Case Studies of BIM Practices within Mechanical Contractors

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ABSTRACT

Mechanical contractors play a vital role during construction of a building project, which could significantly affect the overall project success. Traditional 2D paper based solutions for design and fabrication of Mechanical, Electrical, and Plumbing (MEP) components has proven to be an inefficient and fractured method to communicate the project design. Moreover, if a problem rises during construction such as clashes between MEP systems and structural components, the problem often has to be solved on site which is not cost efficient as it often requires rework. Therefore, most mechanical contractors today are switching from traditional paper based workflows to adopting Building Information Modeling (BIM) processes into their practices. One of the greatest benefits of BIM is that it facilitates exploring clashes and coordination issues within a virtual environment instead of in the field, and consequently reduces requests for information and change orders along with the associated health and safety risks. This paper presents a case study based on content analysis results of the interviews conducted with two leading Midwest mechanical contractor companies. It explores current BIM applications such as clash detection and fabrication, benefits as well as challenges of implementing BIM within both companies. The first major finding of this research is that BIM standards and manuals are helpful tools for the development and implementation of BIM models. It is also found that contractors need to make adjustments to their workflows to achieve better results with their BIM implementations. Finally, there is a need to investigate how to use BIM models for facility management in an effective manner, and possibly fuse them with building automation systems.
INTRODUCTION

According to the BIM handbook, Building Information Modeling (BIM) is defined as: “(1) a more integrated design and construction process that results in better quality buildings at lower cost and reduced project duration, (2) “contains precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realized”, and (3) “accommodates many of the functions needed to model the life cycle of a building, providing the basis for new design and construction capabilities and changes in the roles and relationships among a project team” (Eastman et al. 2008). Overall, the model helps visualize the geometry, geographic information, and spatial relationship, and demonstrates the properties and quantities of building elements (Bazjanac 2006).

Mechanical contractors play an important role during construction of a building project, which could significantly affect the overall project success. This is particularly true today, since the building systems are becoming more complex, and the demand for green buildings is increasing which requires more effort in mechanical construction (Boktor et al. 2013). Mechanical contractors are the top BIM adopters among the construction industry (Jones et al. 2008). However, limited research was conducted specifically for studying the BIM practices by mechanical contractors.

Thus, the purpose of this study is to understand the current application of BIM as well as its benefits and challenges through literature review and face-to-face interviews with two Midwestern leading mechanical companies. The selected participants of this study included BIM champions/coordinators, project managers, sheet metal managers, piping managers, and BIM modelers from both companies in order to get full perspectives from professionals who are actively involved in daily BIM practices but taking different roles.

LITERATURE REVIEW

The top five BIM software used by mechanical contractors are: Autodesk® Revit MEP, Autodesk® AutoCAD MEP, Autodesk® Navisworks, Autodesk® CADduct, and CAD-PIPE (Boktor et al. 2013). BIM is implemented at different levels of detail (LoD) for each project phase. According to the existing level of detail systems for BIM, such as the ones developed by the American Institute of Architects and Autodesk, there are LoDs 100-500: conceptual, approximate geometry, precise geometry, fabrication and as-built. MEP models are created at LoD 400 level, construction documentation at fabrication level of detail.

Benefits of BIM Implementation for Mechanical Contractors

A study conducted by Hanna et al. (2013) analyzed the interview results conducted with mechanical contractors in North America in order to get an understanding of BIM practices in mechanical and electrical construction industries. Findings of their study showed that mechanical contractors believe that the most evident benefits of implementing BIM include effective clash detection and better visualization. Additionally, field conflicts and system deficiencies could be greatly reduced. Cost savings could be also seen from the reduced amount of rework and less expensive as-built drawings (Hanna et al. 2013). According to the study by
Stanford University's Center for Integrated Facility Engineering, BIM reduces up to 40% of change out of the budget and reduce up to 80% of time required to perform a cost estimate. CRC Construction Innovation (2007) reported that there is a 3% increase in the accuracy of a cost estimate produced using BIM compared to traditional way of estimating. Finally, the study conducted by Khanzode et al. (2008) reported 5-25% field productivity increase observed by the mechanical contractor as a result of implementing BIM tools on a large scale healthcare project.

Risks Associated With Using BIM

Boktor et al. (2013) study reported that the largest risk for mechanical contractors is that there is no BIM contractual guide which specifies “file sharing, model ownership, model file formats, personnel leading specific trade models, scheduled model submission for review, and responsibility of model changes on a specific project basis”. The second largest risk according to the study is that majority of project team members do not have sufficient skills to use BIM software. There is also the risk of going over budget when implementing BIM since it requires extra investment in hardware, software and personnel training. Azhar (2011) looked at risks of implementing BIM related to both legal and technical aspects of a project which include: undefined ownership of the BIM data, difficulties in determining responsibilities for accuracies of the model, and possible difficulties in integrating the scheduling and cost data into the model. This case study was conducted to build on the previous studies and to further explore the state of BIM implementation by mechanical contractors.

CASE STUDIES

Research Methodology

Case study approach was adopted for this study in order to better understand current BIM practices by two Midwestern leading mechanical contractors. The major data source was interviews. Both within-case analysis and cross-case analysis were performed after collecting the interview data. Participants of the interviews included BIM champions/coordinators, project managers, sheet metal managers, piping managers, and BIM modelers from Baker Group and The Hill Group. Baker Group has been implementing BIM technology for all their jobs and manufacturing processes for more than 15 years. The Hill Group started implementing BIM technology with clash detection and fabrication about 13 years ago. The approval was obtained from each company and confidentiality issues were properly addressed. Face-to-face interviews were conducted either with individuals such as a project manager or with groups such as BIM modelers. As it is suggested in (Taylor et al. 2011), semi-structured questionnaires were developed and sent out to the participants a few weeks before the formal interviews. Coding analysis was conducted for data collected from interviews with each company and the results were compared and summarized in one table. After data analysis is done, the results were sent back to participants for member check and also reviewed by other research professionals at Iowa State University.
BIM Implementation in Baker Group

The Level of BIM Technology Adoption

Baker Group uses BIM term rather than VDC when referring to 3D parametric intelligent models and modeling process. The company does not create 4D models (3D models tied directly to project schedule) for their projects, however they calculate man hours directly from 3D BIM models, and use it to create project schedules. Moreover, 3D models help them visualize work sequences. With the advantage of 5D (cost estimating) component built into Autodesk® CADduct software, base-bid summary can be generated for the selected objects in a model (Figure 1). Adopting BIM technology was driven primarily to increase overall production as it allows creating 3D design models at fabrication level of detail and to use these models directly in CNC machines (Figure 2) for production.

![Figure 1. Base bid summary from 3D model](image)

Baker Group has its own electronic template as a start point, and the collision checks would be performed continuously in Autodesk® Navisworks® as they create the models. As software is constantly changing, the company sends their CAD detailers who are responsible for creating models for out-of-house training as the need arises. Moreover, the detailers can get help with the software from in-house key individuals if they need to. Those key individuals regularly attend online seminar and training programs to stay current with the products.

Ownership and Sharing of the Model

For some jobs, Baker Group is the keeper/manager of the model, but majority of the time they supply sheet metal & piping CAD files to project BIM manager. More often, General Contractor or Construction Manager (GC/CM) manages BIM modeling/implementation process. Completed BIM model is usually owned by other parties that the company is working with/for, and BIM model would be shared with all parties involved. If a project requires a format they cannot support (e.g. Revit), extra time and money needs to be spent to redraw the model. It should be noted here
that CADduct (.dwg) files can be used directly in project collaboration tools such as Autodesk® Navisworks® and Tekla® BIMsight. The company uses FTP site and other sharing platforms such as box.com for file transfer. It is always important to have a thoughtfully developed file storage and retrieval protocol developed at the beginning of a project, but too often this is not done in reality.

In terms of budget for BIM, they spend around $30K ($15K software + $15K hardware), plus training cost which is around $20K to $40K per person.

**Benefits and Challenges of Using BIM**

Collision checking is one of the major benefits of BIM, which makes it possible to detect potential problems on a project and prevent future rework. For the Baker Group, BIM implementation reduces approximately 20% of rework and saves 5 to 10% of cost on mechanical rework. BIM models also help users visualize and decide which trades should install their parts first to increase productivity. BIM models also make it easier for mechanical contractors to claim “no fly zones”, which is intended to leave the maintenance space for the owner during the facility management phase, for mechanical components. 3D BIM models improve project visualization, and therefore “no fly zones” can easily be visualized in a project model and communicated with other project participants. BIM implementation also helps increasing fabrication productivity since it makes it possible to design mechanical components at fabrication level of detail. Figure 2 shows the equipment guided by BIM model is in operation for ducts manufacturing.

![Figure 2. Equipment for ductwork manufacturing](image)

One of the biggest challenges regarding BIM implementation used to be persuading other trades to share their model files. Currently, however, this is not an issue. Another challenge the Baker group encountered during BIM implementation was to work with other trades that did not model in 3D. There were cases where Baker Group employees had to teach sprinkler suppliers and trade contractors to model their components at the beginning of a project. For some companies, this is still true. Some trades are lagging behind in adopting BIM technology into their processes which makes project collaboration difficult. With regard to project delivery
systems, design-build methods facilitate BIM implementation since they allow the contractor to collaborate with the designer early during the design phase. There were several projects where The Baker Group was brought in during the design phase, and in some cases they had to raise ceilings or to make other design changes which solved numerous problems that would have resulted in change orders and redesign without early involvement.

**Future Plan and Potential Improvement Areas for BIM**

Baker Group plans to extend their BIM implementation by using the latest technology available in order to stay competitive in the business. Based on their past experiences, the following areas could be improved in the future:

- The BIM process should start sooner rather than waiting until the construction begins.
- Mechanical contractor should work closely with others during the design phase to ensure that sufficient space is available for mechanical components.
- It would be beneficial to use BIM models for facility management. For example, the maintenance schedule could be tied into the BIM model to remind the facility manager to perform a required maintenance or replacement.

**BIM Implementation for the Hill Group**

**The Level of BIM Technology Adoption**

The Hill Group employees use both the BIM and VDC as their terminology when referring to 3D parametric intelligent models. In the past they have used BIM, and recently they started using VDC as well. In fact, they changed the name of their BIM integration group to Virtual Construction and Coordination (VCC). Same as The Baker Group, they do not create 4D models, however they do calculate man hours and develop cost estimates from 3D BIM models. They mainly use Autodesk Fabrication MEP software.

The Hill Group started implementing BIM technology with clash detection and fabrication about 13 years ago. Today they use BIM for almost all of their projects except very small ones such as projects under $10K. Additionally, they use 3D laser scanning technology in order to obtain existing MEP conditions. 3D point clouds obtained with laser scanning technology are then used to create 3D BIM models.

The Hill Group has a full manual / process book and BIM implementation plan. The BIM standards that were created cover everything that is needed (from clash detection to fabrication). For example, it is easy to understand how to build a pipe spool from the model by looking at the manual. The manual would be updated to accommodate any changes in the upgraded software. The company typically provides in-house training on the software for their employees. Furthermore, modelers who all use the same software, gather on a monthly basis to discuss any questions or problems they have encountered when using the software. Additionally, they take advantage of Mechanical Contractor Association of America’s (MCAA) online BIM training programs. MCAA plays an important role on BIM
implementation by mechanical contractors, by offering various online BIM training programs.

Ownership and Sharing of the Model

The Hill Group has 40-60 CAD detailers, 50-55 modelers, and 3 CAM operators. Usually, the completed BIM model is owned by the parties that the mechanical contractor is working with/for, and it is shared with all parties involved in a project. Most of the companies that The Hill Group works with are using Autodesk products, so the model files are usually exported into .dwg format to be shared with other companies and trade contractors. They keep an active working BIM model which is shared through the Autodesk® Buzzsaw®, FTP site, SharePoint, or their internal servers. Furthermore, Hill Mechanical provides office space for other trades during the project period, so that communication between the various trades can happen almost instantly on a face-to-face basis.

In terms of budget for BIM, they spend around $15K per seat for the software with $90K maintenance cost per application, and around $20K to $30K for hardware per year.

Benefits and Challenges of Using BIM

BIM technology has helped The Hill Group by increasing the productivity and safety on their projects—these improvements mostly occur because the time spent in the field is decreased. BIM models also help project participants better visualize whether MEP components would fit into a certain space and how to install them. Hill personnel claim that it is possible to achieve up to 40% savings on a project by implementing BIM. In addition, fabrication becomes more productive and accurate since it is done in a more controlled environment (prefabricating in the shop rather than fabricating in the field), directly from BIM models.

![Figure 3. BIM model for building piping system](image)

Until recently, it was a challenge to persuade general contractors and other trade contractors to implement BIM. One of the biggest challenges today is related to software updates; these occur with relative frequency in the BIM world. However, some people and organizations are reluctant to invest the time and funding required for making the updates. When project participants are working with various versions
of the same software application, the seamlessness of data transfer for BIM models may be compromised. This may lead to obvious challenges as project participants attempt to closely collaborate. The Hill Group employees claim that design-build and integrated project delivery (IPD) are the best type of project delivery methods to use when implementing BIM, since mechanical contractors can be involved early in the design phase to ensure the constructability of the design model.

Future Plan and Potential Improvement Areas for BIM

The Hill Group plans to continue to implement BIM as part of all of their projects, and they indicated that the following areas could possibly be improved in the future:

- BIM models should be built by well trained professionals.
- Software vendors should allow import/export files from/to various BIM software applications.
- BIM utilization for facility management should be investigated more in the future; currently it remains only a concept.

Summary Results from Case Studies

The major results for two case studies conducted in this research are summarized in Table 1.

<p>| Table 1. BIM Implementation Summary from Baker Group and the Hill Group |
|-----------------------------|---------------------|--------------------------|
| <strong>General term</strong> | <strong>Baker Group</strong> | <strong>The Hill Group</strong> |
| Project size | all sizes | projects &gt; $10,000 budget |
| Standards/guidelines | customized electronic template | own full manual / process book and BIM implementation plan to follow |
| BIM training | yes, in-house, out of house, &amp; online seminars | yes, mostly in-house, and online training if needed |
| Ownership | Other parties that Baker Group worked with | Other parties that The Hill Group worked with |
| Data sharing | Box or an FTP site | Autodesk® Buzzsaw®, FTP site, SharePoint, or their internal servers |
| Model transfer | any formats can support | usually .dwg format |
| BIM budget | software $15,000, hardware $15,000, training $20,000-$40,000 per person | software $15,000, software maintenance $ 90,000 per year, hardware maintenance $ 20,000-30,000 per year |
| Benefits | collision check | more business |
|  | reduced rework | reduced field time, increased safety |</p>
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<tr>
<th>Challenges</th>
<th>Baker Group</th>
<th>The Hill Group</th>
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<tr>
<td>increased productivity</td>
<td>more productive fabrication</td>
<td></td>
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<tr>
<td>maintenance space recognition</td>
<td>better visualization</td>
<td></td>
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<tr>
<td>reduction of 20% rework, and 5-10% of cost on rework</td>
<td>roughly 40% cost savings</td>
<td></td>
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<tr>
<td>incomplete info</td>
<td>people's refusal to changes</td>
<td></td>
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<tr>
<td>lack of modeling skills for other trade contractors</td>
<td>It was a challenge to persuade other trade contractors to use BIM (mostly an old problem, now less problematic)</td>
<td></td>
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<tr>
<td>no single software for all project participants</td>
<td>retrofitting to old/existing buildings</td>
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<tr>
<th>Delivery method</th>
<th>design-build works better</th>
<th>design-build or integrated project delivery (IPD) better</th>
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<tr>
<td>start the process sooner</td>
<td>use qualified personnel</td>
<td></td>
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<tr>
<td>mechanical team works w/ architect in the design</td>
<td>allow files to import/export to various BIM software applications</td>
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<tr>
<td>tie the model to facility management</td>
<td>investigate the use of models for facility management</td>
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<th>Future improvements</th>
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**CONCLUSIONS**

This paper presented a case study based on content analysis results of interviews conducted with two leading Midwestern mechanical contractor companies. The results of this study confirmed the results obtained from the literature review and explored further on actual experiences of implementing BIM by these two mechanical companies. Examining the BIM implementation practices within these two companies shows that a good practice of BIM implementation involves creating full company standards or manuals for BIM model development and BIM implementation process. Furthermore, it appears that having monthly BIM coordination meetings between BIM modelers and designers increases overall productivity as these meetings create an environment for exchanging experience and knowledge with each other. In terms of the project delivery method, design-build or integrated project delivery (IPD) are believed to be the most efficient for BIM implementation, especially for building construction projects, since mechanical contractors could involve earlier and ensure that there is sufficient space for mechanical components. In terms of future BIM applications, both companies stated, from mechanical contractor’s point of view, that there is a need for BIM implementation for facility management. Because it is important for facility managers to know exact locations and conditions of MEP systems of the facilities they operate. Finally, integrating building automation...
systems into BIM models could be another promising future application as these systems could be set up in order to alert facility managers for required upcoming maintenance ahead of time.

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