The Pegula Ice Arena

University Park, PA

Technical Report III

November, 12 2012

Shane Marshall
The Pennsylvania State University
Department of architectural engineering
Construction Management Option

AE 481 W – Fall 2012
Faculty Advisor: Raymond Sowers

Executive Summary

The focus of Technical Report 3 is investigation into potential areas of research for the upcoming Spring semester of Senior Thesis. Technical Report 3 focuses in five areas of investigation. These areas are: a LEED Evaluation, Schedule Acceleration Scenarios, Value Engineering Topics, PACE Roundtable Ideas, and future Technical Analysis Options. This report was accomplished by attending the PACE Roundtable and by interviewing members of the Mortenson Construction project team on site at the Pegula Ice Arena.

An in depth LEED Evaluation was performed. The Pegula Ice Arena is on track to receive LEED Gold. There is still plenty to be accomplished in terms of LEED on this project that ultimately could make LEED Gold not able to be accomplished; however, if the project team needs to settle for LEED Silver, this still exceeds LEED Certified which is all Penn State is requiring for this project.

An investigation into potential acceleration scenarios was also done. It was discovered that overtime is certainly an option to accelerate the schedule as is getting crews into the site before winter arrives. The specific example given in this section is in regards to the curtain wall crew. Specific risks to the project completion date are the enclosure not being done for winter as well as a delayed scoreboard installment.

Value Engineering Ideas were also thoroughly researched. Accepted value engineering items such as the metal wall panels and fill site helped the schedule and cost of project significantly. There were also many value engineering ideas that were not approved which are detailed in this section of the report.

On November 6th, 2012, industry professionals came to Penn State to discuss industry trends within construction. There were many things learned that can potentially be utilized into a depth analysis; specifically, ideas regarding prefabrication were discussed in depth.

The last section of this report focuses on potential depths that can be utilized going forward into thesis. I am still in the process of gathering ideas but there are three potential ones that I am currently exploring. One is prefabricating the wall systems to include a brick façade. Another thought was to remove the community rink from the critical path which could theoretically save schedule time but would require a structural redesign. Lastly, I am considering sequencing the work differently. This method is detailed later in the report but improves the overall crane logistics, however, might not impact the schedule in a positive way.

Overall, many things were discovered, that will help moving forward into the proposal presentation and report.

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LEED Evaluation

The Pegula Ice Arena is currently aiming to achieve a LEED Gold Rating. LEED Gold requires 60 LEED certification points to be achieved. Pegula is set to be awarded exactly 60. Therefore, it is feasible that, upon completion, the project team may not be capable of achieving every point set out for, which theoretically could drop the project to a LEED Silver Rating. However, the owner, Penn State, only requires a LEED Certified Rating on new construction. Therefore, if the project does not achieve LEED Gold and has to settle for LEED Silver, the project will still have exceeded their minimum expectations.

Scorecard

Most of the categories are heavily utilized for the construction of the Pegula Ice Arena. The one category of LEED that is not being heavily utilized is Energy + Atmosphere. Energy + Atmosphere has 11 out of a possible 35 points being utilized where all other categories utilize at least half of the possible points on this project. However, this does make sense. A significant amount of energy needs to be input into something such as an ice arena in order to maintain proper ice and humidity control. Due to this high energy input most LEED points within Energy + Atmosphere were not achievable.

Table 1: LEED Scorecard

LEED Scorecard				
Y	**?**	**N**	**Point Category**	**Possible Points**
17	5	4	Sustainable Sites	26
6	4	0	Water Efficiency	10
11	5	19	Energy + Atmosphere	35
7	1	6	Materials + Resources	14
13	0	2	Indoor Environmental Quality	15
4	2	0	Innovation + Design Process	6
2	2	0	Regional Priority Credits	4
60	**19**	**31**	**Pegula Ice Arena**	**LEED Gold**

A Full Project Scorecard can be seen in Appendix A.

Detailed Scorecard Breakdown

Sustainable Sites	**Penn State Requirements**
Site Selection	**Minimal Effort**
Development Density + Community Connectivity	**Minimal Effort**
Since the building is to be used as an arena where public sporting events are to take place, it is considered a building a community connectivity.	
Alternate Transportation – Public Transportation	**Minimal Effort**
Penn State provides a public bus transportation system around the entire university.	
Alternate Transportation – Bicycle Storage + Changing Rooms	**Significant Effort**
Alternate Transportation – Parking Capacity	**Minimal Effort**
Storm water Design – Quantity Control	**Mandatory**
Heat Island Effect – Roof	**Significant Effort**
Penn State requires significant effort in regards to this since the price of highly reflective roofing (TPO) comes at a relatively inexpensive cost.	

Water Efficiency	
Water Efficient Landscaping	**Minimal Effort**
Water Use Reduction	**Minimal Effort**

Energy + Atmosphere	**Penn State Requirements**
Optimize Energy Performance	**Mandatory**
Penn State requires this be achieved on some level. A proposed energy simulation narrative was proposed for the electrical system and an energy model was provided to prove its plausibility.	
Enhanced Commissioning	**Mandatory**
Enhanced Refrigerant Management	**Mandatory**
Another Penn State mandatory LEED credit. This ensures that the refrigerant used pollutes the ozone less than the standard.	
Green Power	**Mandatory**
Materials + Resources	
Construction Waste Management	**Mandatory**
Penn State mandatory credit that requires construction on the university's campus to recycle non-hazardous materials.	
Recycled Content	**Mandatory**
10 to 20 % of material must be made from recycled material.	
Regional Materials	**Mandatory**
10 to 20 % of material must be extracted, harvested, or recovered within 500 miles.	
Certified Wood	**Mandatory**

Indoor Environmental Quality	**Penn State Requirements**
Outdoor Air Deliver Monitoring	**Mandatory**
Construction IAQ Management Plan (Construction)	**Mandatory**
Construction IAQ Management Plan (Post-Construction)	**Mandatory**
Mandatory Penn State LEED point which requires an Indoor Air Quality Management Plan for the building opening which includes a system flush out to remove any dust from any ductwork.	
Low-Emitting Materials - Adhesives + Sealants	**Mandatory**
Low-Emitting Materials - Paints + Coatings	**Mandatory**
Low-Emitting Materials - Flooring Systems	**Mandatory**
Low-Emitting Materials - Composite Wood	**Mandatory**
Indoor Chemical + Pollution Source Control	**Mandatory**
Constructability of Systems - Lighting	**Mandatory**
Constructability of Systems - Thermal Comfort	**Significant Effort**
Thermal Comfort - Design	**Significant Effort**
Thermal Comfort - Verification	**Mandatory**
Daylight and Views	**Minimal Effort**
Significant effort was used to ensure that day lighting could be maintained in at least 75 % of the occupied spaces.	

Innovation + Design	**Penn State Requirements**
Innovation in Design – Green Cleaning	**Minimal Effort**
Innovation in Design - Education	**Minimal Effort**
After construction, Penn State will give regular tours explaining the history of the ice hockey program and some of the oddities within the innovation in design of the ice cooling system.	
Innovation in Design – Ice Generation	**Minimal Effort**
LEED Accredited Professional	**Minimal Effort**

Regional Priority Credits	
Regional Priority – SS C.4.4 – Alternative Transportation	**Minimal Effort**
Regional Priority – WE C.1 Water Efficient Landscaping	**Minimal Effort**

Schedule Acceleration Scenarios

The Pegula Ice Arena is sequenced in a way where construction starts on the X9 line located along the southern portion of the building. Reference Figure 1. This is essentially where every trade starts work on site. Therefore, this portion of the building ultimately drives the critical path. Every trade needs to start on time in this portion of the building in order to maintain the schedule.

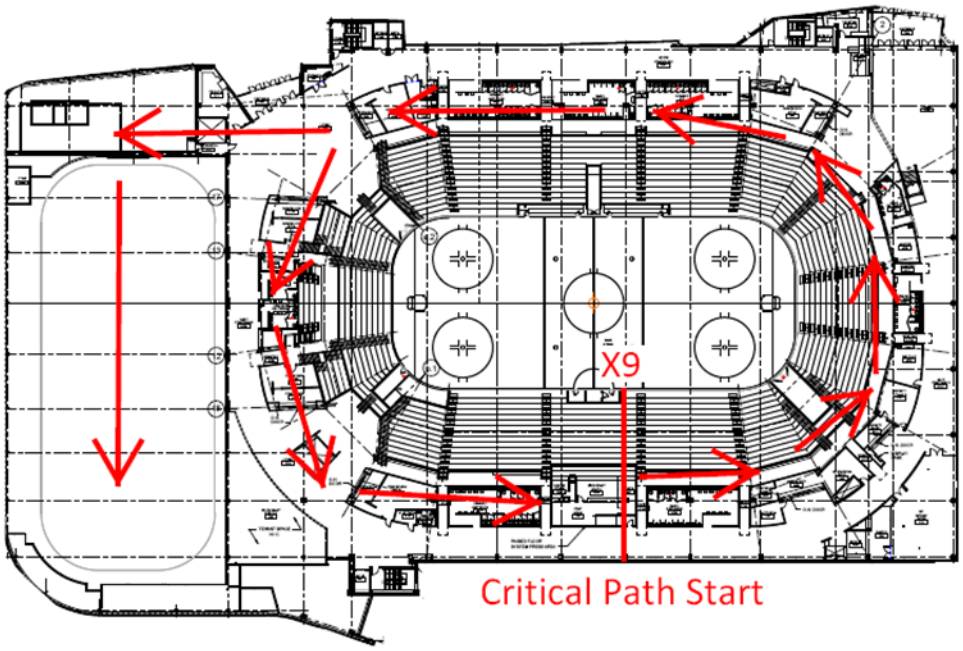

Figure 1: Work Sequence

The critical path activities include site work, concrete, steel, rough-in, enclosure, finishes, and closeout items. All of these items must start on the appropriate date, along X9 in the south, in order to ensure the building is finished on time.

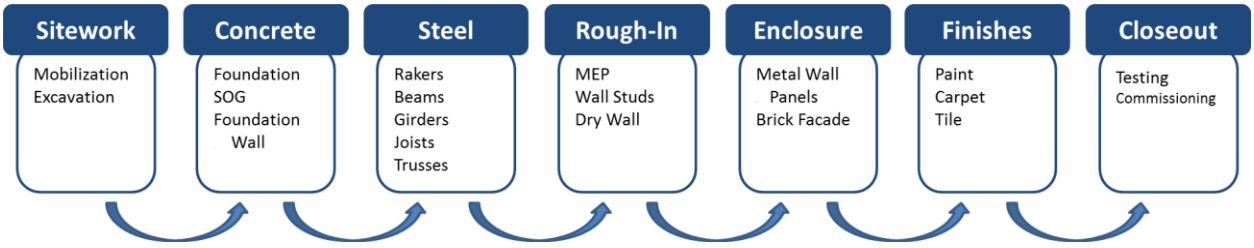

Figure 2: Critical Path

Risks to the Project Completion Date

Enclosure – The enclosure is probably the biggest risk to the project completion date. The reason this is such a critical item is that in order to begin most finish work the building must be enclosed. Some finishes can commence before the building is water tight but two systems must be in place to ensure temporary heat can be utilized. These systems are the metal wall panels, and the metal deck for the roof. The wall panels started slowly but now have made up ground and seem to be on pace so that temporary heat can be used. The largest area of concern, to ensure building enclosure occurs before winter, is the metal deck. The topping off ceremony occurred last Friday which should allow the steel crew to still successfully lay all roof metal deck but this does need to be finished by the 26th of November.

It should be noted that there is brick tied to a CMU backing around the community rink, but all CMU is already installed meaning the community rink has already been enclosed.

Scoreboard – The successful installation of the scoreboard is a large risk to ensure the project is completed on time. This building is especially difficult to test and commission due to the uniqueness of it. There are many systems that need to be tested, specifically in regards to ice rink cooling. In order to have enough time to test this the ice rink mechanical contractor has to begin with the underground work in the rink on time. In order to ensure this crew can get inside the rink on time the scoreboard has to be in place.

The scoreboard is a piece of equipment that only gets one shot to be installed properly. Therefore, proper planning must be done to ensure that the scoreboard can properly be in place by January 18th, 2013. The scoreboard equipment must also be tested, to the extent it can be, before the pieces show up on site to ensure that work does not need to be performed more than once because there simply is not space in the schedule for this to happen.

Schedule Acceleration Scenarios

Increased Workforce and Overtime – These are two ways to accelerate basically every project. Increasing the work force is always something that can be done. Unfortunately, there typically is a proper amount of workers for every task. Exceeding this number will decrease the productivity per team member even though it will ultimately move the project along faster. Paying more people for less productivity at times needs to be done but is never truly beneficial.

Overtime is something that can also be done. However, there are many problems that can be associated with overtime. For starters, overtime can decrease overall productivity. People usually can initially maintain productivity, however, the more overtime people are asked to work the more productivity goes down. Saturday overtime also usually sees major loss of productivity. Usually people are ready to leave by noon and really decrease their rate of work for the rest of the day.

Safety also becomes a concern with overtime. When people stop paying attention and lose focus during work, this can cause very stupid accidents to occur, such as tripping and pinched fingers. Although, these types of injuries are not typically detrimental to a person's long term health, they still absolutely cost a company major expenses in the form of medical bills.

Overall, large amounts of overtime have very serious cost implications to a project. Not only is overtime pay required, there is also the fact that you are paying more for less work due to productivity loss, and safety implications can also cost a company serious amounts of cash.

Soffit – The curtain wall crew is going to arrive this week. The main reason they were unable to arrive sooner was because there was not a soffit yet installed at the roof. The schedule could have been rearranged to allow this soffit to be installed much sooner. Installing this soffit sooner would have allowed the curtain wall crew to already be done and out of the way. The closer winter gets the more safety concerns there are going to be. Therefore, the curtain wall crew is going to have to be much more careful when installing the curtain wall which will directly result in a time loss. Having installed this soffit already and having got the curtain wall going and possibly finished would have simply just got rid of another hazard and another crew on site which would have logistically freed up the east side of the sight which is a highly trafficked area.

Getting crews on and off site as quickly as possible is extremely critical to the overall schedule. Had the crew been on site earlier they would not have been in the way and work could potentially have already been finished that is now just beginning.

Value Engineering Topics

Value engineering is the process of determining the actual value when comparing cost, schedule, and design. Most often this process incorporates the construction management team and design team to determine the maximum value the owner can receive for construction. During preconstruction, both teams collaborated and came to an agreed upon list that would most benefit the owner. Listed below are some of these ideas that were presented.

Approved Value Engineering Ideas

Prefabricated Metal Wall Panels – The wall panels were one of the more innovative value engineering items. This includes building prefabricated metal wall panels in 10 foot lengths approximately, and then erecting them with a crane. This idea was important to Mortenson. They need to have the building largely enclosed by winter to ensure they can properly start applying some of the finishes. Therefore, prefabricating these panels allows for a much quicker erection which makes it possible to get the building enclosed. This system also came out essentially to be the same price as stick building which made it a good value engineering issue. At the PACE Round Table John Bechtel, of OPP, mentioned specifically the continued interest Penn State has in prefabricating systems to increase safety, schedule, and cost. This made this particular value engineering beneficial to all parties.

Figure 3: Prefabricated Metal Wall Panels

Floor Upgrades – Ultimately, at the summation of the project, the building will be turned over to Penn State whom will have to maintain it. Because of this the architect suggested two different floor upgrades. At two of the entrances, areas of high traffic, it was decided that terrazzo should be used. Also, in the strength room mondo flooring was added. Both of these floors were added from a maintenance stand point. The expected life cycle of adding of the floors proved beneficial even though the upfront cost of these floors is significant.

Vomitory Wall Foundation – Additional foundation was added to the southwest vomitory wall entering into the main rink. The construction team decided this area was needed to move heavy equipment in and out of the rink. Specifically, trucks and hydraulic cranes need access through this area to support construction. Therefore, due to expected increases in weight at this location the foundation needed to be upgraded.

Lean Fill Allowance – Typical of construction around University Park is that deep foundations are required. This is true of the Pegula Ice Arena as well. However, certain areas areound the building are not heavily loaded and can therefore rest on continuous footings. The one contingency associated with this, is that these footings need a layer of lean fill underneath them to help distribute the loads. There was approximately $75,000 dollars to make this accommodation but this was still cheaper than using deep foundations at these locations.

Fill Site – The decision to utilize a fill site is one of the most beneficial value engineering items that was approved. There was a large amount of dirt that needed removed off site. Ultimately some of this material needed to be used as backfill along the walls. In order to ensure the excavation contractor, Hawbaker, could constantly truck dirt off and on site in a quick fasion, it was required that there be a nearby fill site in which they could store dirt. Therefore, Penn State agreed to rent space to Hawbaker, at one of the tailgating fields near the stadium. This allowed for a faster schedule and significantly decreased the cost of moving excavated earth.

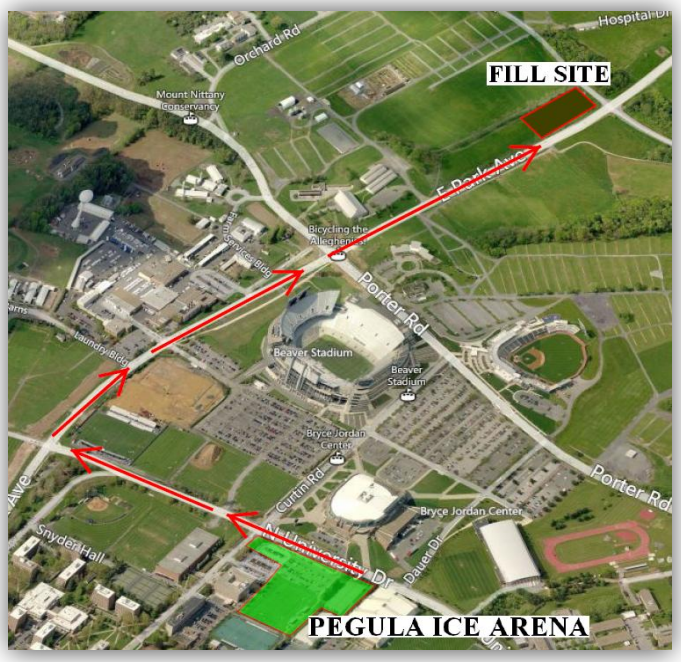

Figure 4: Fill Site

Declined Value Engineering Ideas

Skate Lines – The design team created a decorative pattern at the major entrances of the building where terrazzo is being utilized. Crawford, the architect designed a pattern, which makes the floor appear to have skate lines running through it to follow along with the buildings theme. Crawford proposed the same idea with some of the site concrete along the perimeter of the building. Ultimately, Penn State did not see the value in doing that.

Winter Heat Enclosure – When initially reviewing the schedule, Mortenson was afraid that the fire proofing would not yet be completed by the beginning of winter. Therefore, they requested that Penn State add in an allowance for the possibility of temporary heating for the fire proofers. Ultimately, Penn State rejected this idea which required Mortenson to have the fireproofing follow the steel finishers very closely.

Dasher Board System Along Community Rink – Penn State had made clear they wanted two rinks built at this site. Crawford suggested that both rinks have the capability of playing high school level hockey games and higher. In order to properly do this, dasher boards would be required around the perimeter of the rink. Crawford proposed ways that would make them removable and posed how to stand temporary ones around the community rink, but ultimately Penn State decided against it. Penn State only wants junior level games be played here, ice ballets be performed, and public skating be done at the community rink.

Partnership for Achieving Construction Excellence Round Table

The 21st Annual Partnership for Achieving Construction Excellence was focused around "Improving Efficiency through Innovation." It was held November 5th - 6th at the Penn Stater Conference Center Hotel.

The day consisted of four events. The first was a student panel discussion which focused around the BIM studio class and the benefits surrounded with the team collaboration incorporated into this class. After the student panel the day continued with industry breakout sessions. The different breakout sessions can be seen in Table 2.

Table 2: PACE Breakout Sections

	Supply Chain	Efficient Delivery of Services	Operations and Maintenance
11:00 a.m. to 12:00 p.m.	Integrating Strategies and Technologies	Measuring Effective Collaboration	Energy + BIM
1:15 p.m. to 2:30 p.m.	Modularization	Efficient use of Integrated Design	Model Handover

It was decided that I would attend the supply chain breakout sessions. The reasons for choosing these sections was that they spurred the most interest as well as being the most likely to assist with thesis ideas. Integrative approaches to construction does interest me but would be hard to translate to an actual thesis research idea for the Pegula Ice Arena. BIM, on the other hand, could certainly be a great research topic to explore further within the Pegula Ice Arena, however, I have no future plans of becoming a virtual design coordinator and subsequently decided against attending the Operations and Maintenance breakout sessions.

The last portion of the day consisted of a focus group which consisted of small groups of students and one industry professional to discuss thesis ideas.

Notes from the 21st Annual PACE Round Table can be seen in Appendix B.

Student Panel

Recently, the Penn State Architectural Engineering curriculum has added a focus of collaboration and integration. The program has done this in many ways but has really experimented with it in BIM Studio and Senior Design. At the round table 4 students, Alexander Byard, Matthew Hoerner, Brian Lachance, and Andrey Penov, answered questions from Professor Robert Holland about the advantages of these classes.

The first topic of discussion was the student's opinion of how they learned about areas of study, outside construction management, and whether they learned more or less as compared to the more traditional path of independent research. Matthew Hoerner described that he greatly benefitted from having people with more expertise in areas of construction outside management. He explained that through the collaborative effort, he grew an understanding of why systems must work the way they do. He did admittedly make the point that he works best in teams and that not everyone would need a team atmosphere with help when doing research.

The second interesting discussion point was the structure of leadership within the groups. Alex Byard explained that although everyone took responsibility for their work, the Architect had to really take the bull by the horns. He explained that everything more or less started with the Architect and the designs he/she presented to the project team. After this design was established the rest of the project team was capable of getting their hands on the drawings and model and discuss with the architect areas of potential improvement and areas that simply needed changed. Alex did go on to explain that as a construction management representative he was largely responsible for pushing the process along and establishing deadlines.

The discussion was also opened to the floor. One of the questions was how much change was thrown the students way throughout the process. Professor Holland actually spoke up and implied very little. Brain Lachance quickly spoke up and agreed that there is not change in terms of change orders, but that the design was a continuously changing part of the process which required reworks in schedule and estimating quite frequently. Another question came in regards to whether a budget is established. The program has considered this but ultimately decided against it due to possible stifling of creativity.

Andrey Penov spoke on behalf of the experience with group dynamics. Most of the AE students know and understand one another, but bringing in Architecture students created interesting situations. Andrey explained that there were clashes between the architect and the rest of the students, but through these situations he genuinely learned a lot. He learned where to pick his battles and where to give in. He learned how to properly fight within the construction business.

Key Lessons Learned:

- Conflict can be good. It can produce effective design.
- There is the potential to learn more when individuals have expertise in different areas of construction.
- The course helps students present professionally in front of a jury.
- The course teaches students how to defend ideas.

Breakout Session 1: Integrating Strategies and Technologies

The first breakout session attended focused on integrating strategies and technologies within the supply chain. Within this topic, the reasons supply chain is a problem and existing innovative technology that could potentially help resolve these issues were discussed.

The first discussion point arose from the difficulty procuring items from other countries. Specifically mentioned was the immense language barrier that comes with this. Along with this comes a cultures different schedule as well as a potential significant time lag. It is very possible that while Americans begin work other countries are just heading to sleep. Ultimately, procuring items from other countries is difficult. The best way to deal with this is to spend the money to make a site visit. Pictures can be a very powerful tool, but seeing a company's operation and ensuring that products that have been ordered are in good shape, free of damage, and possibly ready to be delivered is critical.

The next discussion point focused on the procurement process. Certain items have long lead times that must be procured immediately after the project has been awarded. This requires quick submittal time turnaround which must be meticulously managed from a construction standpoint. Another procurement items arises when certain items must be procured at the very end of a project. This can often happen in hospitals where they want the latest and greatest items. The specific issue with this comes in the form of design. Often times architects will plan for specifically sized equipment which when changed can cause spacing issues. This can force the architect to focus on small redesigns which can potentially delay construction. Issues like this will always arise but early involvement and communication can help minimize this issue.

The last discussion focused on inaccurate material deliveries. This is a common problem that can cause issues with schedule and cost. One suggestion for resolving this issue were that proper management and tracking must be done. Spreadsheets must be created that detail which products have been fabricated and delivered. Another suggestion for resolving this issue was a bit more innovative. This process included tagging all materials with bar codes that must be scanned upon arrival on site. The example given was with door hardware. It is not uncommon for multiple door frames to show up mixed together and not in perfect sequence. However, with the tags as the frames are unloaded they must be scanned which then identifies specifically how many and what type of frames are on site. This not only helps ensure that the schedule will stay on pace but also can save money for subcontractors. Specifically, it was mentioned that one subcontractor enjoyed using the bar code method because he/she never ordered double of the same frame. It can at times be difficult to manage all of the material and this particular subcontractor would often look for door hardware and not find what he/she was looking for and then a week later find the part only after already ordering a duplicate. However, with the barcode tag he/she knew exactly what material was on site.

Breakout Session 2: Modularization

The second breakout section focused on modular construction. This was of particular interest to me since modular construction and prefabrication are industry trends that I am considering exploring for a thesis research topic.

The first topic focused on different examples of prefabrication. Some of the common forms of prefabrication included formwork, curtain walls, casework, and brick facades. An employee of Southland Industries was in attendance and discussed some of the interesting prefabrication they have been involved with. He discussed how MEP work has moved into entire racks being built, transported, and subsequently installed only once in walls and overhead. He mentioned very recently that drywall has even begun being installed with the wall systems and ceilings. This truly streamlines the process and allows finishes to quickly follow.

Another topic discussed at length was a cost benefit analysis of utilizing prefabrication. Recently in Professor Dubler's Building Construction Management and Control class he had Ted Border of Whiting Turner detail one of the buildings he has worked on that utilized significant modularization. Whiting Turner modularized the construction of 5 dormitories. They accomplished the enclosing, framing, and applying dry wall in only two weeks for these 5 buildings. However, this nearly doubled the cost of construction. With this information it spurred the discussion of just when it is worthwhile to utilize prefabrication. Moving forward it important that with any research the cost is acknowledged equally when compared to the construction schedule.

The final topic involved many of the issues with prefabrication. Some of the challenges involved with prefabrication include the absolute necessity of early subcontractor involvement, constructability, site logistics, transportation, tolerances, and design when the prefabrication is exposed. These topics must all be addressed if any sort of prefabrication is to be an area of research.

Focus Group

The focus group was the last item on the itinerary. Brandon Tezak, Ghaith Yacoub, and myself met with industry professional Jeffrey Angstadt of Foreman. Throughout discussions, we proposed several ideas, with regards to potential thesis topics, to Mr. Angstadt in hopes that he could provide direction as to how ways to approach these ideas and problems that may be encountered. Mr. Angstadt provided a lot of valuable information and possible contacts for future information. These topics discusses with Mr. Angstadt will be covered in detail in section "Problem Identification and Technical Analysis Options." Contacts that will be utilized moving forward are listed in Table 3.

Table 3: Contacts for Thesis Research

Contact	Company	Research Area
Jeffrey S. Angstadt	Foreman Program and Construction Managers	Prefabrication
Heidi Brown	Mortenson Construction	Schedule Guidance
Jason Brown	Mortenson Construction	Site Logistics
Kyle Guenther	Mortenson Construction	Safety Hazards
Gene Hodge	Mortenson Construction	Business Development
Steve Laurila	Mortenson Construction	Cost Impacts
Sam Thayer	Mortenson Construction	General Field Guidance
John Bechtel	Pennsylvania State University	Owner Concerns
Marv Bevan	Pennsylvania State University	Owner Concerns
Raymond Sowers	Pennsylvania State University	General Guidance

Problem Identification and Technical Analysis Options

Prefabrication

Depth

Prefabricating the brick façade is an area of potential exploration. There are two ways to approach this. What could be of most interest is to determine a way in which the brick façade could be attached to the metal wall panel system. When speaking with Heidi Brown, project manager with Mortenson, she explained that she had never seen brick attached to a metal stud system. Therefore, there would need to be much research done to see if this is possible. The weight would be an issue that needs explored; whether during transport and and lifting the structure would be stable enough that nothing would break or crack would need explored; and finally the logistics of having a framing contractor and masonry contractor come together in a central plant and who would ultimately be responsible for the structure once it showed up on sight would need explored.

The second way to approach this is to design the wall with a thin layer of brick embedded into concrete. This method is often done which was talked about at length with Jeff Angstadt at the PACE Round Table. He is in the process of providing contact information with an employee of High Concrete. High Concrete specializes in prefabricated systems such as this and they could provide insight as to how this building process works.

Breadth

The obvious breadth associated with prefabricating the brick would be an architectural one. The important architectural feature to focus on would be the design at the joint. There are systems that just use an expansion as well as systems that leave a large gap where then a decorative brick pattern that protrudes out from the building. Within these panels it must be determined the most appropriate way to pattern the brick to match either the expansion joint, gap, or other architectural design.

Sequencing #1

Depth

In speaking with Heidi Brown, she mentioned that one of the areas she would have been interested in potentially sequencing differently is the work between the main rink and community rink. The community rink section of the building has very little finish work that needs done. The only significant section of much work within this part of the building is located within the mechanical room. Therefore, removing the community rink off the critical path of work could be beneficial.

Sequencing the work in a way that would focus on the main rink and then later come back to build the community rink would allow the steel crew to focus solely on swinging the steel and precast stadia for the main rink. The main rink has many activities that follow the steel where the community rink does not. This could come with a schedule acceleration scenario as well as potential cost benefits. However, it does present issues within other breadths.

Breadth

The issue that comes out of sequencing the work this way is associated with the structure. The community rink utilizes joists that span into the structure supporting the main rink. These joists partially support the air handling units which are largely located on the roof in this portion of the building. This then would require a structural redesign. The structural redesign would have to pay particular attention to vibratory implications being that they are located directly under heavy machinery.

The second breadth which could be explored is an architectural one. The structural redesign would force some sort of angle braced system over the community rink which would significantly change the looks of the community rink. Therefore adjustments would need to be made to match the design look around the entirety of the rink.

Sequencing #2

Depth

There is another area that I am interested in sequencing differently to see the potential schedule impacts that could result. Mortenson started activities in the center of the building along the south most portion of the building. They then left a slab unfinished at this location to allow the crane to escape from the building. I am interested to sequence the building so that the first section of the building starts further west and then works counter clockwise leaving a space for the crane to head into the community rink eventually and erect that. Before the crane left the main rink the overhead trusses would be installed and then as the crane was backing out it would pick and set the steel and precast for that last section. This would require extensive research into the schedule and the determining that no critical path items are significantly altered.

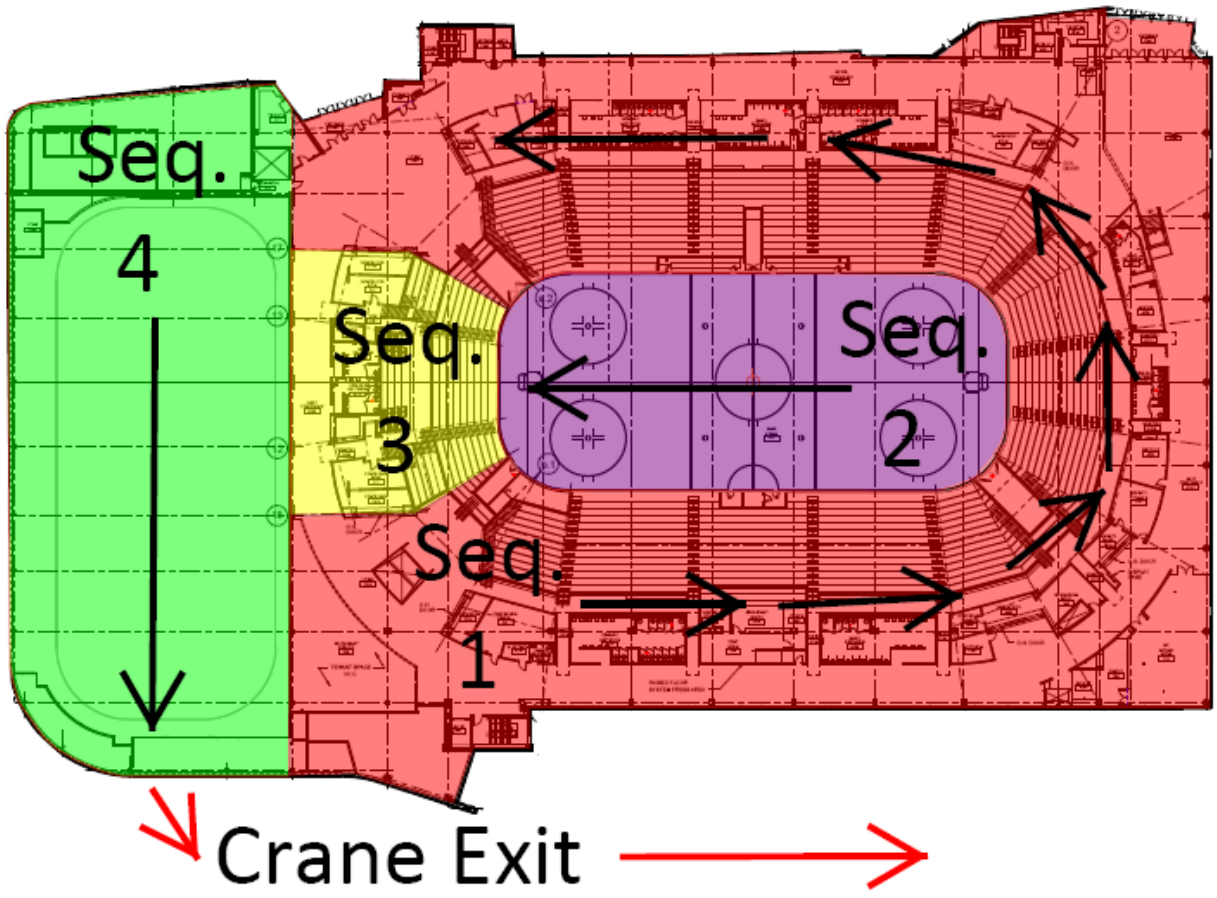

Figure 5: Sequencing

Appendix A: Project Scorecard

Yes	?	No	Sustainable Sites	Possible	PSU Requirements
17	5	4		26 Points	
Y			Prereq 1 Construction Activity Pollution Prevention	Required	Mandatory
1			Credit 1 Site Selection	1	Minimal Effort
5			Credit 2 Development Density + Community Connectivity	5	Minimal Effort
		1	Credit 3 Brownfield Redevelopment	1	Minimal Effort
6			Credit 4.1 Alternate Transportation - Public Transportation	6	Minimal Effort
1			Credit 4.2 Alternate Transportation - Bicycle Storage + Changing Rooms	1	Significant Effort
		3	Credit 4.3 Alternate Transportation - Low-Emitting + Fuel-Efficient Vehicles	3	Minimal Effort
2			Credit 4.4 Alternate Transportation - Parking Capacity	2	Minimal Effort
	1		Credit 5.1 Site Development - Protect or Restore Habit	1	Minimal Effort
	1		Credit 5.2 Site Development - Maximize Open Space	1	Significant Effort
1			Credit 6.1 Stormwater Design - Quantity Control	1	Mandatory
	1		Credit 6.2 Stormwater Design - Quality Control	1	Significant Effort
	1		Credit 7.1 Heat Island Effect - Non-Roof	1	Minimal Effort
1			Credit 7.2 Heat Island Effect - Roof	1	Significant Effort
	1		Credit 8 Light Pollution Reduction	1	Not Pursued

Yes	?	No	Water Efficiency	Possible	PSU Requirements
6	4	0		10 Points	
Y			Prereq 1 Water Use Reduction - 20% Reduction	Required	Mandatory
4			Credit 1 Water Efficient Landscaping	2 to 4	Minimal Effort
	2		Credit 2 Innovative Wastewater Technoligies	2	Minimal Effort
2	2		Credit 3 Water Use Reduction	2 to 4	Minimal Effort

Yes	?	No	Energy + Atmosphere	Possible	PSU Requirements
11	5	19		35 Points	
Y			Prereq 1 Construction Activity Pollution Prevention	Required	Mandatory
Y			Prereq 2 Site Selection	Required	Mandatory
Y			Prereq 3 Development Density + Community Connectivity	Required	Mandatory
5	5	9	Credit 1 Optimize Energy Performance	1 to 19	Mandatory
		7	Credit 2 On-Site Renewable Energy	1 to 7	Not Pursued
2			Credit 3 Enhanced Commissioning	2	Mandatory
2			Credit 4 Enhanced Refrigerant Management	2	Mandatory
		3	Credit 5 Measurement + Verification	3	Not Pursued
2			Credit 6 Green Power	2	Mandatory

Yes	?	No	Materials + Resources	Possible	PSU Requirements
7	1	6		14 Points	
Y			Prereq 1 Storage + Collection of Recyclables	Required	Mandatory
		3	Credit 1.1 Building Reuse - Maintain Existing Walls, Floors, and Roof	1 to 3	Minimal Effort
		1	Credit 1.2 Building Reuse - Maintain 50% of Interior Non-Structural Elements	1	Minimal Effort
2			Credit 2 Construction Waste Management	1 to 2	Mandatory
		2	Credit 3 Materials Reuse	1 to 2	Minimal Effort
2			Credit 4 Recycled Content	1 to 2	Mandatory
2			Credit 5 Regional Materials	1 to 2	Mandatory
	1		Credit 6 Rapidly Renewable Materials	1	Minimal Effort
1			Credit 7 Certified Wood	1	Mandatory

Yes	?	No	Indoor Environmental Quality	Possible	PSU Requirements
13	0	2		15 Points	
Y			Prereq 1 Minimum Indoor Air Quality Performance	Required	Mandatory
Y			Prereq 2 Environmental Tobacco Smoke (ETS) Control	Required	Mandatory
1			Credit 1 Outdoor Air Delivery Monitoring	1	Mandatory
		1	Credit 2 Increased Ventilation	1	Not Pursued
1			Credit 3.1 Construction IAQ Management Plan (Construction)	1	Mandatory
1			Credit 3.2 Construction IAQ Management Plan (Post-Construction)	1	Mandatory
1			Credit 4.1 Low-Emitting Materials - Adhesives + Sealants	1	Mandatory
1			Credit 4.2 Low-Emitting Materials - Paints + Coatings	1	Mandatory
1			Credit 4.3 Low-Emitting Materials - Flooring Systems	1	Mandatory
1			Credit 4.4 Low-Emitting Materials - Composite Wood	1	Mandatory
1			Credit 5 Indoor Chemical + Pollution Source Control	1	Mandatory
1			Credit 6.1 Constructability of Systems - Lighting	1	Mandatory
1			Credit 6.2 Constructability of Systems - Thermal Comfort	1	Significant Effort
1			Credit 7.1 Thermal Comfort - Design	1	Significant Effort
1			Credit 7.2 Thermal Comfort - Verification	1	Mandatory
1			Credit 8.1 Daylight and Views	1	Significant Effort
		1	Credit 8.2 Daylight and Views	1	Minimal Effort

Yes	?	No	Innovation + Design Process	Possible	PSU Requirements
4	2	0		6 Points	
1			Credit 1.1 Innovation in Design - Green Cleaning	1	Minimal Effort
1			Credit 1.2 Innovation in Design - Education	1	Minimal Effort
	1		Credit 1.3 Innovation in Design - Waste Stream	1	Minimal Effort
1			Credit 1.4 Innovation in Design - Ice Generation	1	Minimal Effort
	1		Credit 1.5 Innovation in Design	1	Significant Effort
1			Credit 2 LEED Accredited Professional	1	Minimal Effort

Yes	?	No	Regional Priority Credits	Possible	PSU Requirements
2	2	0		4 Points	
1			Credit 1.1 Regional Priority - SS C.4.4 - Alternative Transportation	1	Minimal Effort
1			Credit 1.2 Regional Priority - WE C.1 Water Efficient Landscaping	1	Minimal Effort
	1		Credit 1.3 Regional Priority - WE C.2 Innovative Wastewater Treatment	1	Minimal Effort
	1		Credit 1.4 Regional Priority -	1	Minimal Effort

Yes	?	No	LEED Credits	Possible
60	19	31		110 Points

Platinum = 80 to 110
Gold = 60 to 79
Silver = 50 to 59
Certified 40 to 49

Appendix B: PACE Notes

Student Name Shane Marshall

Session #1

Topic: Integrating Strategies & Technologies

Research Ideas:

(1) Systems/Programs that yield the most beneficial to the procurement process.

(2) Working/Procuring items from different countries

Session #2

Topic: Modularization

Research Ideas:

(1) Cost/Benefit analysis to using prefabrication (Include Safety)

(2) Prefabrication of brick Facade onto Metal wall panel system at Pegula.

Student Panel

Industry Panel: Differentiation in a Down Economy

Research Ideas:

(1) How to fight & defend ideas without the construction industry

(2) The ways in which conflict can benefit the overall construction process

Student Form *Pg. 1*

Industry Member Discussion

Key Feedback:

Which research topic is most relevant to industry? What is the scope of the topic?

The prefabrication seemed most relavent to the industry& more particular to potential research ideas within thesis. Talking to Jeff Angstadt of Foreman; he provided insight into possible ways of prefabricating the brick onto the metal wall panels & some of the concerns that would be associated with doing that.

Suggested Resources:

What industry contacts are needed? Is the information available?

Jeffs Angstadt told me he would assist further with any questions I might have in regards to a prefabricated brick facade. He also mentioned that he would give contact information of someone from Hugh Concrete, whom specialize in prefabricated facades.

-Team members of Mortenson & Penn State are also important to have

Student Form *Pg. 2*