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Technical Assignment Three

Penn State AE Senior Thesis

Executive Summary

Technical Assignment Three is focused on ideas and innovations that may lead to more efficient construction of the project in question. This includes an interview with the project manager on the Moore Building Addition which focused on topics that outline where the project could have been improved and how some challenges were handled during the construction of the project.

The first three sections focus on the interview of the project manager as it pertains to the Moore Building Addition, a 57,000SF addition to the existing Moore building and the renovation of its 13,000SF North Wing in the process all as part of the first phase.

First, the topic of "Constructability Challenges" was discussed and three challenges were brought up with their solutions, the first being the issue with closing the alleyway that connects the site of the Moore Building to the buildings behind it. This was handled with OPP and the alleyway was closed without costing the project timely delays. Secondly, a heritage tree had to be preserved, and a stepped foundation was excavated around it to keep it standing during construction. Finally, tying in to the new building will be an issue and although it has not been solved (structure is not built as of this report), there is extensive coordination with this portion of the building.

"Schedule Acceleration Scenarios" were then explored. The most important portion of this section was the critical path items that would have the greatest effect on the project schedule and cost. For the Moore Building Addition this was the structural steel and its timely arrival. Its arrival would open up the floor for every other trade to begin work. The second section focused on efforts to accelerate the construction process and this was attempted twice by the construction manager, with both trials relating to the early delivery of the structural steel and with both attempts failing, yet not costing the project neither time nor money.

The final interview topic was "Value Engineering Topics" and on the Moore Building Addition there was no Value engineering done by the construction management team due to it being a few million dollars under budget to begin with. The full extent of the value engineering in the design phase could not be determined as of the publish date of this report as the information is proprietary.

In creating the next section, a great amount of innovative thinking was required. The focus of the final two sections was to outline ideas that could possibly benefit the project in terms of schedule acceleration, constructability, value engineering and critical industry issues. First, nine problems were laid out. Then, four of these problems were selected to become analysis topics. Based on the four criteria that had to be satisfied, the four analysis topics were titled "Demolition," "Façade," "BIM Coordination," and "Structural Steel" in relation to the problems they address. All of these topics are further discussed in their respective sections.

Contents

Constructability challenges

Alleyway Utilities

The alleyway that connects the Moore Building to the buildings behind it (to the South) goes down from the West side of the building (figure 1). This alleyway was an important piece of the project as there were quite a few challenges involved with its closing and upgrading the mechanical utilities located there. These utilities included chilled water piping (both supply and return) and telecommunications lines.

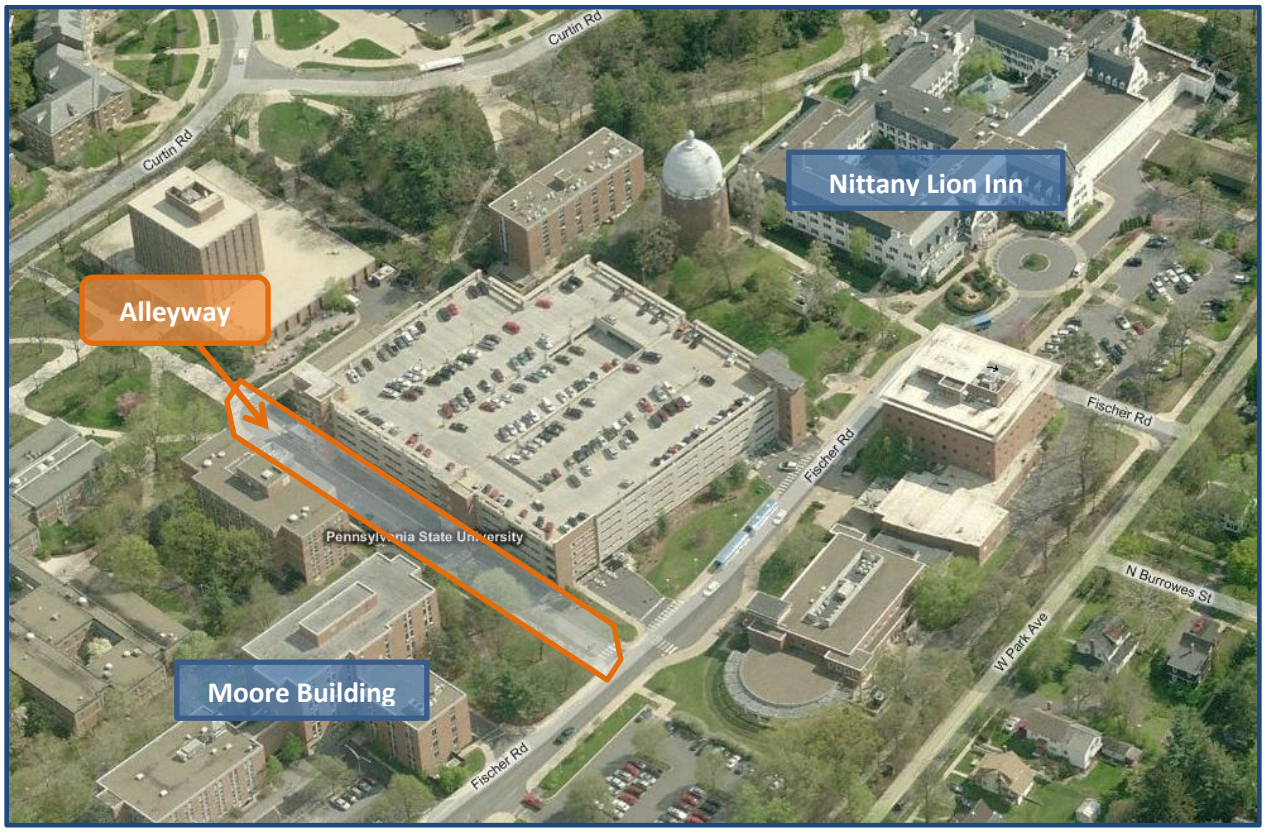

Figure 1: *Aerial view of NW area of campus*

Among other issues, the main one was to convince Penn State, through the Office of Physical Plant, to allow the shutdown of the alley and reroute pedestrian traffic through the Nittany Lion Inn as a temporary solution. However, the alleyway in question provides access to highly frequented buildings that are located behind Moore Building. Those include Chambers building, Kern Building and Rackley Building and access to these buildings will become tougher for those who frequent the alleyway.

The challenge had more of a "political" side to it as the physical work to be done was not difficult, but the ability to close down the alleyway was crucial to the completion of the project on time as the upgrades to the utilities were crucial to the building.

As mentioned before, the solution would be to reroute traffic from through a road in the Nittany Lion Inn located to the West of the Moore Building Addition, and this solution was the route taken by the university.

Interestingly, the alleyway produced a sinkhole during the short amount of time it was allowed to be closed down, and although this was the case the sinkhole was taken care of promptly and had no effect on the schedule of the project.

Heritage Trees

According to the University's forestry/tree department website, heritage trees are:

> *"…Individual trees on the Penn State University Park Campus that have developed exceptional historical, cultural, and/or aesthetic value because of their age or their association with an important event or person."*

Figure 2: *Aerial view of heritage tree*

On the southwest corner of the Moore Building Addition site there is a heritage tree that has been maintained for many years and whose importance has grown ever strong. By request of the university, tree was to be kept and maintained during all construction activity, and so, excavation and construction had to, and still must, be coordinated around the tree.

Normally trees are removed as part of the excavation of a new site, but for this tree its status meant that a stepped excavation had to be engineered and put in place in order to prevent the tree from losing its grip on the soil and tipping over.

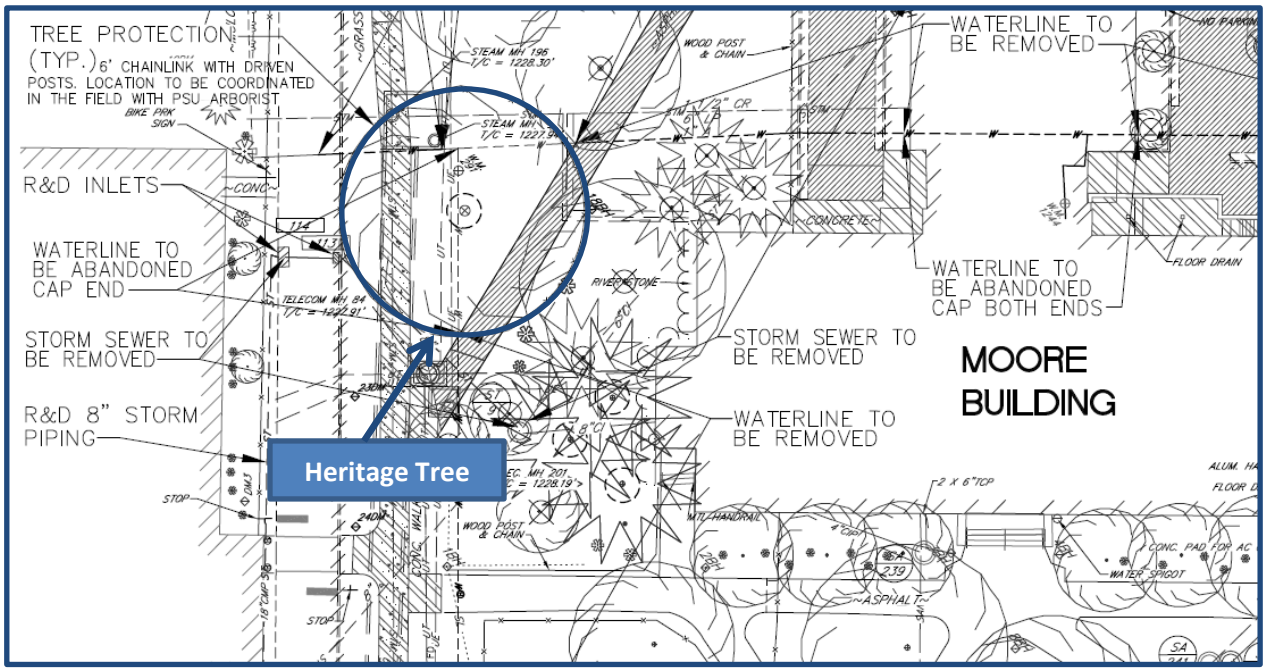

Figure 3: *Diagram of Heritage Tree Location*

Apart from the stepped excavation, a low-pressure steam line had to be re-routed around the tree as the original route would have compromised the tree's stability. So far the tree has not been a disturbance to the overall schedule of the project, but if not closely monitored, it may become a setback. So, this means that this is an ongoing challenge with a high-maintenance—yet low cost—solution that needs to always be in action.

This is all very important to the appeal of the Pennsylvania State University as their care for trees is a highly monitored aspect of construction, with the department of forestry having a very active role in the preservation of heritage trees. No heritage trees may be chopped down, and construction will not occur where they lay. In the most extreme of cases, the tree(s) that may be affected will be relocated.

The construction manager on the Moore Building Addition has employed the used of stepped excavation in efforts to preserve the tree. This along with monitoring is the final solution.

Tying in

Another unique aspect of the Moore Building is that the north wing of the building and the new structure being built are independent of one another in terms of their structures and load-carrying capabilities. Although this portion of the project has not yet been undertaken, the tying together of these two structures is going to be an important part of this project's on-time success.

There are a lot of surveys being undertaken to determine all the as-built locations of tie-in points on the building. These will be used for all subcontractors as a universal set of drawings so that tie-in points are exactly the same for all builders.

Coordination will be somewhat difficult as all the tradespeople and contractors need to be "on the same page" in terms of how and where the structure will tie in. Fortunately, the existing structure was built very close to the as-built drawings (roughly 40 years ago) and so this makes the job of coordinating tie-in points much less difficult than the task would have been if there had been many changes to the final structure.

Tolerances here do still make the tying in portion very crucial to the success of the building as a whole. No compromises can or will be tolerated as this may cause very undesirable results if even the settlement of the building was not considered properly.

One of the first solutions will be to procure the steel on time, and to have the foundations cured by the time the steel begins to be erected. Since this process has not yet started (as of this report) no further solutions may be discussed.

Schedule Acceleration Scenarios

Description of the Critical Path

The critical path of the Moore Building Addition is fairly simple. First and foremost, asbestos abatement and removal has to occur before the structure can begin to be erected. This will be done before excavation even begins. The next key part is the arrival of the steel to the site. This is the most critical part of the schedule. Once the steel is delivered, it will be erected and then the sequence of work from the ground floor to the top floor will begin, which includes laying the track, rough-ins and drywall installation. Also, just as this sequence is beginning, all the mechanical equipment will go into place in the basement.

A more detailed, yet simplified visualization of the critical path, and the most important items to the completion have been outlined in figure 4.

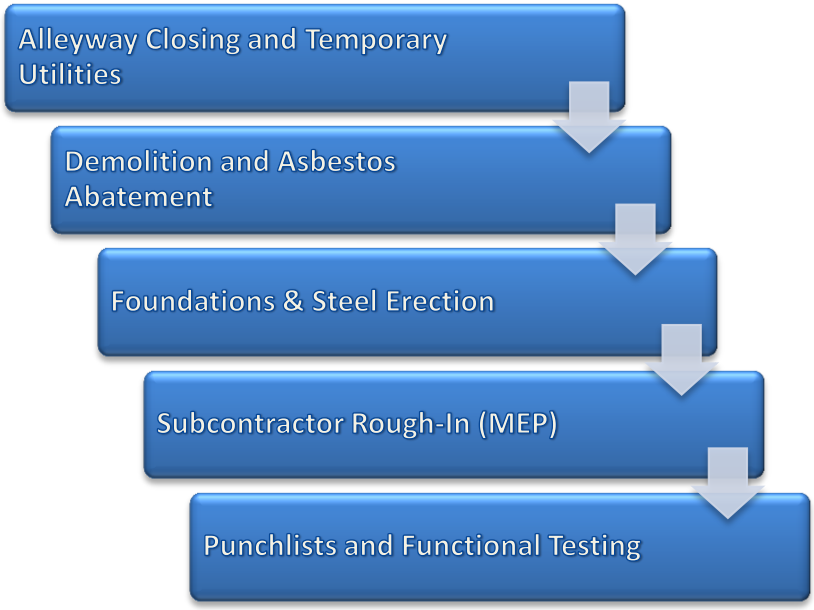

Figure 4: *Critical Path of Moore Building Addition*

Acceleration Techniques Utilized

As previously mentioned, the most critical item on the project is the steel used for the structure. The delivery of the steel would determine whether or not the building will be finished on time, as once the steel is erected, work on all other aspects of the building can begin. It is the single most crucial part of the schedule and all efforts to speed up the project schedule were based on the early delivery of the steel and its early erection.

The first attempt at having the steel delivered three weeks in advance (in terms of the final schedule) was to release the steel fabricator even before the construction manager's contract was signed. This meant that the steel fabricator would be producing steel members with no contract in place to cover payment should anything wrong would have happened to the building. So, it is to no surprise that the

steel fabricator did not work on the members earlier than the signing of the contract, and, so the steel was fabricated and delivered on time.

Another attempt at allowing early steel erection was to push the foundations contractor to work to a much more stringent schedule in an effort to erect steel members as they arrived—with the first being the ground floor's steel (which would be delivered first), followed by the next floor and so on, until all steel members have been delivered and erected. This would also result in a three week advance in the schedule, but this attempt was to no avail. The stringent schedule was unmanageable and unrealistic and had to be changed. This also meant that the schedule was not going to change

There were no costs associated with either of the acceleration techniques that were tried in the Moore Building Addition as neither of the contractors fulfilled what was suggested, and, the construction manager put no money towards either. So, the schedule remained unchanged and the project's costs were unchanged as well.

Value Engineering Topics

There have been no value engineering efforts on the Moore Building Addition. This is mainly due to the project being a substantial amount under-budget.

The value engineering that was performed on the building was done during the design phase of the building. Understandably, the construction management firm played no part in this process, and although efforts were made to produce the steel earlier than the schedule determined, this did not happen. No other efforts were made, and a quote to the effect of "no value engineering was used on this project" replaced the main page of the value engineering section of the proposal binder.

The project came in about $3Million less than had been anticipated in the GMP (guaranteed maximum price) of the project by the construction manager through to the bidding process. So, there was no need for value engineering as a result as most of the value engineering was performed by the designers in the schedule of the building and coordinating that in depth before the building was bid to a contractor. Also, there was some value engineering done to reduce the estimated dollar value by the designer. Neither of these was accessible to the project manager interviewed at the time of this report.

The full extent of the value engineering in the design phase could not be determined as of the publish date of this report as the information is proprietary.

Problem Identification

Problem 1 – Demolition

The Moore building addition is set to tie into an existing structure of structural steel members. This existing structure is 13,000SF and will be stripped to its structural steel and concrete decks before any work can or will be done. This portion is called the North Wing.

The north wing will undergo asbestos abatement and removal in the beginning phases of construction. To some people it seemed odd that the north wing would not be completely torn down and rebuilt. This would eliminate the need to abate and remove asbestos in the north wing. Also there would be much less of a coordination hassle when trying to tie the two structures together. The fact that a new structure will be built will mean that no special excavation practices would need to be put in place to preserve the integrity of the standing structures.

This would be a very interesting problem to fix, as it would be of valuable information to find out the difference in cost and schedule time taken had this route been taken from the beginning.

Sub-Problem

There is a Geotextile Bentonite Waterproofing material that is used on the west side of the north wing. This may or may not be eliminated had the above root been taken. This would be an interesting subject to study as a subtopic.

Problem 2 – Façade

For the façade of the Moore Building Addition all masonry and panel work will be installed on site by masons. Since efforts have been made to speed up the delivery of the building, it would make sense to look for a faster and possibly cheaper way to put up the façade.

One of the most obvious options would be to install the façade pieces as pre-cast members that sit on the structure's steel. This would mean that the façade can be fabricated off-site once the structural steel is up. Then, the pieces could be installed on site at any time.

Figure 5: *Façade of Moore Building Addition*

Problem 3 – Atrium Size

On the south side of the Moore Building addition, on either ends, are small atriums that rise up to the second floor looking down at the first, and up to the fourth floor looking down at the third floor. The size of the atriums is very small, with dimensions of about 10'X10' for the top atrium and about 10'X20' for the lower one. These atriums are extremely small and are located around areas that will be used by

employees to have a break. So, the space could be used much more wisely, as their value as a scenic addition is very marginal, and the maintenance of the glass may be costly in terms of their size. This is about 600SF that can be better used. Their removal could also allow the columns beneath them to be moved to the edge of the wall, freeing even more space and allowing for loads to be split between members, also possibly reducing the cost involved.

One option would be to add more labs in the spaces where the atriums were. This would be more beneficial to the program as a whole.

Problem 4 – Reinforcing

One possible method of accelerating the schedule time, whilst bringing costs down slightly as well, may be to re-engineer the reinforcing that is in the concrete. It may be possible to completely eliminate the welded wire fabric available in the elevated slabs, as they seem to only serve the purpose of reducing cracks due to shrinkage. This can be compensated for with an admixture that slightly lengthens the curing time. Also, if absolutely required in areas of negative moment (like the center) some rebar can be used instead, removing the need to reinforce the entire floor(s).

The value of this would be that less time will be needed while laying out the WWF and also, quality control issues can be addressed. That means that since it is not simple to lay out the WWF and ensure that it is not "wavy" along the slab, there would be less time brought to that issue's attention and more valuable time can be freed up. Also, it may be useless to the structure if the WWF is in fact placed incorrectly. So, this method will remove the cost associated to begin with.

Sub-Problem

Also, since the deck is composite, there will be shear studs in the concrete which will allow it to reduce the effects of shrinkage. So, another possible method of reducing cost would be to increase the GAGE of the metal deck, and through this reduce the number of shear studs. This amounts to less work on the site, and less that could go wrong. And, apart from reducing the cost, there will also be a decrease in schedule time to install all the studs, allowing the pouring of concrete to begin earlier and freeing up some time in the schedule.

Problem 5 – Drywall Prefabrication

In an effort to further improve the schedule, whilst slightly bringing the costs down, another prefabrication option may be explored. This option would be to use prefabricated drywall with all the equipment in the walls upon delivery. This would mitigate the amount of workers on site, it would allow for controlled quality control procedures with some of the more sophisticated wiring and electrical equipment. Also, all this work can be done while the steel is being erected, and will go in the building almost immediately after the decks have been poured, possibly shortening the schedule length by a sizeable amount.

The main problems will be transportation as both a time-factor and a cost to the project, but, with a project already under-budget, it would make sense to pursue as it would allow the building to be in service much sooner than previously anticipated.

Problem 6 – Subgrade Issues

With the amount of issues faced by the project team on the Moore Building Addition in terms of sinkholes, the money spent into mitigating their effects on the schedule could have been better used if there was a better risk analysis done to the area.

State College is not unfamiliar with sinkholes of this nature on their grounds, and, with proper assessment, the sinkholes could have been predicted. This, in turn, would allow resources to be spent on more important issues, and delays that may have appeared later on the project. Especially with one of the sinkhole taking 3 cubic yards of concrete to fill, the concrete could have been better used.

The issue on the Moore Building Site could have also been a little dangerous, as these sinkholes were quite common and some quite large. A better geotechnical analysis could have been implemented to save time and money on these issues.

Problem 7 – Occupancy Staging

During construction, the entire 6th floor of the Moore Building Addition would be occupied, with other floors being vacated throughout the beginning phases of construction. This staging could be an area of better coordination, as work must halt and resume based on the occupants. Also, since underpinning sometimes brings about issues, problems may have occurred, and there would have been no need to have occupants during such tasks.

Problem 8 – Structural Steel

The structural steel on the Moore Building Addition was and still is the most important critical path item. This is due to the fact that the structural steel opens the doors for every other subcontractor to begin putting work in place. However, with the two failed attempts to have the structural steel delivered early, it is possible that more could have been done to ensure its early delivery.

Had PSU bought the steel in advance for the structure, it would have eliminated the risk involved with the construction management firm in purchasing or ordering steel without a contract in place. Not only would this have saved schedule time, but no construction management firm overhead and profit would be incurred on the structural steel, which would reduce cost as well.

Problem 9 – BIM Coordination

BIM coordination is still in its development phases and has not reached the desired efficiency. However, there are quite a few buildings that have greatly benefitted from the implementation of BIM and these buildings are often used as an example and/or for research to better the options for BIM.

On the Moore Building Addition BIM has been used extensively, and the coordination is prime to keeping the project under budget and the schedule running smoothly. However, a well-coordinated BIM team does not come without its issues and problems. One of these was the time in which BIM was implemented; with construction documents almost 100% complete.

The ability to understand the timing of BIM could be beneficial in determining how its effect could have been better suited to the project and if its timely incorporation would have affected the schedule positively, and if it would have cost less money to operate.

Technical Analysis Methods

Topics discussed in this section are the most attractive options of the problems identified in the previous section. These are more elaborate with detailed outlining of how the analysis will be carried out.

Analysis 1: Demolition

The Moore building addition is set to tie into an existing structure of structural steel members. This existing structure is 13,000SF and will be stripped to its structural steel and concrete decks before any work can or will be done. This portion is called the North Wing.

This North Wing will undergo Asbestos removal and abatement during the "Demolition and Abatement" phase of construction. Most of this demolition and abatement phase will be from June 2010 to up until the beginning of September 2010. So, the process will take about 90 days to complete, and whilst that is part of the schedule, there may be room to accelerate the schedule by eliminating this process entirely.

Since the building is undergoing an addition as well as a renovation, it must be up to code when the renovation is done, and asbestos must be removed from the entire building. This portion of the schedule may be much easier to manage if the North Wing is completely removed. This North Wing can then be completely eliminated from the design, which also removes any design constraints involved with it. Or, the North Wing can be re-built, and that may save time and money used on asbestos preparation equipment as well as the actual removal of asbestos.

The analysis will be comprised of understanding the cost and schedule time involved with asbestos removal and abatement of the 13,000SF of the North Wing. This will be followed by understanding the cost and schedule time involved with building a structure consisting of 13,000SF and four floors. Furthermore, the cost of tying in the two buildings (although they are independent structurally) will be examined and included in the analysis. Finally, labor costs and equipment for both of these will be included for both processes and all this data will be compared.

As an addition, quality control issues involved with both processes will also be determined as there will still be tying in involved if the North Wing is built up from the ground up. However, that cost will be included as part of the original structure since the original structure is meant to tie into the rest of the building as well.

This method is aimed to reduce the overall schedule time necessary with constructing the building. It may also reduce the overall cost of the project to the owner. And as an additional sub-topic, the necessity of having a Geotextile Bentonite Waterproofing material will be examined and the cost of this included as part of the analysis.

Analysis 2: Façade

For the façade of the Moore Building Addition all masonry and panel work will be installed on site by masons. This is a time-consuming process that will produce large amounts of waste as well as congestion and possibly quality control issues. However, the most important part of this is the time factor.

This is the reason why a prefabricated façade system may be extremely beneficial to the Moore Building Addition; it will reduce the time taken for erecting the façade. This along with the added cleanliness of the site will allow the other trades to better navigate the site and reduce the risks involved with façade construction.

For this analysis, the cost and time taken to erect the type of façade on the Moore Building addition will be examined. Also, the time and cost it takes for a near-identical façade to be fabricated off site, as well as transportation time and costs involved with delivery will be examined. Finally, the time taken to erect the prefabricated façade will be taken into account, as well as the time in the schedule that it can be implemented (i.e. after first floor is constructed or after final floor is constructed).

This information will allow for an objective analysis as to how a prefabricated façade system can be more beneficial, and, if the cost savings (if any at all) could be used to further improve the efficiency of the building's glazing as an added incentive.

Analysis 3: BIM Coordination

BIM coordination is still in its development phases and has not reached the desired efficiency. However, there are quite a few buildings that have greatly benefitted from the implementation of BIM and these buildings are often used as an example and/or for research to better the options for BIM.

On the Moore Building Addition BIM has been used extensively, and the coordination is prime to keeping the project under budget and the schedule running smoothly. However, a well-coordinated BIM team does not come without its issues and problems. One of these was the time in which BIM was implemented; with construction documents almost 100% complete. The main problem with this is that the model required more work in order to be up to the standard in which it can be effectively used as a tool and not simply a marketing media. However, the architect had done a good job in making the model have a constructability purpose as well as a media in which it can showcase its design intents. This, however, meant that one of the parties involved had to update the model with all RFIs and Change Orders; a job neither party was very interested in being bound to, as these models become high maintenance.

The issues that have arisen on the Moore Building Addition can be considered time-consuming, costly and very un-necessary. This is because of lack of communication between all parties involved (architect, construction manager and owner). This lead to legal issues as well, which is not very pleasant for a situation like this.

This analysis would need to outline the benefits of having had the model implemented from the start, and the benefits it would bring to the construction team. Data would need to be collected on what would have happened if the legal documents were in place by the owner to organize the BIM portion of the project and pay for the model's rights and ownership. This would then be updated by parties appointed by the owner. So, this process may have taken down the communication barrier and prevented legal interferences.

More information would need to be collected on the processes involved in bringing in BIM from the planning phases of a building's life, and the impact that would have on the actual cost of the project (in terms of time and money).

In summary, the main data that would be required are the costs (time and money) of early introduction of a BIM team, added benefit to modeling process through comparisons of other similar projects owned and operated by the Pennsylvania State University (e.g. Hershey Cancer Institute), and the comparison to the actual cost of the building at this point, with all delays and monetary costs included.

Analysis 4: Structural Steel

The structural steel on the Moore Building Addition was and still is the most important critical path item. This is due to the fact that the structural steel opens the doors for every other subcontractor to begin putting work in place. However, with the two failed attempts to have the structural steel delivered early, it is possible that more could have been done to ensure its early delivery.

As a solution to this problem, more could have been done from the owner's side, especially because the operation of this building affects them the most and it would be an intelligent decision to pursue the option of purchasing the steel contract before even awarding the contract to the construction management firm.

The idea with this suggestion is that Penn State as an owner could, as a work order or contract, purchase the steel from the steel contractor before the rest of the bidding results and before even selecting a construction management firm to carry out the project. As the option to start the steel was explored by the construction management firm, it might have been wiser for Penn State to step in to aid their own project. Added benefits include zero risk involved for neither the owner nor the construction manager, as the project would already be funded and its design finalized. Another benefit would be that the construction management firm would add a smaller profit and overhead margin to the structural steel contract, as they incur much less risk with its contract. So, this would, in theory, reduce the time required to have steel delivered to the site, which would allow the steel to be erected earlier in the schedule, and, ultimately allow the building to be in service much sooner, which is appealing to the owner in this case.

Data would need to be collected on the time for fabrication, and delivery of the steel pieces as well as the possibility for phased delivery and the costs involved. There would also need to be a study to

understand the possibility for the owner to buy the structural steel and if that would be a viable option or not. Finally, the owner's perspective on the importance of having the project be completed early in contrast with the extra money spent (if required) and risk taken to have the structural steel arrive early on site in order to achieve an early finish.