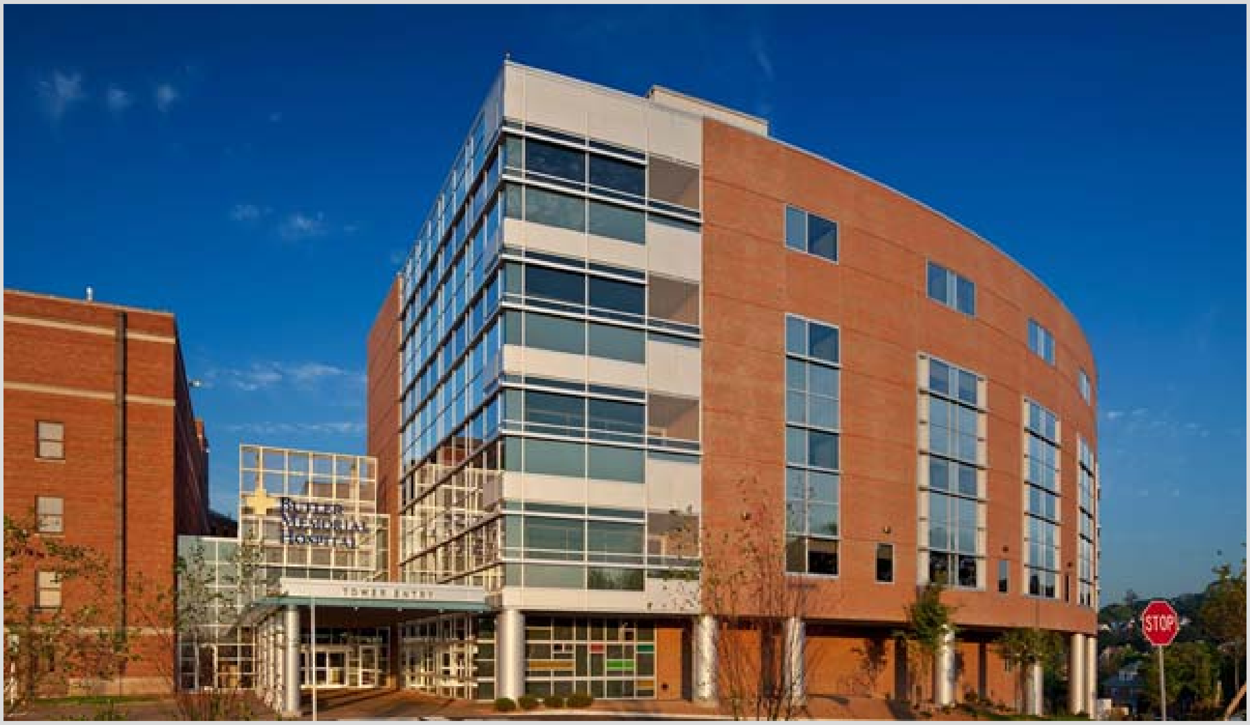
Technical Report 3

November 29th, 2010



Butler Health System

New Inpatient Tower
Addition and Renovation
Butler, PA

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Construction Option

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Penn State AE Senior Thesis

Executive Summary

For Technical Report 3, the New Inpatient Tower at Butler Memorial Hospital was analyzed in terms of several different topics. By speaking with Turner's personnel, there were various aspects of the construction process that were examined and evaluated. These issues involve constructability issues, schedule acceleration scenarios, and value engineering topics. Once these topics were thoroughly evaluated, specific problematic features were analyzed and analysis methods were devised to look into these features.

As with all construction projects, constructability issues existed on several different levels. This report includes three main challenges that were addressed during the project. One issue involves the placement of two air handling units, which were located in a position that was difficult to access without developing a new technique for construction. Another challenge involved the coordination between the designers and the engineers for the project. Because of problems with coordination, owner furnished equipment presented a problem to the project team. The last constructability issue included in this report involves the safety precautions that are necessary for a hospital project. In order to properly combat safety risks, the project team produced a specific safety plan based on ICRA requirements.

As with all projects, schedule is a driving factor from planning through construction. The project team for this project put together a specific plan in order to ensure that the project met the strict deadlines. This plan included critical path analysis, fast-tracked design releases, planning for inspections from the Department of Health, and implementation of 3D Coordination to minimize schedule impacts in the field.

Throughout the project, the team continually looked into techniques to value engineer the building. This report includes some of the key value engineering ideas that were accepted, as well as those that were rejected by the owner. The decision to accept or reject these ideas was based off of the owner's needs in terms of cost, schedule, or quality.

The report concludes with observations of problematic features for this project, or places to improve. These observations include technology implementation, sustainability, the use of prefabricated systems, and safety. Because these ideas were seen as aspects that could be improved, technical analysis methods were discussed for each observation. This final section includes information on how the analyses will be performed. These analyses will eventually be used as a basis for assembling a proposal for this thesis project.

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Constructability Challenges

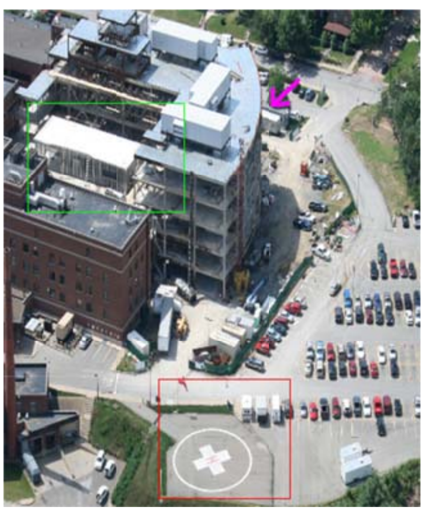
Air Handling Units Installation

A main constructability issue for the new Inpatient Tower at Butler Memorial Hospital involved the setting of two of the air handling units. Two of the eight air handling units are located on the fifth floor roof. These two units, AHU-4 and AHU-5, serve the Operating Rooms, which are located on the third floor. While the other six units were installed without difficulty, due to their accessible location, AHU-4 and AHU-5 were located in a difficult position.

These two units, located on the fifth floor roof, were difficult to access after the structure of the building was already completed. With the structural system already in place, the on-site crane did not have the capacity to perform such a pick. This is an issue that was not realized early on in construction, and was not addressed until later in the project. With the erected steel interfering with the pick, a new method had to be devised.

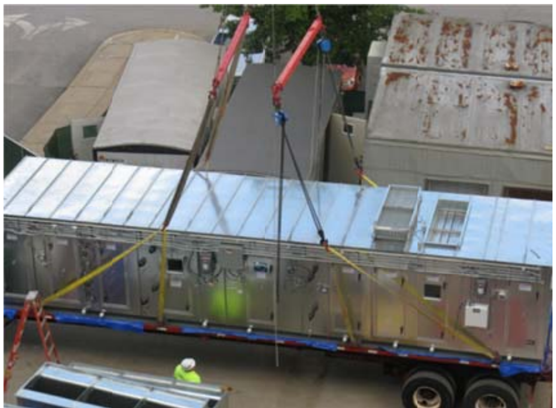
To actually make the pick, Turner proposed the idea of bringing in a new crane. A 450-ton crane would be needed to move the air handling units to their proper position. This would be an expensive operation, and would last approximately three days. This duration included the building of the crane, the pick, and the disassembly. This also presented another problem because the pick would need to be made near the existing helipad. This area was also used for hospital parking, and would not be plausible to shut down for the setting of these units. Also, because the helipad was in use throughout the construction process, this would produce even more difficulties.

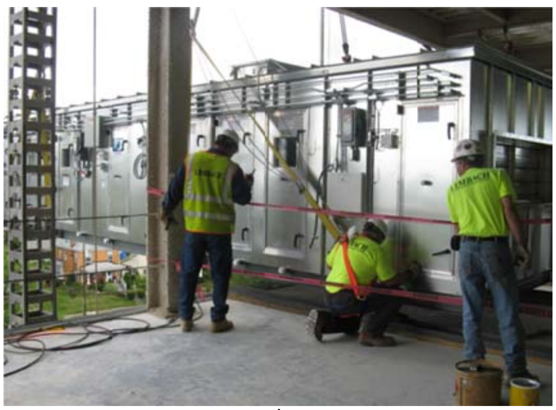
In order to negate some of these potential problems, Turner created a different plan to set the air handling units. A decision was made for the mechanical contractor to use a smaller crane and hoist the units up to the proper level, on the west side of the building, which is the opposite side of the desired location of the units. Once the units were hoisted to the fifth floor, they were set onto tracks and a spider crane would be utilized to move the units from one side of the floor to the other. This was possible because minimal interference actually existed on the newly constructed floors. The following picture depicts the constructability issue.

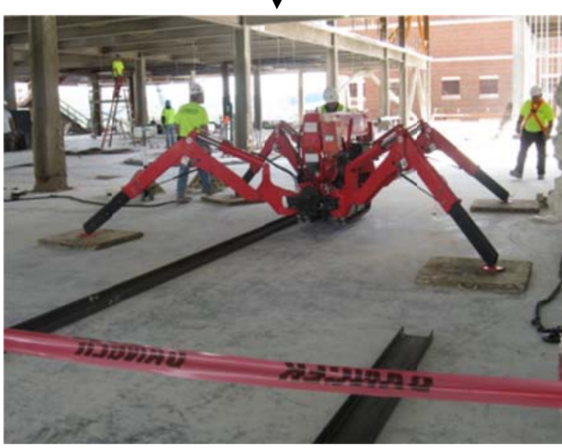


GREEN: Location of Air Handling Units 4 & 5
RED: Original planned location of crane
MAGENTA: Placement location of units (West)

This decision was clearly not a conventional method to deliver the units to the appropriate position. The following images represent the sequence of installation of the units:


AHU Being Hoisted


AHU set onto 5th floor

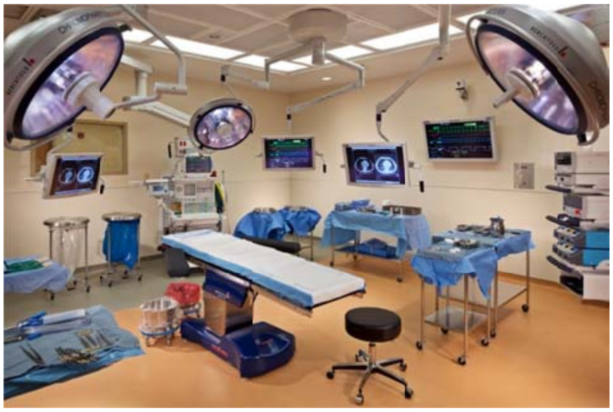

Spider crane set to move Unit

Owner Furnished Equipment

For the New Inpatient Tower at Butler Memorial Hospital, owner furnished equipment is a critical construction issue. Because of the intricacies of hospital operations, the medical equipment is clearly imperative. The owner furnished equipment includes all of the medical equipment in each room. This would include items such as the medical gas columns, medical booms, and any other type of medical equipment. This equipment is included in the patient rooms, operating rooms, peri-op rooms, among others.

For this project, the owner furnished equipment presented some major problems. In most situations, it would be beneficial for the architect to coordinate the equipment with the design and the engineers. For this project though, all of the engineers were employed under the hospital and not under the architect. Because of this, the engineers coordinated their designs for the equipment separately. Also, the vendors of each type of medical equipment coordinated the layout of their equipment separately. Due to the large number of parties involved with the owner furnished equipment, and a project structure minimizing coordination, this led to constructability and design difficulties.

The constructability issue related to owner furnished equipment can be made apparent by looking into the medical booms, which are installed in the operating rooms and several of the patient rooms. The design of the medical booms at Butler Memorial Hospital is now being seen as a state-of-the-art feature. This is due to the fact that these booms are completely mounted from the ceiling. In the operating rooms, this is particularly evident because there is no need for mobile medical equipment. Everything that the doctor would need is easily accessible at all times. The below picture shows the ceiling mounted medical booms in the operating rooms.



Ceiling Mounted Medical Booms

With this high-tech design, it is clear that the vendors must coordinate this equipment with the architect and structural designer. With the large amount of equipment being mounted from the ceiling, a need for more structural steel became evident later in the project than desired. Because this was not realized at the time of design, the steel design was updated and changed during the construction process.

Once this problem was realized, Turner determined that it was an issue that needed to be proactively addressed. To coordinate the effort to re-design the owner furnished equipment issues, one of the project engineers took charge. As the equipment was released and shipped to the jobsite, weekly meetings were held with Turner, the architect, hospital representatives, and purchasing agents. The re-design of the owner furnished equipment was only possible due to the hands-on approach by Turner Construction. While this problem did institute an added cost into the project, the collaborative approach helped minimize the negative effects of the problem.

Infection Control Risk Assessment (ICRA)

Because the new Inpatient Tower at Butler Memorial Hospital ties into an existing facility, a specific plan is necessary in order to eliminate infectious risks. Because the hospital is an occupied critical care facility, patient care is the main concern of the construction project. This is a constructability issue that must be addressed throughout the duration of the project. This is due to the fact that construction, demolition, and remodeling activities have been linked to infections in hospitals.

Due to the importance of infectious controls, this is an issue that is looked at as a major constructability challenge. In order to respond to the critical aspects of infectious control, significant pre-construction planning took place. Turner held weekly meetings, which communicated the infection control requirements to the construction crew, subcontractors, maintenance personnel, hospital administration, nurses, patients, and the general public. Through this extensive planning, a response plan was also developed. This response plan was based off of scales that ranked both the type of construction activity and the type of patients in a particular area. By utilizing these two scales, the required infection control precautions were determined for each tie-in to the existing facility.

During the construction project, several different breakthroughs to the existing facility had to be analyzed for ICRA purposes. When constructing the containment barriers, several requirements had to be followed:

- Airtight plastic barrier extended from floor to ceiling. All seams must be duct taped.
- Drywall barriers must be erected with joints covered or sealed.
- Seal all penetrations in existing barrier airtight.
- Barriers at penetration of ceiling envelopes, chases and ceiling spaces to stop movement of air and debris.
- An anteroom or double entrance openings must be available in areas where protective clothing is required.
- HEPA equipped air filtration machines will be provided, if necessary.

It is evident just how important ICRA is for a construction project on a hospital facility. With the fragileness of patients, the smallest error in the construction of ICRA barriers can lead to fatal consequences. Due to the criticalness of the barriers and prevention of contaminants, Turner has also established an Infectious Control Construction Risk Assessment Worksheet. All parties involved in the construction process are to abide to this document. This document includes the following:

- Response Plan Worksheet- Pre-Construction Planning
- Infection Control Construction Permit
- Utility Interruption 48 Hour Notification
- Hazard Pre-Occupancy Interim Life Safety Measures Evaluation Record
- Utility Systems Evaluation
- Pre-Construction Meeting Minutes
- Interim Life Safety Measures Implementation Record

Turner's regard for infectious control is quite apparent with the extent of information analyzed for the entire construction process. Because these barriers existed for a majority of the project, the entire project team constantly monitored the effectiveness of these barricades. Also, a full-time safety manager was responsible for the upkeep of the ICRA barriers.

Schedule Acceleration Scenarios

Project Critical Path

The critical path of the project is composed of several key activities during the construction process. It begins with procurement, fabrication, and delivery of structural steel. From there, it continues with erection of steel and decking of the tower, starting from the North end. Concrete and Slab-on-Grade work follow as the next critical path activities. After the structure of the tower is complete, the critical path segues into spray-on fireproofing, exterior studs and sheathing, and building dry-in. From here, the critical path encompasses interior finishes followed by punchlist, balancing, commissioning, and substantial completion activities.

All of the activities described above are seen as the biggest risks for the project. From the initial procurement of structural steel to the final completion activities, every step is crucial in order to meet the scheduled completion date. Because of this, every step of the construction process must be thoroughly reviewed and monitored. If any of these activities were to fall behind, the plan of meeting the set date would be jeopardized.

Fast-tracked Design Releases

To aid with the strict schedule requirements, the project team determined early on that the project would be fast-tracked. This was done by breaking the project into smaller segments. By doing this, different systems designs were released at specific times of the project. This allowed the project to begin prior to the design being complete. The specific Design Releases (DR) include the following:

- DR 1: Site Utilities- June, 2008
- DR 2: Structural, Foundations- August, 2008
- DR 3A: Core & Shell- November, 2008
- DR 3B: MEP GMP- January, 2009
- DR 4: Interior Build-Out – April, 2009

The running releasing of these Design Releases always kept the construction rolling. Because of this, the project was able to continue without any missing information from the design.

Department Of Health Inspection
Because schedule was the driving factor in this job, specific dates were laid out early in the project that had to be met. This was due to the set dates for medical operations and procedures that were scheduled in the new facility. Butler Health Systems explained the fact that there was no room for error in terms of schedule.

As the project approached completion in the summer of 2010, the most impending event was the inspection by the Department of Health (DOH). While the Department of Health always inspects new buildings for life safety, the inspection for a hospital project is much more stringent. This inspection relates to the facility's ability to provide adequate medical services to patients. These inspections are particularly critical on projects with a specific schedule deadline. The project team realized the importance of this inspection.

For the Department of Health, inspections are scheduled months in advance. It is the responsibility of the project team to verify that the project is acceptable to be inspected at the time of the arrival of DOH representatives. The Department of Health reserves the right to immediately exit a site if the project is not deemed "ready for inspection." This would obviously entail that the project had failed the inspection.

Once the Department of Health believes that a project is ready to inspect, a thorough and concise inspection is performed on the entire building. The inspection includes, but is not limited to, the following:

- Testing of Fire Alarm Systems and Sprinkler System Activation
- Testing of MEP Systems
    - Fire Dampers
    - Smoke Dampers
    - Emergency Power
- Verifying all Sealants for Fire Wall Penetrations are Adequate

If the Department of Health representatives feel that any part of the building is not adequate for life safety, the project will fail the inspection. It is at this point that a list is turned over to the project team of all insufficient issues. It is then the responsibility of the team to correct all issues prior to the next visit by the DOH. This is a process that is very critical because scheduling a DOH inspection is not a trivial task. The representatives will typically not be able to revisit the site for at least one month.

While working on the site, I learned from DOH representatives and the construction team that it is extremely rare for a project to pass on the first inspection. This is particularly true for medical facilities. This is due to the fact that there are so many intricacies in a construction project. Even if the team does everything in its power to ensure that the building will pass the inspection, the smallest issue will not allow the building to be considered acceptable. As with most projects, Butler Hospital did not pass the first inspection. It is from here that the team made a significant effort to make sure that the building will be acceptable for the second DOH inspection. The key to success for this effort is proper and efficient documentation. It is critical for the project team to document all issues reported by DOH and correcting the issues prior to the next inspection.

Because of the long lead time in scheduling a DOH Inspection, this must be accounted for in the project timeline. In most situations, the team desires to schedule the first inspection much earlier than the desired acceptance date. With the rareness of passing the first inspection, this again must be factored into the initial scheduling date. Butler Hospital's New Inpatient Tower did pass the second DOH inspection. This was not without considerable effort by the project team. With the list of unsatisfactory findings in the first inspection, the effort to correct the issues was thoroughly documented.

Implementation of BIM

In order to properly address the schedule issues with this project, the topic of Building Information Modeling was addressed during the pre-construction process for several reasons. Due to the complexities of all building systems in a hospital, the decision to use Building Information Modeling (BIM) was made early on in the project. While there are several different BIM uses, only a few were employed for this project. The uses that were defined as requirements, by Turner, include the following:

- 3D Coordination for all MEP Systems
- 4D Modeling for Steel Erection
- 4D Modeling for Exterior Envelope Construction

Because hospitals are known for having intricate MEP systems, Turner found it appropriate to utilize Building Information Modeling for coordination purposes. This is a system that Turner is starting to employ on several of their projects. Turner required the proper parties to provide a model of their systems. These models were then all brought together to coordinate the systems and eliminate all clashes in the design. Through ongoing meetings with all of the model participants, Turner was able to drastically reduce any clashes that would have been discovered in the field. While the process was a very involved effort prior to construction, it was able to reduce field difficulties and therefore help the schedule along. This early MEP coordination also gave the schedule another advantage. Because the systems were closely coordinated and analyzed, the construction of wall studs was able to take place before the MEP work was in. By doing this, contractors were not held up by detailed MEP work. By allowing these two types of work to overlap, the schedule of the project was clearly benefiting.

BIM was also used in depth for 4D modeling of both the steel erection and exterior envelope construction. Because the steel erection was a 52 sequence process, a visual aid of the construction was useful to all members of the construction team. This was also necessary because steel operations were the first critical path activities of the project. The 4D scheduling model of the steel erection would be used to schedule the procurement, fabrication, and delivery of each piece of steel. Because the model showed an accurate portrayal of the construction process, the project team was able to see what steel needed to be present at which point in time. Also, by seeing what sectors of the building were being constructed at particular times, other trades were able to coordinate their own work.

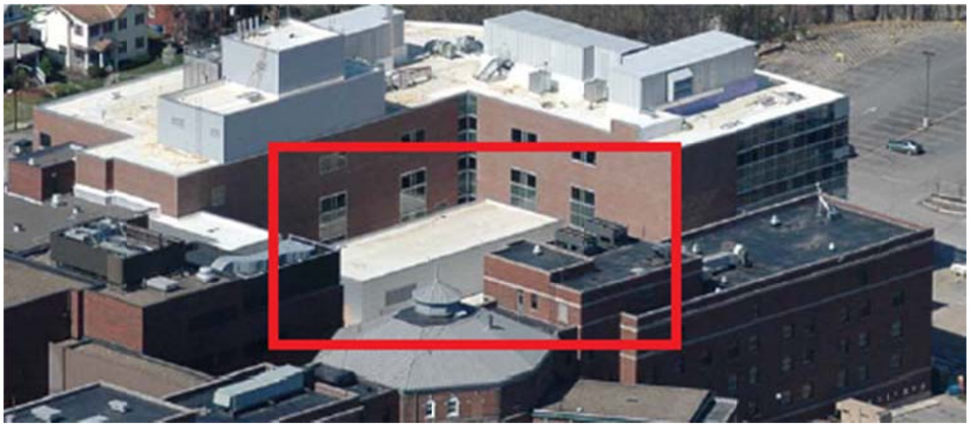
While all of these additional efforts did increase the overall cost of the project, the benefits were evident. Because schedule was the driving factor, and not cost, the owner was able to understand the benefits added to the project by BIM. Turner's dedicated BIM coordinators were able to clearly analyze the models provided by the different subcontractors. Turner's ability to efficiently use BIM was also a prime reason that they originally received the contract on the project.

Value Engineering Topics

For the new Inpatient Tower at Butler Memorial Hospital, value engineering was investigated on several aspects of the project. Several ideas were proposed by both the designer and Turner Construction. These ideas were presented to the owner in order to determine if they would be pursued. The owner would evaluate the ideas based on cost, schedule, and the overall goals of the project. Some of the budget information is not available due to owner restrictions.

Roof Screen Wall Removed

One accepted idea of value engineering was the removal of a roof screen wall on the 5th floor roof. This screen wall was designed in order to avoid unsightly views of the Air Handling Units supplying the 3rd floor Operating Rooms. Due to the layout of the roof, the units would be in sight for several of the patients on the 5th floor. The image below shows the location of the units and the view is apparent from the windows of the new tower:



Visible Air Handling Units from 5th Floor Roof

For cost savings, Turner presented the idea of eliminating the screen wall. Butler Hospital determined that this screen was not a necessity for the project. Because of this, the final decision was made to eliminate the screen from the scope of the project. This decision saved the owner approximately $500,000.

Hydraulic Elevators Changed to Holeless

In locations with difficult drilling conditions, there are often problems with the installation of the elevators. This is because a significant hole is needed for the jack, underneath the position of the elevator. By changing the hydraulic elevators to holeless elevators, the team benefited in a couple of ways. This will reduce the construction cost, because no additional excavation is necessary for the elevator pit. Maintenance and replacement of the jacks is also more cost efficient because it can be accessed much easier. Because it is not below the ground, maintenance costs decrease. This is a benefit clearly recognized by the owner.

Additional Implemented Ideas

Along with the value engineering ideas described above, some others were also used for the project. These include the following:

- Light fixtures were changed to another manufacturer
- J-Hooks were used for the mounting of cable tray
- Flooring products were changed to another manufacturer
- Changed one electric traction to a machine-less room elevator
- Changed fire alarm cabling to MC cable

Each of these ideas was seen as a benefit to the overall cost or desires of the owner. While these ideas were implemented, several did not follow through for this project. The reasons that these were not implemented were because they did not work with the system design or for political reasons with the owner or contractors.

Ideas not Implemented

As mentioned earlier in this section, some ideas were presented to the owner, but not implemented on the project. The ideas that were proposed but not implemented include the following:

1. Removal of Finn Tube Radiation over the Outdoor Walkway
    a. Owner determined that this was necessary for the project. Despite cost savings, this was not removed.
2. Removal of Radiant Heating Ceiling Panels
    a. Although the project team felt that enough heat would already be produced inside the building, the owner desired to keep the panels.

Problem Identification

As with all construction projects, there were several features of this project that could be looked at as problematic features. By problematic features, this could represent a couple different types of issues. These can be problems that were encountered during the construction of the building. It could also represent potential areas of construction that could have been made more efficient in a manner of time or cost.

Technology Implementation

Because of the complexities of this project, and the importance of the project schedule, 4D modeling was deemed necessary for specific aspects of the project. As explained earlier, 4D modeling was mainly used for the steel sequencing and the exterior envelope construction. The construction team believed that these were the most necessary stages to tie in scheduling with the 3D model. While the employment of 4D modeling did benefit these stages in several ways, it may have been beneficial for the project team to utilize this technology for other aspects of the construction project. If 4D modeling had been used for the entire construction process, some issues could have been identified early on in the project. For example, the Air Handling Units installation problem may have been recognized early on. With the steel structure being in the way of the placement of two of the units, a plan could have been devised early on to address this difficulty.

The use of 4D Modeling is not the only technological issue that could be addressed for this project. Because BIM was so successful for this project with 3D clash detection and 4D Modeling, it is possible that a larger implementation of BIM could only benefit the project even more. Building Information Modeling can be used for several more uses and the only restriction on the execution is the cost. With cost not being the driving factor for this project, the entire project team could reap these benefits.

Several of the earlier discussed difficulties could have been recognized earlier through the use of BIM. If all systems, and not just the MEP systems, had been thoroughly documented with Building Information Modeling, the structural issue involving the medical equipment could have been spotted. If each system was implemented into the 3D Model, the project team may have seen this structural problem with the installation of the equipment. Because of this, the additional structural steel could have been purchased and installed faster. Also, the team would have not dealt with the additional difficulty of mid-project coordination meetings. This, in general, would greatly improve the efficiency of the process.

Another implementation of BIM could be the use of technology for dealing with project close-out. Because the close-out process is a very involved procedure over a long period of time, it may be useful to apply Building Information Modeling. Technology could be used in terms of managing deficiencies in the project. With the punchlist, and especially with the corrections needed for DOH approval, computerized documentation of these deficiencies could be highly beneficial to the team. With these several ideas for technology on the project, it is quite clear that more technological ideas are feasible for this project. The only restriction to utilizing these different uses is the owner. The owner will determine what technologies will benefit the project and the benefit of the use compared to the cost.

Sustainability

Other than Building Information Modeling, another main movement in the construction industry is the employment of sustainable building practices. Currently, sustainability is something that is at least touched upon for projects of this size and magnitude. Despite the idea of the new Inpatient Tower being a state-of-the-art facility, sustainability was an issue that was only slightly addressed. LEED certification was not discussed for this project because interest was never expressed by the owner. Although the owner did not explicitly show interest in a sustainable project, it is possible that the advantages of sustainable building were not described well to the owner. Possible sustainable implementations are included later in this report.

Installation of Mechanical Equipment

As with all medical projects, the MEP systems of the building show the most complexity. The project team recognized this and quickly decided to utilize 3D clash coordination. This greatly reduced problems during the installation of mechanical equipment. Due to discussions that took place at the 2010 PACE Roundtable Conference, benefits have been presented in utilizing prefabricated mechanical systems. By using 3D Modeling, specifics are presented for the coordination of the different mechanical systems above the ceiling. Because of the various systems needed for a hospital's operation, it may be feasible to use prefabricated, above ceiling, mechanical spaces. This could reduce on-site issues and labor costs.

Safety and ICRA

Because the building of the new Inpatient Tower is an addition to an existing hospital, safety issues are significant for the entire project. As mentioned earlier, ICRA plans are crucial because there are tie-ins on most floors with the operating hospital. Another issue that must be mentioned is the general public safety of all hospital personnel, patients, and visitors. It is necessary to ensure that all pedestrians are safe from the construction process.

Technical Analysis Methods

Analysis Method 1: Building Information Modeling
As explained earlier, BIM was utilized on this project, but not possibly to the extent that it could have been. Several key uses of BIM were not touched upon, and it is highly possible that the entire project team could benefit with their use. The first issue is bringing the owner on board with the potential increase in costs by increasing the use of BIM on the project. The owner must fully understand the reason and the advantages of maximizing the potential of Building Information Modeling.

Penn State has put together a BIM Execution Guide, which documents the variety of ways BIM can be used. While it is obviously not feasible to bring every use into the project, it may be beneficial to specifically address a few. In order to determine exactly what uses would benefit the project, extensive research would need to take place. This is not an issue that can be quantified in terms of calculation.

By analyzing case studies and speaking with industry professionals, the most beneficial uses can be identified. In particular, hospital projects should be the incorporated projects in this analysis. Contacts from the 2010 PACE Roundtable Conference could be extremely beneficial in the research towards this topic. It is also crucial to look into all parties involved in the construction process. The actual construction team may benefit in some ways, and the owner may benefit in another way. The financial feasibility of employing each BIM use into the project must be compared with the potential benefits that will be provided to the project team.

Analysis Method 2: Sustainable Technologies
Sustainability was never a dominant topic in the design and construction of the new Inpatient Tower at Butler Memorial Hospital. With the amount of energy that this building uses, and the state-of-the-art reputation, sustainability practices would only improve the building. While these technologies will obviously reduce the costs of maintaining the building in terms of utilities, it could also be used as a way to improve the public image of the hospital.

There are various ways that sustainability can be tied into a project of this magnitude. One of the most popular sustainable building practices is the employment of photovoltaic systems. With more than significant space on the roofs of the building, research will be done to determine the optimal layout and size of the array. Because of the high cost of installing these systems, a financial analysis will also take place for this system. This analysis would be the most crucial in convincing an owner that the system should be implemented into the project. This analysis can also be utilized as an MAE breadth topic, based off of AE 598C: Sustainable Construction Project Management.

Analysis Method 3: Prefabricated Mechanical Spaces

The use of prefabricated systems is another practice that is beginning to revolutionize the industry. Prefabrication makes the most of labor time because field installation time is reduced. If units are already assembled, prior to arriving on site, the actual time spent installing the system can be drastically reduced. This shorter installation time will aid the project in terms of both cost and schedule. Because field labor is more expensive and involves more risk than shop labor, the cost of the project is reduced. The production of these units in the field reduces risk such as on-site conditions and site congestion.

In order for this practice to work efficiently, it is crucial that the design is coordinated closely between contractors. With BIM being used for 3D Coordination, there may already be enough information provided to produce these prefabricated systems. To analyze this process, more case studies will need to be utilized. Any projects, especially hospital projects that have used this technology would be exceptional research tools. To determine the feasibility, the cost and schedule of producing these systems must be compared to the conventional practice of installing the systems in the field. This study can also be incorporated into the sustainable ideas of this project. With prefabrication, there is always reduced waste in the field. This can be tied into the sustainable approach of building this project.

Analysis Method 4: Public Safety and ICRA

Safety is always the most crucial part of a construction project. For this project in particular, the safety of patients, staff, and visitors must be taken into account. This is on top of the safety considerations already made for construction personnel. For this project, the application of BIM can also be used for safety. With 4D Modeling already being used for several parts of the project, safety can also be considered by using this model.

The developed models already include the steel erection sequencing as well as the exterior enclosure. These two stages of construction usually present the largest safety concern during a project. This is due to the materials and personnel being hoisted to high distances. The project team could use these models to see exactly what areas would present risks to hospital personnel as well as construction personnel. As with the other technical analysis methods, past projects that utilized this technology would be the most beneficial for research. By looking into these projects, the cost and benefits of employing this BIM use can be compared.