The Pennsylvania State University
Health and Human Development Building

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Construction

Final Proposal

December 16, 2013

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Executive Summary

The Penn State Health and Human Development Building is being constructed on a very tight site with many potential schedule risks. With a strong project completion turnover date, it is imperative to analyze problematic areas to ensure that the project is not put behind schedule. With many items on the critical path of the schedule, there are multiple areas of concern to hinder the schedule progression. Along with the schedule, the owner's major concerns include quality, cost, and safety. The objective of this thesis proposal is to address these issues and find ways to accelerate the schedule while keeping the project under budget and maintain quality through the investigation of four analysis areas.

The first analysis will address the issue concerning the concrete shear wall stair tower. This analysis will be performed to redesign stair tower A into a steel braced frame. This proposed analysis would accelerate the schedule, improve quality of the product, and reduce safety concerns. This depth area will be utilized as my structural breadth as beam sizing will need to be performed.

The second analysis will focus on the coordination of system installation in the atrium. The atrium will be extremely congested during the construction phase. It will be imperative to arrange the sequencing of this area such that safety and efficiency can be maximized. The analysis will include a 4D schedule depiction and different options will be explored. With a multi-prime contract, there will be many different subcontractors working on site at once. Coordination of these trades will be critical.

Analysis 3 will investigate potential options to deal with a very tight ceiling space. A very complex MEP system has been implemented into this project. The proposed solution to this is a return air plenum. This system will remove a large piece of ductwork in the ceiling, but it will cause for larger floor-to-floor heights and require all materials to be plenum rated. This depth will allow me to explore a mechanical breadth to analyze the CFM requirement of the return air space.

The final analysis will focus on alternative excavation methods. When the soil was found to be solid rock, the project team decided to use rock excavation blasting techniques as opposed to the traditional rock hammering. This analysis will compare these two methods of excavation and determine the cost savings and schedule acceleration. Research will also be performed to determine if other methods could be utilized to accelerate the schedule further.

These analyses are expected to provide potential solutions to the current issues on the project site. The intention of these analyses is to prove the best possible acceleration scenarios while maintaining cost and quality.

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Technical Analysis Descriptions

Analysis 1 - Stair Tower-A Redesign [Structural Breadth]

One of the major problematic areas on the project was stair tower A. This is a full cast-in-place concrete stair tower that is acting as a shear wall for the structural steel system. The installation of this stair tower was very tedious and was a major schedule concern. It required strip forms, the placement of rebar, and a concrete pump truck for the concrete pour. On site, it was required to have a concrete pump truck, a crane, and a JLG lift in order to raise the forms and make the pour. Not only does this require a large amount of coordination on site, but also it is a major safety concern for construction. While up on the forms installing the rebar, it was important to ensure that the personnel was properly tied off and standards were met for guardrail restrictions. However, with the strip forms, a 42" guardrail requirement could not be met due to the height of the stair tower forms at the concrete placement height. This was a major safety concern that had to be monitored and additional restrictions were required. Also, there is always a concern for crane safety on such a tight site. The schedule impacts were seen immediately in the first level construction of the stair tower. The construction of this shear wall took long periods of time. This time was estimated to be about 1 week per level. Figure 1 provides a visual of the size and detail required for the installation of the stair tower.

Figure 1 Installation of Stair Tower A

The main focus of the owner on this project is the quality of the building at turnover. After installation was complete, it was discovered that there were issues with the quality of the tower. When steel arrived on site, a survey was completed to make sure that the stair tower was installed correctly and that the steel would fit in properly. After the survey was completed, it was found that the tower had minimal twisting as it grew in height. From the top of the tower to the bottom, it was off by roughly 3 inches. This led to incorrect matching of steel beams. Some pieces were too short and some were too long, which caused additional time in the schedule.

In order to solve the concerns of safety, schedule, and quality, I am proposing to change the concrete shear wall to a steel braced frame. This would reduce safety concerns, accelerate the schedule, and improve quality. Changing this structural feature will require an analysis of what size beams and columns would be required to support the forces from the rest of the structural steel system as well as creating areas where the stairs can be tied in to the structure. This altercation will not get rid of all safety concerns, as a crane will still need to be used on site. However, the amount of equipment that will be required will be significantly minimized as well as the manpower. There will be significant schedule advancement by implementing this system. A comparison of time requirements for the two systems will be performed to see how much time it could save on the schedule. Also, a cost comparison could be performed that analyzes the structural members that will be placed compared to the concrete, as well as equipment time required to perform the activities.

The analysis of the structural steel members that would be required to substitute the concrete shear wall would act as my structural breadth for my spring thesis project. This will be a very challenging breadth to investigate as it will require an in depth structural analysis for the steel frame. In order to accomplish this analysis, there will be multiple sources that I will need to consult. The first person that I would seek out to discuss this idea would be the structural engineer of the project. I would need to get the structural loads that are being put on the concrete shear wall by the structural steel. The next person that I would consult would be an industry member that specializes in substituting concrete shear walls with steel braced frames. This is someone that I have met through networking and would be able to assist me in the step-by-step process. Lastly, it would be beneficial to meet with the general contractor (LSF) in order to estimate the construction of the concrete shear wall and to determine the equipment that was required.

Analysis 2 – Re-Sequencing of Atrium Systems

A major constructability concern for the project is seen in the atrium of the building. The major issue in this area is the concern for the material finishes being installed. In the atrium, there will be a very elaborate staircase put in place as well as an architectural screen wall. The material finishes of both of these systems require for a tempered environment, which would mean that the building would need to be entirely enclosed. This presents an issue with the constructability of these systems. In order to accelerate the schedule, the project team has elected to construct both of these systems at the same time. As seen by Figure 2, this will be a very challenging area due to the coordination that will be required in such a tight space. Another issue is how the wood panels will be able to be lifted into place. Typically, a crane would be brought in and the prefabricated pieces will be raised into position. However, if the building needs to be enclosed, a crane will not be able to be used. A scissor lift has been established to be the alternative to hoist the panels into place. Scaffolding will also be put in place in order to install the screen wall and for other activities to be performed at the same time. Coordinating where the scissor lift can be placed in between the scaffolding will be a challenge. Congestion in this area will be increase when stair C is being installed. When the stairs are placed, the slate finish will be on the stairs and will need to be preserved. So, it will be critical that the finishes are protected from any other activities taking place after the stairs are in place. The last issue regarding this activity is safety. When working with large pre-fabricated pieces, it is important to establish a system that works in an efficient manner and is safe for employees to install. The scaffolding equipment will be a major safety concern as workers will be at the top of the scaffolding while other work will be going on underneath them. Also, the maneuvering of the scissor lift will have to be carefully monitored to ensure that it does not disturb the scaffolding in any way.

Figure 2: View of Atrium During Stair C and Screen Wall Installation

The constructability concerns related to the installation of the screen wall and stair C is an area that could be further analyzed. This would be a construction breadth that focuses on sequencing of activities inside the atrium. I believe that different sequencing options can be analyzed in order to establish the safest, most efficient, method of installation. An analysis of the schedule for durations and predecessors will be required to see how long specific activities are anticipated to take and which activities can be overlapped. This analysis has the potential for BIM coordination. I believe that a 4D model would be very helpful in the coordination process and would be a good way of exploring different options. The potential to do the activities separately would add time to the schedule, however it may ease the installation process, as more room would be provided for the workers to complete their tasks. There is also the possibility of splitting the atrium into zones where the systems could be sequenced so both trades could work at the same time, but separately. Many options can be analyzed in order to derive the most logical solution. Figure 3 shows what the finished product is to appear. As is seen, this will be a major aesthetic feature in the atrium space. In the end, it may be found that the plan as scheduled is the most logical decision, but it will be interesting to explore the different ways of coordinating trades to maximize efficiency and safety.

Figure 3 Atrium Finishes Rendering (Bohlin Cywinski Jackson)

Due to the fact that this is a multiple prime contract, there will be multiple contractors performing this work. This adds to the issue of coordination that will need to be required. The coordination of different trades will need to be properly managed and members from each trade will need to be contacted to ensure that their jobs can be done in certain situations. In order for this to be a successful analysis, information regarding manpower, equipment, and materials will need to be gathered from the different contractors. It will be important to understand the method of construction as planned so as to ensure that the other options will follow a similar process in the erection sequence. The person to contact for this information would be the BIM coordinator of the project. There have been concerns about this area on the project already and the BIM coordinator has worked with the contractors to ensure that the equipment can fit inside the building and the pieces could be erected properly. John Mesner will be a good contact for this analysis as well. I plan to meet with him in the Penn State ICON lab to create the 4D schedule of the work in this area.

Analysis 3 - Return Air Plenum [Mechanical Breadth]

Another concern on this building is the complex MEP design in the ceiling spaces. This is a major reason why BIM was implemented for coordination. Figure 4 depicts an area next to a mechanical room, which contains heavy congestion in the ceiling space. With any high-tech building, there is always a concern with fitting all of the equipment into the space that is available. The Health and Human Development Building is no different. With this complexity of design in a small space, it is important to get all trades involved early in the project and for the equipment sizing to be known before installation. As previously mentioned, this is a multiple prime contract. So, there will be multiple contractors working in this tight ceiling space to make sure that all of the materials are put in place correctly. The major concern in this area is trade coordination. With this, comes a potential schedule drawback. All materials arriving on site need to be sized to the exact dimensions as on the BIM model with a very little tolerance to ensure that all pieces fit.

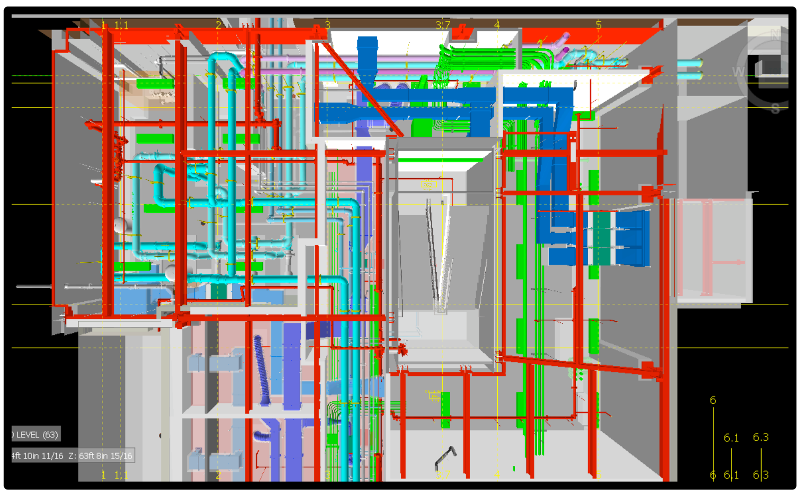
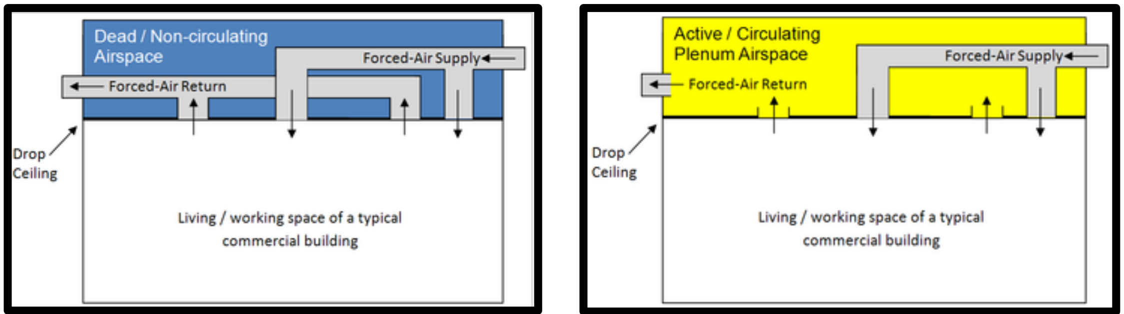


Figure 4 BIM Model Showing MEP System Congestion

When dealing with a tight ceiling space, there are many different alternatives to increase the amount of space in the ceiling plenum. As a mechanical breadth, I am proposing to remove the return air ductwork and implement a return air plenum. A return air plenum would eliminate a large piece of ductwork and save space inside the ceiling to allow the contractors to have more room to work with. Figure 5 shows a comparison of a return air plenum and a typical return air piece of ductwork. As is shown, the ceiling space is much more open due to the loss of the return air ductwork. This analysis would require increasing the floor-to-floor heights, analyzing the CFM requirements for this space, and plenum rating all of the materials in the ceiling. This would require an estimate for the cost increase of the added floor-to-floor height. This will be accomplished with the estimates that were completed in Technical Report 2. A cost per square foot for structural steel will be utilized. In order for a return air plenum to work correctly, all materials in the ceiling will need to be plenum rated. This is a small change that could make a huge difference on this project.



(a) (b)

Figure 5 (a) Typical Return Air Ductwork (b) Return Air Plenum Drop with Drop Ceiling

This adjustment works best in hallway spaces. So, since the area off of the mechanical room on the first floor is an extremely congested area, I will look to utilize the return air plenum in this space. This idea could be further multiplied throughout the rest of the hallway areas in the building. An analysis will be performed to determine the cost addition or reduction from implementing this system, as well as time savings. In order to perform this analysis, it will be important to interview a company that specializes in return air plenum systems. A company like Truland may be a good option to consult with. This analysis will be performed to determine cost reduction and/or schedule acceleration with the implementation of this new system.

Analysis 4 - Alternative Excavation Options [Research]

A major challenge on this project was found in the very early stages of the project. When the geotechnical report was done for this project, it was found that the soil was composed of solid rock. Then, when initial excavation began, it was confirmed that it would take a long period of time (estimated 3 months) to hammer out the rock and excavate. With the phase occurring in the summer months, it would have been okay to have constant hammering and not disturb any classes. However, the idea of rock excavation blasting was proposed as a method of reducing schedule time and decreasing the amount of noise that would occur from long periods of rock hammering. Rock Excavation blasting is done by drilling holes roughly 15 feet down in the ground, filling them with explosives, and setting off charges to break up the rock and allow for easier excavation. This process requires a significant amount of planning and coordination of everyone on site as well as people from the surrounding buildings. During the initial planning phase, it was important to analyze the entire site and how the blasting would affect the surrounding areas. For this project, it was established that a 300-foot safety radius would be needed for a complete automobile and pedestrian shutdown. This requires a huge effort from a management standpoint. In order to establish a safety barrier, it is important to ensure that a proper staff will be provided. Figure 6 depicts the perimeter safety radius and the personnel required.

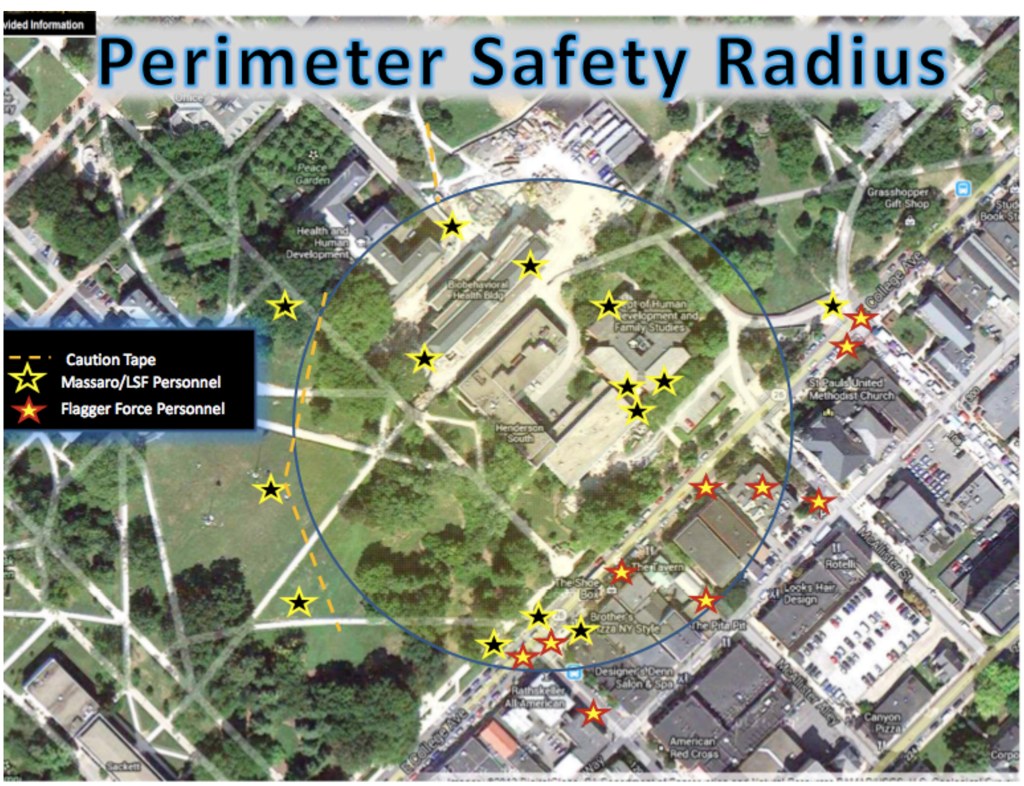


Figure 6 Blasting Perimeter Safety Radius

A professional traffic control team was hired in order to handle all automobile and pedestrian traffic on the very busy College Avenue. Hiring a professional traffic control company not only ensured a professional group of people, but also helped to establish traffic control based on PENNDOT standards. There were roughly 30 people involved in the day-to-day activities of the rock excavation blasting. With this amount of activity and the idea of explosives being used, it is imperative to notify students and faculty in the surrounding buildings. This is a large effort, with major results in schedule acceleration.

I have found a very strong interest in this method of excavation. I think it would be very intriguing to compare the process of rock excavation blasting to the traditional jack hammering. Also, I plan to research alternative methods to excavating solid rock. One particular idea is a piece of machinery that breaks up the rock. This is called a rock hawg. This type of machinery utilizes Top Down cutting technology, which allows its teeth to cut down into the rock and break it up into smaller pieces. In order to make sure that this heavy machinery would cut the rock that would be required to be cut on site. Also, I would need to contact a company who owns this type of machinery and has performed this work before so that estimated durations could be established. To get the most accurate analysis, contact will need to be made with the general contractor who was initially planning to perform the jack hammering and excavation. Also, it would be helpful to contact the blasting contractor (Douglas Explosives) in order to derive the sequencing information for the blasting procedures. This will be an intriguing researching opportunity to explore the different means of performing excavation.

Appendix A

Breadth Topics

Structural Breadth [Incorporated into Analysis 1]

The stair tower redesign, as described in Analysis 1, provides an opportunity to research and analyze a breadth outside of the construction management option. This area was initially analyzed because it was seen as a problematic area on the project. In order to speed up the construction schedule, a redesign of this stair tower will be performed. The proposed steel braced frame will incorporate the use of structural steel members as opposed to the concrete shear wall. An analysis of the structural steel connections to the braced frame will be required as well as tie in points to the so that the stairs can be put in place. Also, an analysis can be performed to determine fireproofing requirements for the steel members. This proposed alternative would accelerate the schedule, which is crucial because this area is on the critical path. From a structural analysis standpoint, this will be a very challenging redesign.

Mechanical Breadth [Incorporated into Analysis 3]

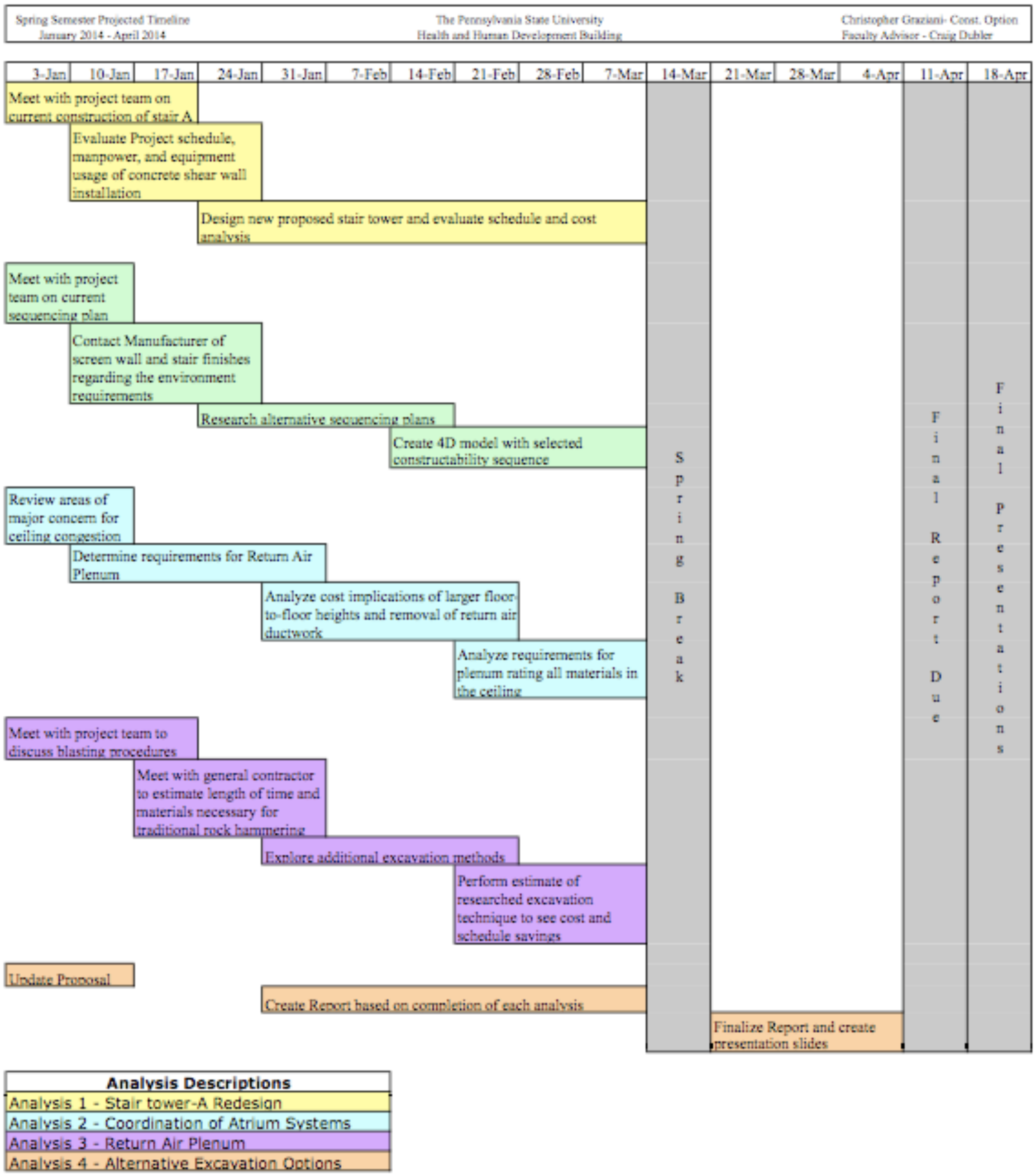
The tight ceiling space does not allow for much tolerance for placement of MEP equipment in many areas of the building. One of the major areas is the hallway outside of the mechanical room on the first floor. This allows me to perform a mechanical breadth analysis as mentioned in Analysis 3. In order to have a successful return air plenum in this building, the floor-to-floor height will need to be raised. The CFM requirements for the return air piece of ductwork that will be removed will need to be analyzed so that a proper plenum can be installed to meet those requirements. Also, in order to have a return air plenum, all materials in the plenum need to be plenum rated and the ceiling space needs to be sealed. It will be interesting to see the type of schedule impact this system will have on the project. It will obviously save time if you are not installing a return air duct, but it will take time to plenum rate all of the equipment and materials in the ceiling space.

Appendix B

Table 1 - Weight Matrix

Description	Critical Industry Research	Value Engineering Analysis	Constructability Review	Schedule Reduction/ Acceleration	**Total**
Stairtower Redesign	5%	5%	10%	10%	30%
Atrium System Coordination	5%		10%	5%	20%
Return Air Plenum	5%	5%	10%	5%	25%
Alternative Excavation Methods	5%	5%	10%	5%	25%
Total	20%	15%	40%	25%	100%

Spring Semester Estimated Timeline



Appendix C

Resources

All renderings are courtesy of Bohlin Cywinski Jackson, the architect on the project.

Google Image Search

Massaro CMS BIM Model