Buckhorn Medical Office Building

Senior Thesis

Technical Assignmet III

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Executive Summary

This technical assignment covers the construction challenges, schedule acceleration scenarios, and value engineering topics of the Buckhorn Medical Office Building. It also covers problem identification with possible analysis methods as to how to solve these problems. The Buckhorn Office Building had several constructability challenges. The most critical challenge was the sitework and excavation of unsuitable fill located on the site. This led to delays in the sitework and ultimately delays in the overall schedule. There was also the challenge of erecting steel and pouring concrete during winter months due to the sitework delays. This required a lot of extra work while resulting in less productive crews.

The Buckhorn Medical Office Building's critical path followed the sitework and excavation and then moved through the steel erection. Once the steel was in-place, mechanical trades were able to begin rough in work, but the exterior metal studs and plywood sheathing took the critical path in order to enclose the building. Lastly, the interior finishes moved through the building. Although the metal panels were not on the critical path, they were the last scheduled item to be completed. The easiest schedule acceleration methods that were used were to increase manpower during the steel erection process as well as use some overtime/weekend hours for some of the MEP subcontractors.

Value engineering was important to the construction manager as well as the owner. Several value engineering ideas were initially proposed. The Buckhorn Medical Office Building originally proposed a geothermal heat pump system. This was the most economical system over the life cycle of the building; however, it was scrapped because high upfront costs and poor soil subsurface conditions. Recycled rubber composite floor tile was chosen for the main lobby over porcelain tile due to its LEED credit as well as its safety factor. For the exterior enclosure, an EIFS system was proposed to replace the expensive aluminum panels; however, this idea was rejected due to higher maintenance and less durability.

There were several issues in the Buckhorn project that should be identified including: cost estimating strategies, construction phasing and planning, delivery of as-built drawings and O&M manuals, communication and transfer of data, and building façade and exterior enclosure. Each of these issues could be analyzed by various technical methods; many of which revolve around the use of a building information model. The application of BIM should be further studied as part of this project.

Constructability Challenges

There are many aspects of the Buckhorn Medical Office Building that made it a challenging project. One major aspect was that there was a significant amount of fill that had been placed on the site that was unsuitable to build on top of and therefore had to be removed before foundations could be placed. A second challenge was that the schedule called for erecting steel and pouring floor slabs during the winter months. The last challenge was that the aluminum exterior panels fell behind during fabrication resulting in a delay to the overall project schedule.

Unsuitable Site Soil Conditions:

The first geotechnical report was given to Geisinger in January 2008, but only provided a preliminary analysis for the construction of the office building. The geotechnical engineering firm, Geo-Science Engineering Co., Inc., went back to perform a full site investigation in May of 2008. In this second geotechnical report, they found that on the north portion of the site, the fill area suggested +/- 20 feet of fill. In the southern area of the site, there appeared to have been a cut of up to 20 feet to provide some of the soils for the north end fill. In the north end fill, the geotechnical firm found pieces of broken asphalt, poorly graded stone, grasses and other vegetation mixed in with poorly graded silty clay. There was no topsoil layer present and the firm recommended that the fill be removed from the site in order to achieve an acceptable bearing capacity.

Figure 1: The existing site before excavation

To solve this problem, Alexander chose to remove nearly all of the fill located along the northern part of the site and move it off site. They felt that it would be the better decision that having to worry about differential settling after the project due to constructing the building on unsuitable soil. Alexander excavated as much fill as needed until they could achieve proper bearing capacity for the foundations. This involved a significant amount of extra work and resulted in the exceptionally long duration on the schedule for site work. Alexander

Figure 2: Excavation for the foundation of the building

compared the cost of leaving the bad fill in-place and redesigning the foundation system using deep foundations versus removing the fill and using the existing spread footings. They found that not only would a redesign of the foundation impact the critical path of the schedule, but it would also be more expensive and would require more geotechnical studies.

Cold Weather Concrete and Steel Erection:

Due to many delays during the procurement, sitework, and excavation processes, the schedule for construction was pushed back approximately two (2) months. The building was originally proposed to break ground in June 2008 and be ready for occupancy in August of 2008. With the delays however, the sitework did not begin until the end of August 2008. In the original schedule, steel erection was to be completed by the end of October 2008, and the slabs were to be completed by the end of November 2008. During the actual construction however, the steel was not completed until the middle of December 2008, and the slabs were not completed until the middle of January 2009.

According to the American Concrete Institute, cold weather conditions exist when the average daily temperature drops below 40°F (5°C) for more than three (3) successive days. When cold weather conditions exist there are special precautions that can be taken in the placing, finishing, curing, and protecting of concrete. In order for concrete to cure properly, temperature minimums and moisture levels must be managed during the curing cycle to ensure the proper strength characteristics are attained.

In order to deal with the problem of concrete curing at below freezing temperatures, several procedures had to be followed. First, accelerators were added to the concrete so the concrete set properly. Second, the areas being poured were tented and heated during the coldest months of the ear to ensure that the concrete reached its proper strength. Working in cold weather also resulted in less production. Not only did tenting and other preventative cold weather measures take more time, but the mere temperature resulted in less productive workers. In order to maintain the schedule, extra manpower was provided by the concrete subcontractor. Overall, the cold weather placement of the concrete was estimated to increase the price of the bid package by 5%-10%.

The steel erection operations were also affected by cold weather due to high winds and exposure. The technical aspects of steel erecting were not different for cold weather conditions; however, the erectors had to consider the

Figure 3: Steel erection during winter months

expansion and contraction of the steel due to temperature changes that could have affected quality. Several of the steel operations that were affected by weather included welding, laying of metal deck, and high-strength bolting. In very cold weather, the welds had to be preheated to prevent the premature cooling of the deposited metal and steel beams had to have snow and ice removed from the tops before they were covered with decking.

Exterior Aluminum Panels:

The architect for the Buckhorn Medical Office Building proposed a design that clad the entire exterior with various types of aluminum metal panels. The delay first began with the processing of the submittals of the aluminum panels. The owner, Geisinger, took longer than expected to decide on exact color and pattern types, and this caused the panels to not be released until several weeks after the scheduled date. Once the panels were released, the manufacturer of the panels began production; however, they were unable to stay on pace for delivery to keep up with the installation on-site. The original schedule provided 57 days for completion of the exterior metal panels; however, with the delays, the metal panels took 75 days and did not finish until the first week in June 2009.

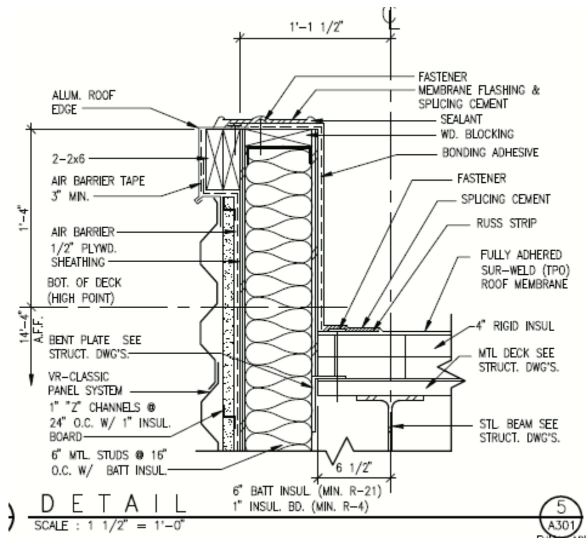

Figure 4: Typ. detail of metal panel installation

The metal panel system was comprised of 6" metal studs placed at 16" on center filled with batt insulation. On top of that was ½" plywood sheathing followed by 1" "Z" channels placed at 24" on center with 1" insulation board. The most exterior layer was the VR-Classic metal panel system. Alexander's biggest challenge was to ensure that the building was water tight through the rainy spring months while the exterior was not completely finished with the metal panels. To prevent water seepage as well as get the building to a point where it could be fully enclosed and heated, Alexander began by sheathing the entire building with the ½" plywood. JLG lifts were used and they worked their way around the building in a clockwise manner. Immediately following the plywood sheathing installation was a crew that covered the sheathing with Tyvek high-density polyethylene fibrous wrap to provide a layer of

Figure 5: Installation of the Tyvek wrap

moisture protection until the exterior system could be completed. Only once the metal panels arrived on-site did the installation crews remove the Tyvek wrap in sections and install the "Z" channels with the 1" insulation board followed by the metal panels. It was important that the Tyvek was only removed for the sections that were being installed in order to keep the building as water tight was possible.

Schedule Acceleration Scenarios

There are many scenarios during the course of construction that cause a project to need to accelerate their schedule. They range from getting through excavation and sitework slowly to having large amounts of change orders. Below is an evaluation of the schedule acceleration scenarios for the Buckhorn Medical Office Building.

Critical Path:
The critical path for the construction of the Buckhorn Medical Office Building was the excavation for the foundation of the building. The extra delay due to removing excessive fill pushed the foundations back and caused the excavation and sitework to become the primary focus. Once the sitework was complete and the foundations were in place, the steel erection followed by the steel decking and concrete placements were on the critical path. While the mechanical trades were able to begin rough-in work, the critical path fell on the exterior metal studs and plywood sheathing in order to get the building water tight and heated in order to begin interior fit-out and finishes. Following the enclosure of the building, the mechanical system drove the critical path working from the third floor down to the first. The finishes were able to keep up with the mechanical contractor and were completed a few days after the mechanical contractor was finished.

Risk to Completion Date:
The biggest risk to completing the schedule as planned was getting out of the ground on schedule. The geotechnical report showed that there was insufficient soil in the northern end of the site and the construction team knew they would have to work around this problem. The original Request For Proposal did not provide a very detailed geotechnical report and because of this, Alexander built in contingency for unforeseen site conditions. Although they were able to adjust for the additional cost of hauling away poor soil and fill, there was a delay to the schedule in the amount of time that was required for excavation.

Another risk to the delay of the completion date was the exterior metal panels. Geisinger's initial plan was to move into the Buckhorn Medical Office Building upon total completion; however, due to the delayed schedule of the metal panels, Geisinger chose to move in once the building passed its final inspection and received its Certificate of Occupancy but did not have the metal panels complete. Alexander was able to complete the building without several of the metal panels in place that were located along the front façade of the building. These panels were then placed once they arrived on-site shortly after the final inspection date. Geisinger felt it was more important to begin using the building without a few panels in place rather than waiting additional time for a few architectural panels.

Areas of Potential Acceleration:

When the sitework and excavation ran longer than the initial schedule, the construction manager had to look into potential areas to accelerate the construction process. Alexander decided to make up some of this time during the steel erection and exterior metal studs erection processes. They made up some of this time by adding additional crews. There were only a few weeks during the metal stud installation where Alexander had to work a few Saturdays. Once the building was enclosed, the mechanical subcontractor started on the third floor and worked down to the first. The rest of the interior trades followed the mechanical subcontractor, but the electrician had to bring in extra labor as well as work some weekends to be able to finish on time. The electrical subcontractor had a lot of rough in work that had to be completed early in the construction process, but they also had a lot of finishing work (install light fixtures, switches, receptacle plates, smoke detectors, etc.) that could only have been completed once other finishing subcontractors moved through the building.

Cost and Techniques:

The costs associated with the delayed schedule with the sitework were not too significant. The additional costs of removing the unsuitable fill from the site were picked up by Geisinger because it was considered an unforeseen site condition. Geisinger was charged for labor of the excavation workers and for the cost to haul away the fill. The additional time that caused the delay impacted Alexander's general conditions estimate; however, because some of the time was made up later in the project, it did not come out to be a substantial charge. No general conditions change orders were made due to overtime. The overtime provided by the steel erection crew and the metal stud crew was submitted as a change order to Geisinger. Because the overtime period was not extended for more than a few weeks, there was no significant decrease in productivity.

Value Engineering Topics

Several areas of value engineering were discussed on this project from the building exterior to the finishes. The main goal of value engineering is to save costs while increasing the overall value of the project. Value engineering does not always mean pursuing cheaper initial costs, but rather lower costs over the life cycle of the building – this includes maintenance, repair, and replacement of products. Because the Buckhorn Office Building is being used by both employees and customers, Geisinger felt that they did not want to compromise quality; however, they wanted to incorporate sustainable and "green" products where they were cost-effective in order to achieve a LEED certification. Because Geisinger was trying to achieve a LEED certification, many recycled products were considered as well as alternative mechanical systems. For the Buckhorn Medical Office Building the value engineering ideas focused on three major areas: the HVAC system, the floor finishes, and the exterior wall system.

HVAC System:

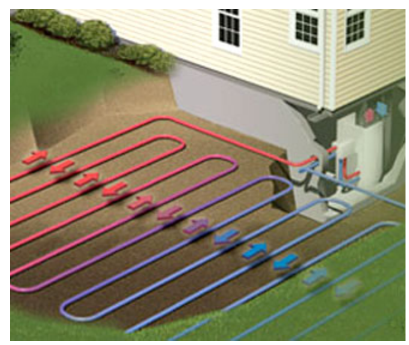

Figure 6: Typical heat pump system. Courtesy of energytechstocks.com

One of the original value engineering ideas was to create a sustainable HVAC system using a geothermal system. This would have had a higher initial cost, but it would have had a lower operating cost and an overall cheaper life cycle cost. This value engineering idea was not implemented due to the geotechnical report and the concern for sinkholes and unstable bedrock at the depths required for the geothermal wells. The geothermal heat pump system had good humidity control, can vary between heating and cooling, had no visible heat rejection equipment, and had the lowest overall estimated life cycle cost. The shorter equipment life, no economizer cycle, and high construction cost created problems. To install a geothermal system, it would have cost approximately $31/SF for a total cost of $2,580,750. Another HVAC system that was considered was a water source heat pump. The system had good humidity control, heated and cooled at the same time, and had the lowest initial cost. The disadvantages of the system were a shorter equipment life cycle and no economizer cycle. The overall initial cost of the system would have been approximately $25.50/SF for a total cost of $2,099,925. The system that was selected for the project was a variable air volume system. The VAV system had good humidity control, an economizer cycle, and simple systems operations; however, there was a cooling tower and boiler that had to be maintained. The VAV system also had the lowest initial cost of $18.71/SF for a total cost of $1,763,522.

Floor Finishes:

One major finish item that was considered during the value engineering process was using a recycled rubber composite tile instead of porcelain. Porcelain tile flooring is extremely hard and is highly resistant to stain, scratch, and moisture. It is also more resistant to harsh cleaning agents and needs no polishing, waxing, or sealing. The disadvantage of porcelain tile is the high initial cost, the difficulty to match for repair, high repair costs and long installation time. The cost of porcelain tile was approximately $22/SF and a total cost of $73,740. On the other hand, the recycled rubber composite tile only cost $1.47/SF and a total cost of $4,927. The rubber composite tile came in several colors including the option of creating custom colors. It was also easy to install and easy to repair. The rubber composite tile also satisfied a portion of a LEED credit for using sustainable/recycled materials on the project. The major setbacks of the rubber tile were that it was less durable, had a higher maintenance cost, and a lifecycle of only about 20 years.

Figure 7: Example of porcelain tile. Courtesy of tilemarblegallery.com

Geisinger chose to go with the recycled rubber composite tile in order to achieve LEED credit and promote a "green" building. Geisinger also chose to use the recycled rubber composite tile on the architect's guidance in order to create custom floor colors to accent the rest of the building. Geisinger found the initial cost savings significant enough to warrant not using a more premium, lower life cycle costing floor system. The rubber composite tile also had a coarser texture to it that reduced slippage when the floor surface became wet. Geisinger felt this would be preferable over placing walk out mats over the porcelain tile during the winter months. Geisinger, being a company concerned with health and safety, did not want people falling in the lobby as they entered the building due to slippery floor surfaces.

Figure 8: Recycled rubber floor tile at Buckhorn.

Exterior Wall System:

Another item that was considered for value engineering of the Buckhorn Medical Office Building was to replace the proposed aluminum metal panel exterior with an exterior insulation finishing system (EIFS). Because the Buckhorn Medical Office Building had a fairly basic exterior skin, the idea of using EIFS instead of aluminum metal paneling was considered. EIFS consists of first placing a layer of foam plastic insulation that comes in sheets of 2' x 4'. Once the foam is applied to the plywood sheathing, a fiberglass reinforcing mesh embedded in a cementitous adhesive is applied onto the face of the insulation with a trowel. Lastly, a topcoat that can be colored and textured is applied with a trowel. EIFS offers many advantages such as its ability to control heat loss through the building envelope; this helps reduce heating and cooling costs. The EIFS system was also much less expensive. EIFS was prices at approximately $6/SF whereas the aluminum metal panels cost approximately $24/SF.

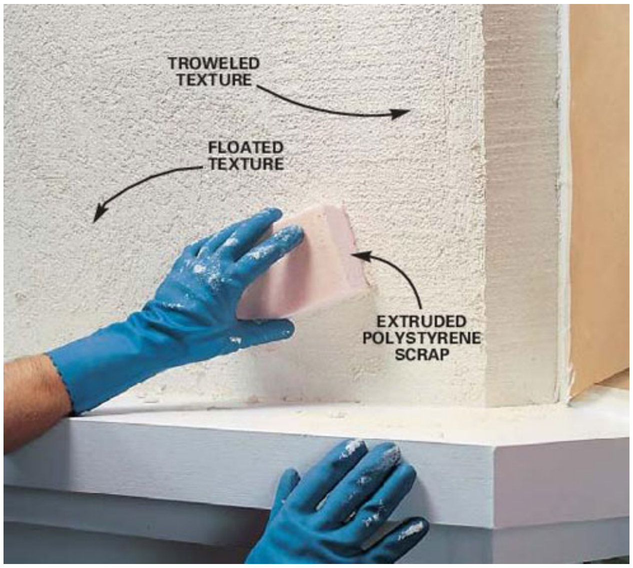

Figure 9: External Insulation Finishing System (EIFS). Courtesy of rd.com

Geisinger, as well as the architect, did not approve the value engineering idea. The architect did not feel that they could not achieve the same aesthetic appeal using EIFS over the aluminum metal panels. Geisinger also did not approve the value engineering idea due to durability and maintenance costs. Aluminum panels are extremely lightweight, yet exceedingly strong. Aluminum panels are also easy to maintain. There is no painting or refinishing of aluminum products required, and the only cleaning generally required is washing with detergent and water. Aluminum is also smooth, dense, and corrosion-resistant which minimizes the adhesion of dirt and overall maintenance. Geisinger found these characteristics very attractive due to harsh conditions of northern Pennsylvania.

Figure 10: Installation of the aluminum panel system

Problem Identification

Cost Estimation for a Construction Management Company:

Alexander Building Construction spent a significant number of resources on the estimation of building projects at various stages of design. Currently, Alexander performs take offs based on paper, two-dimensional drawings provided by the architect. Alexander then uses several Excel spreadsheets to tabulate total quantities and then exports these quantities into Timberline to add cost data. This is an extremely time consuming process and it had to be repeated at each stage of design. Geisinger requested that a Building Information Model (BIM) be created for this project; however, because the model was only created in the middle of construction, it was not able to be used for estimating purposes.

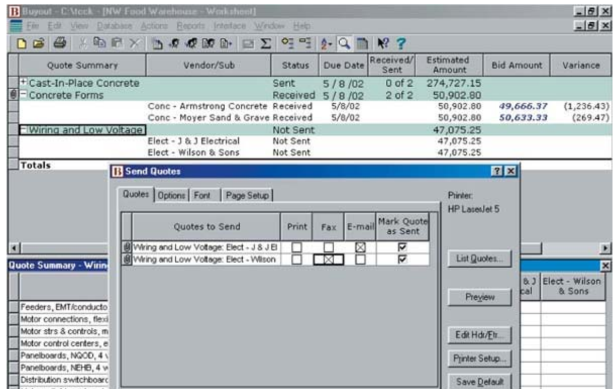

Figure 11: Screenshot of Timberline estimating software. Courtesy of industrydatabase.net

Phase Planning for a Construction Management Company:

One of the most important parts of a construction management project is the phasing of the building. Although this was not an extremely critical for the Buckhorn Medical Office Building due to its simplistic design, phase planning is important in all projects. Phase planning helps break down the schedule into smaller pieces which leads to more accurate duration estimates and in turn, a more accurate schedule. In many situations, it is difficult to portray phasing ideas to people outside of the construction industry using schedules and numbers. Phasing diagrams can be seen in different ways such as using a color coding system or a 4D model. Alexander did not utilize the BIM model for phasing because it was not complete in time to be efficient.

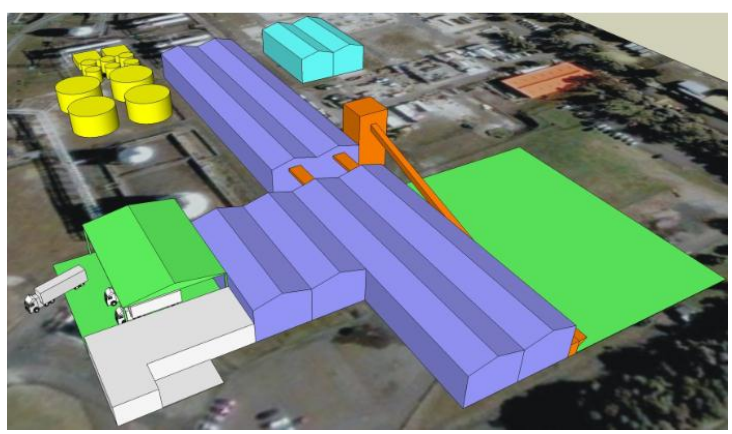

Figure 12: A typical 4D model showing phasing. Courtesy of rni.com

Delivery of As-Built Drawings, Closeout, and Owner Training:

Project close-out and owner training is one of the hardest and most important parts of finishing a project. Closing out a project and turning over a building to an owner is extremely important as a construction manager because it is the last impression left with the owner. Close-out is also a very difficult part of the construction process because it involves a significant amount of owner interaction and cooperation. It is hard to complete owner training because it typically involves coordinating with multiple parties, including subcontractors that may have been off the project for months. Alexander has a basic system for compiling Operation and Maintenance manuals; however, there is currently no good process to catalog and organize O&M data as it is received. With the advent of BIM, there are now a multitude of new questions that arise with regards to how to turn over a model. Not only with Alexander, but with the industry in general, there is no standardization as to how to train owners to use a BIM model for operations and maintenance. There are also no real guidelines as to who is ultimately in charge of turning the model over – whether it is the responsibility of the architect or the construction manager.

Figure 13: Typical O&M manuals to be turned over to the owner. Courtesy of 3rd-dimension.co.uk

Communication and Transfer of Data, Drawings, RFIs, and Submittals:

Many people consider communication to be the single most important aspect to a construction project. Communication breakdowns often occur when people do not have the information that they need to be able to efficiently and successfully complete their jobs. Alexander currently uses various Excel spreadsheets for things such as drawing logs, specification logs, RFI forms and logs, Submittal forms and logs, and O&M logs. This is a very time consuming and counter-productive task for project engineers. Using manually-updated Excel spreadsheets also opens up the possibility for human error in data entry. This process also generates an exorbitant amount of email by sending Excel RFI and Submittal sheets as email attachments. It also doesn't allow communal access to information such as drawing addendums, but instead, relies on one person to make sure everyone is copied on an email with the updates. The communication exchange process needs to be more streamlined to increase efficiency and reduce time erroneously spent on counter-productive activities.

Building Enclosure and Façade Completion:

One of the biggest challenges on the Buckhorn Medical Office Building was completing the exterior skin of the building. Although the activity did not take the critical path until the very end of the project, it was the final item that had to be completed. The main problem that Alexander faced with the aluminum metal panel system was delivery of the product. The vendor argued that the color and panel selections were released later than the scheduled date, and therefore it resulted in a delay in production. Although the metal panel system provided an aesthetically pleasing image, it created delays in the overall project schedule. Alternative building façade systems could have provided an equally pleasing look while still offering the durability and low maintenance of the aluminum panel system.

Technical Analysis Methods:

Cost Estimation for a Construction Management Company:

Autodesk has just released a new software program called Autodesk Quantity Takeoff. This program harnesses the capability of developing accurate quantity takeoffs using a 3D model. This program should be explored for its potential. Alexander has already made the first step into the building information modeling world. Using a BIM model to create quantity takeoffs can often times be considerably more accurate, especially when trying to measure curved surfaces or lengths of piping. This software could be extremely valuable to estimators. The process of developing guidelines for how the model is construction could ensure that quantities can be easily taken using the Autodesk software.

Figure 14: Autodesk Quantity Takeoff. Courtesy of autodesk.com

Phase Planning for a Construction Management Company:

With the advent of building information modeling, there is now potential to create 4D models, where time is the fourth dimension. Complex operations such as steel erection could be evaluated and re-worked to create more efficient crane placements, shakeout areas, and steel picks using tools such as Autodesk Revit and Autodesk Navisworks. On a project-wide scale, 4D modeling could be used to establish general flow of work, short interval production schedules (SIPS), and site layout phases.

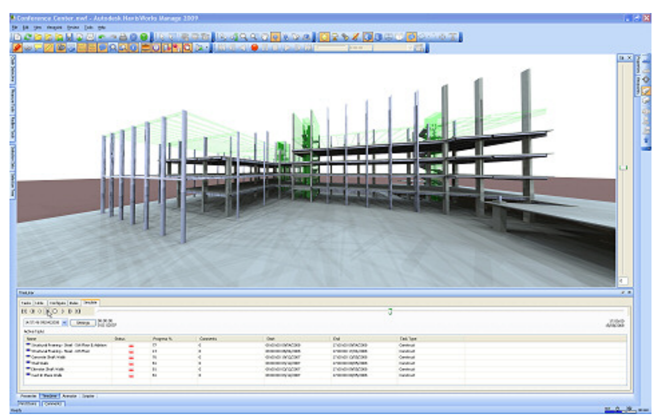

Figure 15: Steel erection sequencing using Autodesk Navisworks. Courtesy of cadalyst.com

Delivery of As-Built Drawings, Closeout, and Owner Training:

The topic of as-built drawings, especially when involving BIM, is currently being investigated across the construction industry. Dr. Messner, along with several of his students, has recently published a *BIM Execution Planning Guide*. This guide may help determine the process and steps to be taken for turning over electronic as-builts, such as a BIM model. The process of establishing a more streamlined approach to collecting and cataloging O&M manuals should also be researched. Currently, there are very few process models of how to integrate information from a building information model into facility management software. An understanding of Geisinger's facility management tools must be done as a first step; furthermore, the programs to replace Geisinger's current facility management tools should be examined.

Communication and Transfer of Data, Drawings, RFIs, and Submittals:

The current process of transfer information between owner, architect, construction manager, and subcontractors is slow and inefficient. New software packages such as Submittal Exchange should be researched to find the benefits of using web-based storage and communally shared information more commonly known as "cloud computing." This new technology could very well unlock new potential in the information exchange process helping people stay up-to-date on drawings, addendums, RFIs, and more. It could also significantly reduce the amount of paper generated during construction projects.

Figure 16: Web-based document management software Submittal Exchange. Courtesy of spinutech.com

Building Enclosure and Façade Completion:

When considering value engineering ideas for the Buckhorn Medical Office Building, the exterior façade system was evaluated. The project team came up with the suggestion of using an Exterior Insulation Finishing System (EIFS); however, the architect said that EIFS was not an aesthetically pleasing substitution, and the owner said that is was durable or easy enough to maintain. There was also the issue with schedule. Although the metal panels were on the critical path until the end of the project, they were the last item to be completed due to manufacturer production delays. Alternative façade systems should be considered such as using a precast concrete panel system. Different systems should be scrutinized through research and contacting vendors. Once an alternate system is selected, its effects on the schedule, manpower, and cost should be inspected. Most likely BIM would be used to perform these inspections.