing at a rate of nearly 5% a year which is ground-breaking (Revolution and Achievement, n.d.). This new approach calls for the increased collaboration among the different fields and critical project management ideas. The design-build approach requires more integration between the design side and the construction side. It offers a faster turn around, stronger collaboration between fields, equal liability, and better communication. Building information modeling is considered an important tool to those firms that are transitioning to design-build, and it plays an increasingly important role to the design, construction, and management of a building. The integrated and fully coordinated information model helps design members produce higher quality work more quickly with fewer errors, while also helping clients better visualize the final building (Revolution and Achievement, n.d.).

4.2.5 Building Life-cycle Management

Building lifecycle management will improve processes and open new business for professionals. Building lifecycle management is the combination of information derived from building information modeling and the collaboration between the different services to solve problems throughout the entire lifecycle of a building including design, construction, and management. By using BIM, there is a significant advantage of being able to share and manage continuous information from the building's beginnings through construction, and going further to building maintenance. This allows easy access to information for long-term management of the building which represents the total management of the building that is a positive. For instance the energy use of the building is available to the owner from the beginning of occupancy and is continuously recorded. This allows owners to quickly locate areas that are consuming the most energy and come up with plans to save energy at those locations (Revolution and Achievement, n.d.).

CHAPTER 5 - Implementing Building Information Modeling for MEP Design

There are numerous advantages of using Building Information Modeling, and yet the building industry is still slow to completely revolutionize the way in which it performs business. This is due to the fact that while BIM offers extensive benefits, they are for the most part long term benefits, and there is no immediate return for the investment. The people who truly benefit from the implementation of BIM are the owners and the overall process; therefore, it is mainly up to the owners to support and back the change (Eastman, Lee, Sack; 2006). Many mechanical, electrical, and plumbing design firms (MEP) feel that BIM is where the industry is heading, and face the decision to implement software such as Autodesk Revit for MEP or wait until they are forced to do so by the market. Many architects have already switched over to the Revit Architectural, and they like it. However, Revit for MEP is only on its first versions and is not as advanced as Revit Architectural which is on its 8^{th} version. For MEP firms facing these powerful decisions, the key strengths and challenges associated with the implementation of Revit for MEP must be examined. (Khemlani, 2004).

5.1 Key Strengths of Implementation

Through studies conducted on firms that are already using Revit, it is clear that there is a need for an effective implementation strategy. Most firms are positive and have significant benefits to their businesses, but often suffer some challenges. The most critical key to implementing Revit is not to lose productivity at the initial stages of implementation. There are many long term advantages of using Revit, but what MEP design firms are concerned about during implementation are the immediate paybacks. There are many of these strengths associated with the implementation of Revit to the overall MEP design as well as the individual design of mechanical/plumbing and electrical systems (Khemlani, 2004).

5.1.1 Overall Benefits to MEP Design

The first benefit is the ease of use compared to other technologies that utilize building information modeling. As mentioned earlier, users can use BIM with many technologies including CAD, object CAD, and parametric building modeling (in this case Revit). When comparing these technologies, Revit provides far more BIM advantages with far less effort. Revit is also trying to be user friendly in that it includes a thoughtful design of features that are beneficial to the MEP designer although it is only in its first stages. It even produces good interoperability with CAD drawings. This allows CAD plans to be referenced into Revit and exported back. This is crucial because it means that MEP designers can still use Revit even if the architect and structural designers are still using CAD (Khemlani, 2004).

When using Revit, the designer does not have to be concerned with making sure that when a change is made every view is updated. The coordinated drawing views and documents allow for instant updates of all views when any change is made within the model. The accurate and informative views provide designers with instant feedback to make decisions and force them to think 3 dimensionally which provides a better thought out design. This feature is available upon immediate use of the Revit program and is helpful in the visualization of the systems. Also, once set up, there is the ability to automatically develop tasks related to the model concerning setup and coordination. This eliminates time consuming and redundant work that does not have anything to do with design itself. The time saved by this feature can then be spent on actual design (Khemlani, 2004).

The speed of which projects can be conceptualized is much faster because all of the information is located within a single file, and a designer does not have to sift through many files to find what they need in order to move ahead with design. Also, all of the information is available from one location which produces better communication with the clients and builders. Even information containing specifications can be captured by the model which is important to contractors (Khemlani, 2004).

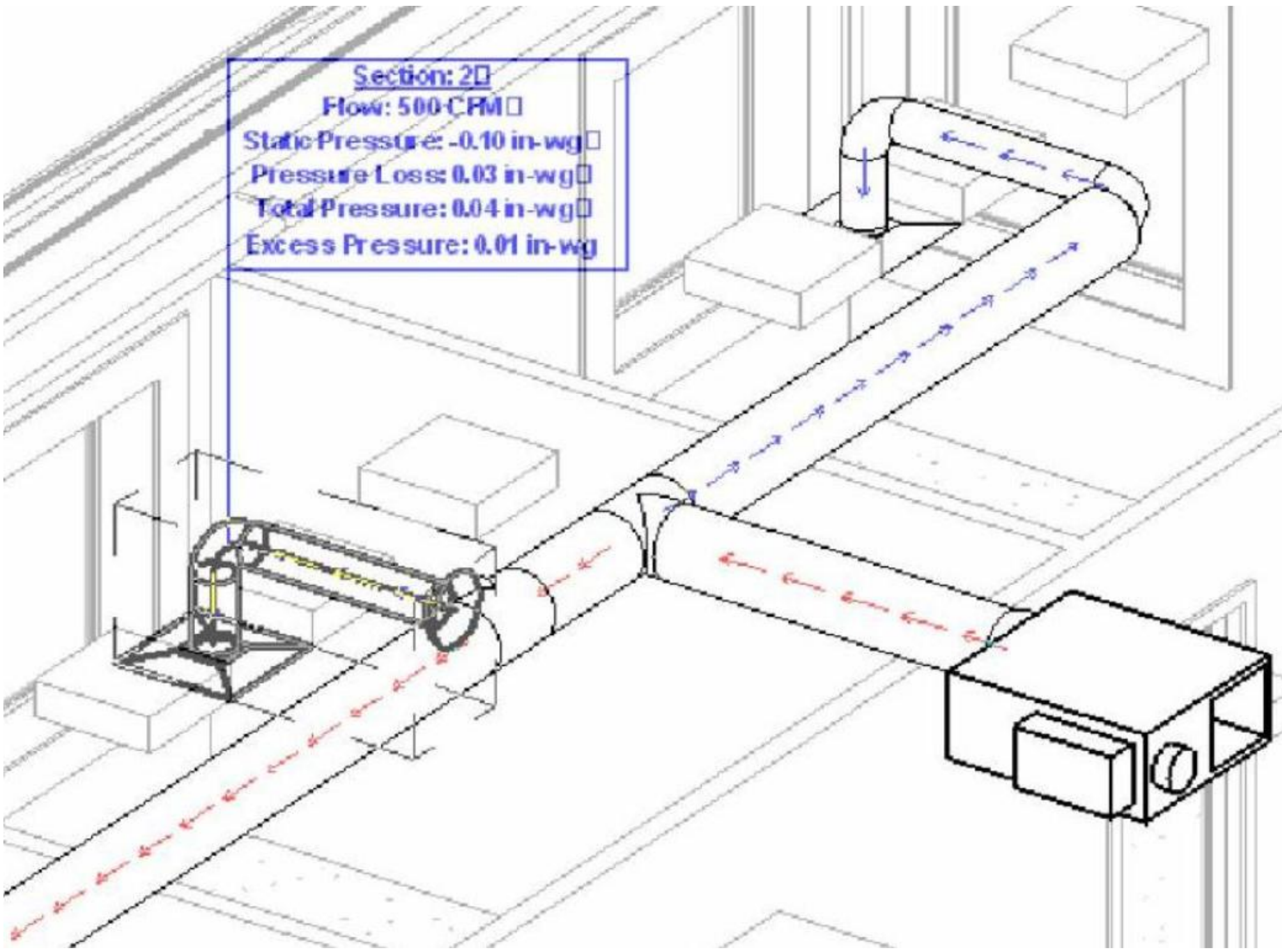
5.1.2 Mechanical/Plumbing Design Benefits

By using the BIM approach with the Revit technology, there are many tools that are provided to aid in the layout of mechanical ductwork and piping, and plumbing systems. Revit allows users to perform the design calculations directly in the model where they can by viewed or printed by anyone in the construction process. These calculations can be anything from sizing duct or pipe mains, branches, or the whole system. Revit integrates industry standards and codes so that they can be crossed referenced, and the system can be instantly sized according to whatever code or standard that is applicable. The design parameters are also able to be updated automatically which eliminates the need of other programs and software that may be used throughout a typical design process such as load software (BIM for MEP, 2007).

Revit can also automatically route duct or piping between any two points. The engineer must select the correct fittings implemented in the design and then Revit will allow them to select, from multiple routing paths, the path that best works for the design. For plumbing, the designer only need input the rise over run for any length of pipe and the software automatically calculates and labels the elevations on the model. This feature will greatly reduce the manual calculations on sloped piping. Also, Revit provides plumbing risers because all the information is integrated which is very useful (BIM for MEP, 2007).

Revit allows color-coding of ducting and piping as a design parameter that provides a better visual representation of the system which in turn gives the engineer a better insight of the design specifications of the system. With this feedback, the engineer is able to identify the areas with the highest pressure loss so they are able to make changes as necessary. Figure 5.1 on the next page demonstrates the immediate feedback of design criteria that is provided to the engineers without additional calculations. The software is also able to detect any clashes between the MEP design and that of structural or architectural design. This reduces costly field work as mentioned earlier (BIM for MEP, 2007).

Figure 5.1: Design information provided by Revit. It includes CFM, static pressure, and pressure loss information (BIM for MEP, 2007).



5.1.3 Electrical Design Benefits

As mentioned earlier, Revit is able to separate architectural, structural, and MEP systems from each other, but it is also able to tell how they interact and effect each other. For mechanical design, the main concern is fitting the system in to the building physically. Electrical design is less concerned with the routing of conduits and wires (it is left up to the contractor), but it is extremely important that all equipment has power. With Revit software, all of the mechanical and electrical equipment is automatically checked to make sure it has power, so that there are no devices that are not assigned to a circuit. This software also makes it easy to calculate the number of circuits needed and the size of the service (BIM for MEP, 2007).

With Revit, the power and lighting will be modeled within the building to ensure that there is enough light and power to each space. Then the light fixtures, power devices, and equipment are connected to a circuit that is connected back to a distribution panel. The user must input the wire type, voltage, distribution system, and demand factor, and then estimated demand loads of the feeders and panels are calculated automatically. Load balancing is also programmed into the software so that the panels will be automatically evenly distributed across buses. Along with the elimination of calculations, schedules are also automatically made and updated at any point in time (BIM for MEP, 2007).

Revit produces many benefits during the stages of implementation, but some of these strengths are out weighed by the challenges that firms also face during the implementation process.

5.2 Challenges Facing Implementation

Implementing Revit requires profound change in the way designers work at almost every level. It requires learning new applications, how to reinvent the work flow, how to staff and assign responsibility, and what to model and what not to. Even with all of the benefits that Revit and BIM offer, sometimes the immediate draw backs are enough to discourage potential users. Therefore, a need for an effective implementation strategy is needed to minimize the challenges that firms are faced with (Khemlani, 2004).

One of the biggest challenges to implementing building information modeling is overcoming the resistance to change. This challenge exists at many levels throughout firms. Many designers are conservative and feel that BIM solutions are only able to model standards and not design specific projects. Many manufacturers do not have blocks, or electronic models, of their equipment that is compatible with Revit, which makes it hard to have custom designs or the flexibility to have a choice of equipment. “Revit is difficult because the equipment is hard to model when there are no blocks for it,” said mechanical designer Brandon Damas of CCRD, a large MEP firm in Dallas, TX that does medical design. Many people feel threatened by Revit’s demand of an overall understanding of the project. Designers cannot cheat or fake their design the way they can in CAD and other two-dimensional representations; however, sometimes it is too difficult to model a design in 3-D because of the limited options. For instance, if a manufacturer does not have their equipment modeled in Revit and a designer wants to use it, the designer will either have to spend time looking up another manufacture’s data or not design using Revit. However, as Revit is used more and more, manufactures will supply more models of their equipment making it easier for designers to specify what they want to use (Khemlani, 2004).

Because building information modeling is a new approach to the design process, a new workflow pattern has to be established within the firm. The makeup of the project team must be re-evaluated to make sure that the most effective approach is being used. For example, a project is generally divided by drawing type, but when the drawings are automatically generated, and then the question is brought up of how to divide a project to ensure the best use of Revit. To effectively use Revit, people feel that it requires too much communication and collaboration than other approaches. They are concerned that with too many people working on a single model at the same time, there will be so many changes that people will not be able to tell what is going on. This is a legitimate concern, and needs to be addressed by any company thinking of using Revit so that they can establish their own process (Khemlani, 2004).

Perhaps one of the most important challenges to immediate implementation is to train people to use Revit. It is rare to find employees that know Revit well; therefore, actual application of the technology can take some time based on how quickly designers can learn the program. Some people will understand immediately, but many do not. Even though the technology is easy to apply and use, the learning curve is still quite steep especially to older non -technology savvy users (Khemlani, 2004).

Another down side to implementing Revit is the initial loss of productivity that often happens due to the learning curve. Many MEP firms are still required to meet strict deadlines even amidst trying to implement a new technology. Through the early stages of implementation, firms find it difficult to guarantee reliable output for projects that are very complex and projects that have short deadlines. Many times firms do not want to take the chance of the possibility of losing profits and decide not to risk implementation until there is a better, more secure strategy (Khemlani, 2004).

Lastly, there is the huge initial investment that Revit and building information modeling require. This large initial investment is mainly due to the high-end hardware resources that are needed to effectively run Revit. Many times firms must replace all of their computers when implementing Revit because it requires such huge amounts of computer power. Integrated with the amount of computer power needed, many users are finding that the software will shut-down after a period of time which makes it easier to lose work. Mechanical designer Ben Weigand of TME, a large MEP consulting firm based out of Little Rock, Arkansas, says, “It’s not if you can do it in Revit; it’s if you can do it before Revit shuts down and you lose your work.” Not only is there the initial cost of replacing much of the existing hardware, but the software itself is extremely expensive because it is so new. The added risk of an initial loss of productivity for a short amount of time also decreases the desire of many firms to start the implementation process (Khemlani, 2004).

5.3 Implementation Summary

MEP firms must acknowledge both the challenges and strengths that Building Information Modeling presents. Each firm must decide for themselves if it is worth the risk. Most firms that have implemented Revit are satisfied with their decision, but that depends on each individual practice. Right now the rest of the building industry is not requiring MEP firms to use Revit. As more and more owners and architects start requiring the utilization of the technology, then that is when there will be even more of a surge toward Building Information Modeling and technologies such as Revit.

CHAPTER 6 - Conclusion

Building Information Modeling is beginning to be heard of more and more within the construction industry. There are few people within the industry who have not at least heard of BIM. There is agreement by most that BIM is the direction that the building industry is going with primarily the use of Revit, but how long will it take to get there? Many architects have already begun to use Revit because of the numerous benefits it offers them. However, the MEP version of Revit is not nearly as advanced as the architecture version. This means that the benefits are not realized to the same degree for MEP design engineers. Currently Autodesk has complete control over the development of the software, and until there is another company that makes the market more competitive the advancement of the Revit for MEP will continue to be determined solely Autodesk. After carefully examining the pros and cons of the technology of today, it is not as advanced as it needs to be for most MEP firms throughout the nation to convert from their current design tools. It is far too difficult for designers to effectively and efficiently produce the same quality of work that they are able to do now with CAD and MEP Autodesk.

As newer versions of MEP Revit are developed, the software will become more user-friendly and will be able to be better used by design firms. Also, as owners and architects use Revit more and more, MEP firms will be required to use it if they want to get the work. It is suggested that MEP firms start familiarizing themselves with Revit now, because in the future it will be an easier adjustment. As for completely converting to only using Revit, it would be a very difficult path as the industry and technology is today.

As mentioned earlier, many firms are resistant to change. It is not that they cannot learn the new technology; it is that they do not want to take the time to learn it. However, most MEP firms do realize the growing market that Revit is providing. Many firms are looking to get at least one (depending on how big the firm is) engineer or designer to master BIM and the Revit technology. The hope is that once one person understands Revit in and out, they will be able to teach it to the rest of the company. This provides an opportunity for recent engineering graduates to become valuable assets to companies if they already have experience with Revit. Colleges that offer architectural engineering degrees may also want to consider offering courses in BIM to keep companies recruiting their graduates. For any young person pursuing a career as an MEP engineer, BIM and Revit is strongly encouraged. Although it may not seem important now, it may be of great advantage in the future.

Abbreviations:

BIM: Building Information Modeling

CAD: Computer aided drafting

EREN: Energy

LEED: Leadership

MEP: Mechanical, Electrical, and Plumbing

USGBC: United States Green Building Council

Glossary:

Autodesk: Autodesk is a software and services company for the manufacturing, infrastructure, building, media and entertainment, and wireless data services fields.

Building Information Modeling (BIM): Building Information Modeling is a an approach that enables a set of information to be generated and maintained throughout the lifecycle of a building. BIM is the process of generating and managing a building information model.

Design Build: Design Build is a construction project delivery system where, in contrast to traditional design-bid-build, the design and construction aspects are contracted with a single entity known as the design-builder. The design-builder is usually the general contractor, but in many cases it is also the design professional (architect or engineer). This system is used to minimize the project risk for an owner and to reduce the delivery schedule by overlapping the design phase and construction phase of a project.

Performance Based Design: Performance-based engineering implies design, evaluation and construction of engineered facilities that meet, as economically as possible, the uncertain future demands that both owner-users and nature will put upon them. The premise is that performance levels and objectives can be quantified, that performance can be predicted analytically, and that the cost of improved performance can be evaluated.

Revit: Revit is architectural BIM software for Microsoft Windows, currently developed by Autodesk, which allows the user to design with parametric modeling and drafting elements. BIM is a new Computer Aided Design (CAD) paradigm that allows for intelligent, 3D and parametric object-based design.

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Appendix A - Survey Results

These are the questions asked to 11 MEP firms for a survey about BIM:

1. Do you currently have a MEP version of Revit?
2. Do you currently do projects utilizing Revit today?
3. Do you have an implementation process in place now?
4. Do you think that Revit is the direction the industry is going?
5. Do you like Revit?

Attached is the table of the results of the survey. All '1' answers mean the answer to the question was yes. All '0' answers mean the answer to the question was no. A small company consists of (1-20) employees, a medium company consists of (21-75) employees, and a large company consists of (76 or more) employees.

Table A.1: Result of Building Information Survey from MEP Engineering Firms.

Company				Answers to Question				
Mark:	Location:	Work:	Size:	Q1	Q2	Q3	Q4	Q5
1	Tulsa, OK	MEP	small	1	0	1	1	1
2	Wichita, KS	MEP & Structural	large	1	0	0	1	0
3	Dallas, TX	MEP	medium	1	0	1	1	1
4	Addison, TX	MEP	medium	1	1	1	1	0
5	Springfield, MO	MEP	small	0	0	0	1	0
6	Little Rock, AK	MEP & Structural	large	1	1	1	1	1
7	Golden, CO	MEP	meduim	1	0	0	1	0
8	Denver, CO	MEP	large	1	0	1	1	0
9	Houston, TX	MEP	large	1	0	1	1	0
10	Dallas, TX	MEP	large	1	1	1	1	1
11	Frisco, TX	MEP	small	0	0	0	1	0
			TOTAL:	9	3	7	11	4
				11	11	11	11	11
			Percent 'Yes':	82%	27%	64%	100%	36%