Technical Assignment #3

* Front elevation rendering photo provided by Alexander Building Construction

George Andonie
Construction Option

AE Faculty Consultant:
Rob Leicht

November 15th, 2013

Executive Summary

The purpose of this technical report is to identify areas in the Geisinger Grays Woods Ambulatory Care Campus project that are good candidates for research and further evaluation. Through the exploration of potential acceleration scenarios, value engineering, and applications of critical industry issues, several ideas for technical analyses were derived.

Even through there was no emphasis by the owner to accelerate the schedule, several acceleration scenarios were identified through careful analysis of the project's critical path. Prefabricating the building enclosure and interior MEP spaces are some potential approaches to reduce the project schedule. Risks to completing the project on time were also analyzed on this report, mainly focusing on equipment procurements and installation.

Alexander Building Construction worked along with multiple trades to identify key areas value engineering areas in the project, with the purpose of providing cost effective solutions while preserving o improving the overall quality of the end product. Some of the key value engineering efforts applied to this project included the removal of the forms for the building foundation, removing the metal screening wall on the southern side of the building's roof, and changing the roof from Thermoplastic Polyolefin (TPO) to Ethylene Propylene Diene Monomer Rubber (EPDM) roofing. This provided over $157,000 total cost savings to the owner. Although other value engineering ideas were proposed by different trades, they were rejected by the Architect as they failed to improve the building's function while reducing cost.

Lastly, many of the critical industry issues discussed at the 22nd Annual PACE Roundtable Discussion were studied in this report. Through two break-out sessions, students and industry professionals shared thoughts on key industry issues regarding the integration of building planning, design, construction, and operation. The two sessions attended were "Information Management for the Workforce" and "Criteria and Drivers for effective Multi-trade prefabrication and Modularization", and a brief summary of the results are present in this report. These topics were analyzed for research areas feasible to the Grays Woods Ambulatory Care Campus, as well as this technical report.

Attending the different sessions allowed students to develop different ideas of possible areas of study. One idea that stemmed from these discussions was the use of prefabrication/modularization in the Ambulatory Care Campus in order to reduce the project schedule. Also, the idea of using virtual mockups to perform design reviews for the operating and endoscopy rooms in the facility was analyzed. These were later discussed with an industry professional in order to receive feedback based on their experiences in the industry.

Taking these analyses along with the previous technical reports into account, several research topics will be developed later on. These will be studied in order to implement alternative methods to improve upon their efficiencies, cost, quality and schedule for the construction of the Geisinger Grays Woods Ambulatory Care Campus.

Table of Contents

Project Manager Interview

In order to better identify various areas of the project that are good candidates for research, I interviewed the project manager for the Gray's Woods Ambulatory Care Campus, Douglas Workman. Douglas has been working for Alexander Construction for over two years and has various years of experience in the construction industry. Being this his second project with Alexander Construction, Douglas has done a pretty good job in keeping the project on track while aligning with Geisinger's goals. Various questions regarding schedule acceleration scenarios and value engineering were asked in order to identify problematic areas in the project and opportunities for technical analyses for my senior thesis project.

Schedule Acceleration Scenarios

Critical Path:

The critical path of the schedule, as illustrated in Figure 1, runs primarily between the three components of this project. As mentioned in the past technical reports, this project consists in the construction of a three tier parking garage, the demolition of the temporary parking lot, and the construction of the new building addition. The construction of the precast parking garage is what mainly drives the schedule for this project, as it delineates when the construction for the new addition begins. Any advancement or delay during this phase would ultimately impact the substantial completion date of the project. By code, there has to be a certain amount of parking spaces serving the existing phase of this Ambulatory Care Campus. Because of this, the new addition being constructed over the existing parking lot could not begin until there was enough space recovered through the three tier parking lot.

Figure 1: Critical Path for Geisinger Grays Woods Ambulatory Care Campus – Phase II Construction

As far as the new addition is concerned, the critical path leads through the foundation, steel structure erection, building enclosure and finally interior & MEP work. The excavation and foundation work for the project could not begin until the existing parking located over the building's footprint was demolished. Steel structure erection is also a critical activity in the project schedule. Any delays in the fabrication or deliveries of these components could affect the entire project. Delays during this stage could potentially turn into delays to floor deck installation and MEP rough-ins. This could be carried through the remainder of the schedule

until affecting the substantial completion date. Because of the timing of this project, the schedule drives to have the building envelope completely dried in before winter. Failing to reach this milestone could not only affect the project schedule but also produce an increase in cost for snow removal and heating of interior spaces. Having the building dried in before winter can facilitate building interior work. As explained during technical report 2, the interior work installation is by far the longest phase of the project with a total of 236 working days. This is mainly due to the intense MEP work that is typical to any healthcare facility, along with the MEP tie in to the existing facility. By tackling this phase of the project, the project schedule could be reduced significantly.

Potential Schedule Accelerations

Schedule acceleration is always something that must be considered in every project. Although there was an opportunity for early completion on this project, Geisinger and Alexander Construction believed there was no need for acceleration as it would require re-coordinating the involvement of vendors and subcontractors in this project. Due to the amount of facilities that Geisinger builds around the area, they handle most of the vendors and subcontractors directly. This is true for elevators, HVAC controls, security, commissioning agents, and medical equipment in this facility. Moving forward with an "unneeded acceleration" would mean a lot of time and effort on their part in re-schedule equipment installation, procuring, purchase orders and commissioning for the project. Because of this, Geisinger, as well as the project team deterred from moving the substantial completion forward. Being ahead of schedule, the project team rather decided to focus on the commissioning process, testing the different systems and making sure everything's working accordingly prior to the owner moving in. This allowed the project team to focus on the building's quality, and the owner to have a smooth transition in moving in to the new addition of their Ambulatory Care Campus.

Even through there was no emphasis by the owner to accelerate the schedule, the project team had could have done it in many ways if needed. If we were to accelerate the schedule for this project, we could focus on the building's exterior envelope. At the Gray's Woods project, a lot of time in the schedule is devoted to enclosing the building. According to the project schedule, it takes a total of 103 days to erect the brick masonry walls, and 25 days to install the complete curtain wall system on the northern façade. One option (discussed in next section) was to unitize the curtain wall system and/or exterior brick walls into prefabricated modules; these could be picked up and set in place by a crane, thus reducing installation time. Due to the amount of brick walls and curtain wall on building's façade, this design option could have a major effect on the critical path and significantly reduce the project schedule.

Another area that could be potentially impacted in order to accelerate the project schedule is interior work. As discussed earlier, this is longest phase of the project, and impacting this phase could potentially reduce the project schedule significantly. One of the biggest problems encountered in this project was coming up with a final design for the operating and endoscopy rooms in the building. This required a 7-8 week mockup process of design changes during the construction of the Ambulatory Care Campus. This mock-up process involved having input from the end users in order to understand where the major equipment and tools should be located within the space. After wall framing was installed, the project team used pieces of cardboard to symbolize different systems, outlets, and equipment connections. Doctors and nurses were continually brought in to these mock-ups, moving the pieces around as they provided input on where different equipment should be located within the space. A patient bed and boom radius were also painted into the floor to get a feel of the real space within the room, as shown in Figure 2 on the right. Once a final design was approved, MEP rough-in and wall sheetrock could be installed in the space. This led to leaving interior work on 4 operating and 4 endoscopy rooms until the end of the construction. Although this created a delay in the project, Douglas explained that it was much better than having constant change orders done throughout the construction process of these rooms. Focusing in a better way to eliminate design reiterations for the operating and endoscopy and rooms prior to beginning construction would definitely provide a decrease in the total project schedule.

Figure 2: Mock-Up Process of Operating Room

Taking advantage of the repetitive room layout on the second floor of this building, there is a potential to use a short interval production schedule (SIPS) to acceleration the construction process. SIPS is an effective tool used for scheduling construction activities that are similar or repetitive. A schedule reduction can be achieved by maximizing the productivity of the tasks involved in the process. This type of scheduling would be useful for the repetitive layout of the second floor medical examination rooms, illustrated in Figure 3. There's a total of seven isles of medical offices along the new addition's second floor, all of which are very similar in nature and overall size. Because of this, SIPS could be a great tool in order to maximize the productivity of the trade involved in each room. Going a step further, these rooms could even be prefabricated out of site and brought in modules to easily install them into place. The possibility of using modularization and prefabrication will be discussed into detail later on this report.

Figure 3: Geisinger Gray's Woods Ambulatory Care Campus Addition 2nd Floor Layout

Schedule Risks & Challenges:

Anytime that a construction project is undertaken, there are always certain risks involved that can affect the schedule and ultimately the completion date of the project. Many of these risks pertain to the activities associated with the critical path of the project, and were outlined in the above section. We discussed how weather could be a big risk to completing this project on time, as well as any delays in the steel fabrication and equipment delivery to the project.

As with any medical facility, another big risk to completing the project on time is equipment procurement and coordination. The owner, Geisinger, is the one responsible for procuring and coordinating the equipment installation in their facility. Any delays in the process of getting the equipment to the project and installing could pose a great risk to completing this project on time. Because of the rapid changes in technology, the owner usually tries to wait as long as possible in order to procure the latest and greatest equipment for their facilities. This brings in a big challenge when it comes to designing the rough-ins, as the contractor does not know exactly the connections each equipment will require. On this project, Alexander did a great job of distributing to the subcontractors a spreadsheet of equipment location with typical rough-ins for each equipment. Steris, the main medical equipment provider for the job, was constantly present during the construction process inspecting the work being done in the facility. The medical equipment is expected to arrive November 2013, and installation is schedule for December, one month prior to substantial completion. By then, the project team will have go back and address the missing outlets and connections for each equipment. This can become a risk to the project schedule if not well planned and executed.

***Answered Interview Questionnaire can be found in Appendix A**

Value Engineering Topics

The value engineering effort for this project was executed prior to beginning the construction of the Geisinger Gray's Woods Ambulatory Care Campus addition. Alexander Building Construction worked along with multiple trades to identify different areas where value engineering could be applied in order to provide the owner with a more cost efficient product without negatively impacting the final product quality. Table1 below summarizes the key value engineering areas analyzed on this project.

Table 1 – Potential Value Engineering Options

Key Areas of Value Engineering			
Division	**Accepted**	**Rejected**	**Under Study**
Concrete Foundation	$32,302	-	$22,200
Masonry	-	-	$12,300
Roof Metal Panels	$55,923	-	-
Waterproofing	-	-	-
Roofing	$40,000	$106,765	$26,690
Metal Panels	$28,706	$4,100	$600
Curtain Walls	-	$9,934	-
Total Cost Saving	**$156,931**	**$120,799**	**$61,790**

**Data Provided by Alexander Building Construction

The largest parts of value engineering effort in this project dealt with the building's foundation, roofing, and metal divisions. With regards to the foundation construction, the project team saved over $32,000 by simply removing the concrete forms for the footing and rather pouring them directly into the earth forms. As these foundations will be completely backfilled with soil anyways, trench pouring was a great solution in order save money on this project. The project team was also able to save a substantial amount of money by removing 192 linear feet of metal screen walls on the southern side of the building. The state of Pennsylvania requires, by code, that roof-mounted mechanical equipment be screened from public view. As the southern façade of the building faces directly towards a forested area, and the roof mechanical equipment is not in the line-of-sight from the sidewalk, the project team managed to remove the roof metal screening wall in this location, saving around $56,000. With regards to roofing, the project team was able to save $40,000 by changing the roof from Thermoplastic Polyolefin (TPO) to Ethylene Propylene Diene Monomer Rubber (EPDM) roofing. EPDM roofs are generally less expensive, and are easier and faster to install than TPO roofing membranes. This is because EPDM roof require no special equipment for installation, while still offering relatively similar performance as TPO roofing membranes. Finally, the project team managed to save over

$29,000 by changing the aluminum panels used on the rear entrance canopy to standard core panels. This was proposed by Marcon, the sheet metal contractor, as they noticed this alternate material would provide the same quality and performance, with the use of a less expensive material.

Some other value engineering areas were also developed but not implemented in the design. Both of the major areas not implemented were related to roofing and curtain wall systems. Archit. Marcon, the roofing contractor, proposed changing the roof insulation from 4" (R=54.26) down to 2" (R=26.22). Marcon also proposed remove the ½" prime dense deck protection board under the roofing membrane entirely. Both of these alternatives would have combined a total cost savings of approximately $120,000, but were rejected by the Architect as they did not meet building insulation requirements. With regards to the building's curtain wall, Nittany Building Specialties proposed changing the center glaze 1600UT (Ultra Thermal) Curtain Wall System to regular 1600 Curtain Wall (Not Ultra Thermal). Once again, this alternate was rejected by the Architect as it detracted from the true purpose of value engineering: increasing value by either improving the function or reducing the cost.

One area where Alexander Construction failed to apply value engineering successfully was on the building's concrete slabs. Before installing the flooring, each slab has to meet the acceptable moisture content required by the flooring adhesives. For this project, Alexander Construction used "Barrier 1", an additive to stop moisture from penetrating into the slab. They only used this method for the slab on grade, as this is the most susceptible to moisture. The second floor slab, though, was poured without any additives and found to be over the acceptable moisture content for flooring installation. This forced the project team to use an alternate and rather costly method to carry out the slab's moisture content. A sheathing product which acts as a vapor retarded had to be laid over the finished concrete and adhered by a machine, costing over $102,000. Failing to foresee this when evaluating value engineering opportunities not only caused an increase in cost, but also an increase in project schedule as a completely new activity had to be performed in order to get the flooring installed on the second floor concrete slab.

None of the value engineering decisions implemented detracted from the owner's goals; if anything, they were advantageous to the overall goals. So far, the project team has been able to save over $156,000 by implementing various value engineering ideas proposed by the different trades in the project. The project team has potential to increase their total cost savings as they finish analyzing whether the rest of the proposed value engineering ideas will add any value to the design without negatively affecting the overall quality for the building.

*** Value Engineering Log for this Project can be found in Appendix B**

Critical Industry Issues

The 22nd Annual PACE Roundtable was held on November 7th at the Penn Stater Conference Center in State College, PA. The Partnership for Achieving Excellence (PACE) organization is "a collaborative organization of industry innovators, engineering students, and faculty who work together with the effort of achieving excellence in the construction industry"[1]. The annual roundtable allows the opportunity for 5th year Architectural Engineering students to interact with various industry professionals and share thoughts on key industry issues regarding the integration of building planning, construction, and operation.

The PACE Roundtable kicked off early in the morning with a brief introduction by AE professors Robert Leicht and John Messner. Following the introduction, there were two break-out sessions in which attendees broke into various groups to discuss about specific topics in sustainability, information technology, or integrated processes. Penn State faculty facilitated the different sessions to foster the interaction between students and industry leaders, and discuss about the critical industry issues regarding each different topic. These break-out sessions served as a tool for students to build upon the different ideas and industry contacts to develop the senior thesis projects. After both break-out sessions were completed, students coupled with other industry members to allow for the students to explore ways they can capture topics attended into their capstone projects. Patrick Harrison, the Vice President and Sector Manager of SYSTRA, also gave a presentation about systems integration for the metro-rail work and the opportunities in building systems.

The theme for this year's PACE Roundtable was "Whole Project Delivery", and focused in various topics centered on sustainability, information technology, and integrated processes. Students were to choose from one of the available topics shown in Table 2 below. I chose to attend "Information Management for the Workforce" seminar for the first break-out session, and "Criteria and Drivers for effective Multi-trade prefabrication and Modularization" for the second session. Following, I will summarize the results of the sessions and how they may be applied to my senior thesis project.

Table 2 – Main Discussion Break-Out Session Topics

A. Sustainability	B. Information Technology	C. Integrated Processes
Session 1A: Safety – Prevention through Design	Session 1B: Information Management for the Workforce	Session 1C: Assembling Effective Cross Functional Teams
Session 2A: Owner Phasing Decisions for Cost Effective Retrofits	Session 2B: Efficient Delivery of Facility Management Information	Session 2C: Criteria and Drivers for effective Multi-trade prefabrication and Modularization

Session 1B - Information Management for the Workforce

I chose to attend the "Information Management for the Workforce" for the first break-out session because of my interest in the growing trend of using technology in the construction industry. Nowadays, building information models (BIM) are not only being used during the design and preconstruction phases, but slowly being seen in the field as well. The purpose of this session was discussing about transitioning information to the workforce in order to facilitate the construction process. We also discussed about the trends, concerns, and future of the construction industry with regards of this topic. Although the main focus of the topic was managing information for the workforce, there were also other general topics discussed with regards of the use of technology in the industry. The main trends and concepts discussed in this session regarding information management for the workforce were:

1. Interoperability of systems for information exchange
2. Generating the right amount of information in the models
3. Making electronic documents and technology available to the workforce

The discussion began by looking at the various trends with regards of the use of technology in the construction industry. Industry professionals participating in the discussion were David Maser, the BIM Coordinator from Gilbane, Chuck Tomasco from Truland Systems Corporation, Ed Gannon from Office of Physical Plant, Dan Kerr from Burns Mechanical, along with John Messner and Craig Dubler from the AE faculty. It was pretty interesting hearing how each company used technology in different ways throughout their projects, but how everyone seamlessly agreed in many issues and trends they've seen with regards of using technology in the industry.

One of the main issues discussed in this session was the compatibility and interoperability between various programs used for managing building information. Interoperability refers to the ability of making different systems work together (inter-operate) [2]. Nowadays, there are so many programs available for developing building models and loading them with information, but there seems to be a barrier in the lack of communication between each other. The industry has to move towards an "open interoperability standard" to allow for a smooth transition from program to program. Figure 3 on the right illustrates this concept, where one program is able to manage the whole project during the different phases of the project, from planning up to building turnover.

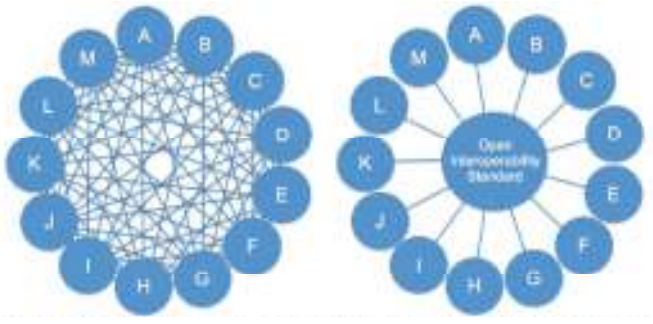

Figure 3: Interoperability: Direct translators vs. an open interoperability standard.

Source: Laakso & Kiviniemi 2012

Everyone in the roundtable agreed that the industry is slowly moving towards this common standard, as big companies such as Autodesk acquire those smaller firms and develop programs with these capabilities.

Continuing the discussion about compatibility between programs, the topic about information exchange between parties was also brought out. The most common questions that were addressed during this discussion were as follows:

- What information does the workforce need?
- Which party should develop what information?
- How much design information is generated but never used?

It seemed as if most industry professionals agreed with the fact that there was inefficiency when transferring information between different parties along the different phases of the project. Industry members were rattled about how they had to take extra time updating their models every time new information was made available from other project participants. The idea of having a "Project Model" available to all the project participants rather than each one having their own models would greatly benefit any project. Each different trade would be required to model those details pertinent to their scope of work, and can be available for everyone else to access it. This, though, would require a greater amount of transparency, collaboration, and trust between the different project participants. Consequently, a much more integrated delivery approach would be required for these projects as trades would have to be brought in earlier in the planning stage in order to develop these models.

The last topic discussed in this break-out session was making electronic documents and technology available to the workforce. I found this discussion pretty interesting because as time goes on, we tend to see technology becoming more prevalent in all levels of the construction industry. In the other hand, there are many issues and concern that have to be addressed in order to make it available to all to the workforce in all projects. The major barriers to implementing these technologies in the workforce are the lack of technological experience by the workforce, and how the use of technology varies from company to company. Not all field personnel have the same experience in using computers and technology. Some may feel far more comfortable in using traditional paper documents rather than electronic documents in iPads and monitors. Also, not all subcontractors have the drive to using these technologies to perform. Sometimes, a lot of time and effort are put in developing models with rich amount of information and are not even implemented in the construction of the project because of this issue. Throughout the discussion, we brainstormed of ways in which these technologies could be made available to the workforce and used efficiently in the construction process.

First of all, programs would have to improve their user interface in order to allow those less technology savvy people to utilize them. Also, a cultural shift has to occur in order to develop comfortability to the workforce in using these technologies. Educating the workforce may be done through intense technology training programs or reverse mentoring from those people who have experience using these tools. Companies and laborers have to keep up with the industry standards in order to compete and win projects.

In conclusion, technology is a tool that is being seen more and more in the construction industry. It can facilitate the planning, design, construction and operating of a building by passing along a building information model to different parties throughout the different phases of a project. The problem is developing these models with the right amount of information so that all project participants may use them effectively. The use of technology, though, is not viable for all types of projects. As there is an upfront cost in using these tools in their project, the use of technology depends on the size, type and complexity of the project. It is the role of the owner to initially set the ground rules, and be clear about their goals to understand whether technology would benefit the construction of the project or not.

This discussion sparked the idea of taking this concept even further. We discussed how information is critical in all stages of the construction process, but how do you generate this information without knowing what the client wants? After speaking with the project manager for my project and attending this discussion, I am looking into using these models to obtain the critical information which will later be used by the workforce. One idea I had was developing virtual mockups for my thesis project. As discussed earlier, the construction team struggled with design reiterations for the operating and endoscopy rooms of the Grays Woods Ambulatory Care Campus. Rather than performing these design reviews within the construction of the project, virtual mockups could be used to obtain valuable input from the end users on where different equipment should be located within the space. Doctors and nurses would be able to navigate these virtual spaces and provide valuable feedback in order to come up with a final design approved. These virtual mockups could also be used by the workforce in order to understand how the building should be laid out. This solution could potentially decrease the project schedule by eliminating the various design reiterations for the operating and endoscopy rooms while also constructing them efficiently. A good key contact that could help me advise me in this area is the BIM Coordinator for Barton Malow, David Maser. Based on his participation in the break-out session, he may the experience and knowledge of the use of this technology in the real world. Also, my Virtual Facility Prototyping professor John Messner and the Teaching Assistant Fadi Castronovo, both present at this discussion, would be ideal contacts for this research topic. This idea was also later discussed with another industry professional in order to receive feedback with regards of the potential use in my thesis research.

Session 2C – Multi-trade Prefabrication & Modularization

The second session I attended during the PACE Roundtable was "Multi-trade Prefabrication and Modularization". I chose this topic because I was really interested in learning the various applications of prefabrication and modularization in the industry. Although prefabrication may benefit a project as a whole, it is not viable for every project. Through this session I would gain a better idea of how, if possible, prefabrication could be potentially used in the Ambulatory Care Campus project in order to achieve reductions in cost and schedule. The main concepts discussed in this session regarding this topic were:

1. Examples of Prefabrication and Modularization in the Industry
2. Where is the Modularization/Prefabrication Process Conceived?
3. Benefits and Limitations of Using Prefabrication

The discussion began by stating various examples on how industry professionals and students have seen prefabrication and modularization being used in the Industry. Typically, prefabrication/modularization is done on projects that are tight on schedule, have tight spaces, and that local warehouses are available for offsite prefabrication. It can be seen in projects as big as prefabricating a whole precast parking garage or as small as prefabricating piping in a building. Prefabricated items are usually convenient when certain pieces of a building are repetitive or present in large quantities. Also, it is important to have these modules developed to a manageable size. Having components that are too big and difficult to handle will detract from the productivity gained during the off-site prefabrication.

Another important topic discussed in this session was where prefabrication/modularization is conceived in a project. Usually, these analyses are done during the during the design phases in order to determine what areas of a building can be prefabricated. It is important to get project participants involved early in the process in order to plan accordingly. There is a great amount of logistics and planning that go along with prefabrication. Permits, transportation, site layout, hoisting and other custom construction equipment have to be planned accordingly in order to implementing this technique in a construction project.

The discussion then led to the various benefits and limitations to using Prefabrication in a project. For the most part, utilizing prefabrication in a project can reduce schedule time, reduce labor costs and increase quality control of the building elements. These benefits can be attributed to the fact that building components are assembled under a controlled environment, and later shipped to the project when needed. By working under a controlled environment as opposed to the jobsite, there is less room for variability. Similar to an "assembly line production", workers may increase their productivity while also working under a safer and comfortable environment. Once the prefabricated sections are completed, they can be shipped

to the job and lifted into place. This also cuts down on-site material storage and provides a better inventory control as well.

It was surprising to learn how there are also many limitations when using prefabrication in a project. A few of the downsides to prefabrication are the long lead times for prefabricated components, transportation, issues with changes in design, and limitations with payment and inspection. When dealing with prefabricated modules, it is important to take into consideration the care and transportation to the site. Who becomes responsible for the care and custody of the prefabricated item until it reaches the sight? Contracts should be specifically written to address what happens in the case of any accidents or delays in delivering these components to the site. Consequently, payment and inspections can become an issue for contractors when it comes using prefabrication. Some lending institutions, or even owners, may present some limitations in pay until the items are in the present in the jobsite. This could become a big issue when dealing with massive projects that require a lot of frontloading to buy materials. Inspection can also become an issue, especially when components are being assembled and placed in different states. Challenges may be presented when dealing with inspection jurisdiction and having them travel to the warehouse rather than to the site. Finally, we have the issue of what happens whenever there's a change in the design and components are already assembled together. Overall, everyone agreed that while prefabrication may be beneficial, it may not be viable for every single project. If used well, prefabrication and modularization could potentially reduce schedule and time while also improving safety and quality in a project.

After hearing both the students and industry members express their ideas about the use of prefabrication in buildings, I thought of how I could apply this concept in the construction of the Geisinger Grays Woods Ambulatory Care Campus. I hope to study prefabrication not only for the intense MEP systems in my building, but also the building façade which is comprised of a large curtain wall system and brick cavity walls. This could be later researched in order to evaluate the effect it may have on the cost and project schedule, and whether it is applicable in the construction of this project.

Throughout the day, I have met several industry professionals that I will most likely be referring to for more advice on this topic. As Southland and Truland are both major leaders in prefabrication and modularization, related questions regarding prefabrication of MEP systems will be directed to Andy Rhodes or Chuck Tomasco. They both seemed to have a variety of experience in the use of prefabrication in their specific fields, and may advise me with the possibility of using prefabrication in the Geisinger Gray's Woods Ambulatory Care Campus Addition. The next step to this roundtable was discussing with an industry member in order to receive feedback on how we could apply these topics into our capstone projects.

Feedback from Industry Roundtable

After both break-out sessions were completed, students met with an industry member in order to explore the ways they can capture topics learned in the sessions into their senior Capstone projects. This was a great opportunity to interact with industry professionals and learn discuss about our building projects, the sessions attended and the opportunities of applying the any of the selected topics into the final project. Industry professionals provided feedback to students based on their experiences, and what they have seen in the industry.

Attending the different sessions allowed me to come up with various ideas of possible areas of study. These included investigating the potential use of prefabrication in my building and the use of virtual mockups for the operating rooms. I was fortunate enough to meet with John O'Keefe from Clark Construction Group, who provided me with valuable feedback about these possible areas of study. Mr. O'Keefe is the Division President of Clark Construction, and has over 26 years of experience in the industry. Following is a summary of the feedback received on each of the ideas presented during my discussion with John O'Keefe.

Research Idea 1 – Use of Prefabrication in Building

After attending the session about prefabrication and modularization in the industry, I tried to build upon some of the ideas that industry professionals and students discussed. As mentioned earlier, I was looking into using prefabrication in the building MEP systems. My project, being a healthcare facility, is intensely loaded with MEP Systems, mainly medical gas copper pining and communication systems. I was also tempting the idea of using prefabrication in the building façade which is comprised of a large curtain wall and brick cavity walls. This exterior system requires large amount of labor hours and scaffolding to install. Prefabricating any of these systems could potentially decrease the schedule and cost of installing these systems. I ran through my ideas with John O'Keefe in order to receive feedback on what he thought about these ideas.

Mr. John O'Keefe was very helpful by providing a lot of insightful ideas in ways I could implement prefabrication in my building. With regards to interior MEP systems, he recommended doing so in corridors where long, manageable sections of preassembled MEP components could be put into place. Most specifically with mechanical ducts, electrical conduits, cable trays, and sprinkler systems in the building. This, though, would require a greater amount of coordination between the mechanical, electrical and fireproofing trades as they would have to work simultaneously in the assembly of these components.

John also explained how this idea could be taken even further by modularizing similar rooms or even wall sections in my building. Taking into consideration the repetitive layout of the medical

examination rooms and offices in the second floor of the Grays Woods Ambulatory Care Campus, there is a great potential to use modular construction in order to reduce the project schedule. These modules, as John explained, could be assembled out of site, pre-inspected, and shipped to the site ready to be installed into the second floor. This could substantially decrease the overall project schedule, as all the interior work, finishes and installation are done out of site and simply put in place by a crane.

As my building is located in an extensive site, John proposed on comparing the costs it would take to prefabricate the assemblies on-site versus off-site. This would require taking into consideration the costs it would take to pour a temporary slab and envelope on site against those of renting a warehouse close-by and transporting the components to the site. Overall, John thought that there is always a great opportunity to use prefabrication in healthcare building; by doing so I could potentially achieve a reduction in cost and schedule while also improving quality and safety for my project.

Research Idea 2 – Virtual Mockup for Operating Rooms

As discussed in the interview with Douglas Workman, one of the major challenges in the construction of the Geisinger Gray's Woods Ambulatory Care Campus was the great amount of changes that went in designing the Operating Room and Endoscopy Rooms of this building. It took over 8 weeks of design input from various doctors and nurses along with a lot of design reiterations in the middle of the construction process to come up with a final design for both of these rooms.

After speaking with the project manager for my project and attending the discussion on the use information models, I came up with the idea of developing virtual mockups in order to allow end users to provide valuable feedback early in the design process. This way, doctors and nurses could be brought in ahead of time until approving a final design before construction begins. The end user could walk around the virtual mockup and review the practicality of the different locations for medical equipment, connections, tools and cabinets around the room. These virtual mockups could also be used by the workforce in order to understand how the building should be laid out and coordinated. This solution could potentially decrease the project schedule by eliminating the various design reiterations for the operating and endoscopy rooms while also constructing them efficiently.

When I proposed this idea to John O'Keefe from Clark Construction Group, he immediately agreed in that this would definitely be a great benefit to the construction of this building. He gave me examples of how Clark Construction had used this tool before in order perform design reviews for the construction of courtrooms. In a courtroom, it is important to consider the layout and lines between everyone participating in the proceedings. It is important for the

judge(s), the jury, the lawyers, and anyone else involved or watching to be able to see everything that happens. Clark Construction used 3D Virtual Mockups to visualize the perspective as like being in it, making it much easier to evaluate the design. According to John, this model not only allowed users to preview the aesthetics and layout of the spaces, but reduced the amount of design reiterations and change order throughout the construction of the building. A similar application can be used for my building in order to receive design input from the end user with regards of how they flow between the spaces and interact with the different tools and equipment inside the operating or endoscopy room of the Grays Woods Ambulatory Care Campus.

Overall, the 22nd installment of the PACE Roundtable discussion was a great success in allowing me to further explore different areas of study for my senior thesis project while also meeting various industry professionals who could serve as great contacts for applying these different tools and concepts on my senior thesis project.

*** PACE Roundtable Notes can be found in Appendix C**

References

References:

- [1] http://www.engr.psu.edu/pace/LinkedFiles/Prospectus_updated_funding.pdf
- [2] http://www.itcon.org/data/works/att/2012_9.content.01913.pdf
- http://www.engr.psu.edu/pace/
- http://bimex.wikispaces.com/Virtual+Mock-ups
- http://www.rtnroofing.com/articles/511.htm\

APPENDIX A

Project Manager Questionnaire

Project Manager Interview Questions

Project: Geisinger Grays Woods Ambulatory Care Campus – Phase II
Name: Douglas Workman
Date: Tuesday, November 5th @ 8.30am

Design Dates...
Parking Garage impact...

SCHEDULE ACCELERATION SCENARIOS (5 Questions):

* 1. **Describe the critical path of the project schedule.**

- Parking Garage

New Addition: Steel Erection & structure

↳ Dried in before winter

↳ Dried in just before 1st snow...

Snow removal ~

Code parking

Had opportunity to finish early → Moved date up by talking to owner.

- Uncoded escalation
- Own vendors for geisinger

* 2. **What are the biggest risks to the project completion date?**

- Weather

↳ Ways to save, but ↑ Costs

No reschedule

↳ Time to concentrate on Quality, testing systems

Commissioning process

3. **What are the key areas that have potential to accelerate the schedule if needed?**

- Typically happens: Last guys take price for meeting project (finishes) → quality

- Accelerate upfront

- Opportunity.

4. **What would be the costs and techniques required in to accelerating the project.**

Schedule already setup,

"Keep up pace of project"

Phasing: 1A-2A

1B-2B

* Operating rooms → Mockup process for each room

weeks long → Reduced for last

1 cp, 1 end, 1 er (Nurses, Drs, etc.)

5. **Describe the biggest challenges encountered during the construction of this building. How has the team overcome these challenges in order to have minimal impact on cost/schedule?**

- Equipment coordination & procurement (by owner)
  - Latest & greatest
  - Wait as long as possible (Newest & $)
    - ↳ Early as possible needed to know
  - Good job (Binders of cutsheets) ⇒ Spreadsheets w/ roughins →

6. **What are some lessons learned in the design/construction of Phase II so far that could have been helpful to implement at an earlier stage in the project to achieve a successful project delivery**

Really Gone well !!!

(LEED) → Flooring ⟶ Moisture content in slab
Not acceptable to meet requirements for m.c. → 102,000 for 2nd floor
* Vapor Barrier after pouring concrete ($$$)
* Allowance ($75,000) / Geisinger's Standard: Barrior-1 Additive → 50G
Delay in schedule

7. **How is the project doing with regards to your goals and Geisinger's expectations so far? Anything that could have helped you achieve these goals more easily?**

Mechanical / Electrical: CUP, System already dictated so

Change orders:
Average
Drawings are not finished
(Issues)

VALUE ENGINEERIN TOPICS (3 Questions)

1. **Describe the key areas of value engineering that were implemented on the project.**

- Done before him onboard

Email for Value Eng. Log

2. **How did these correlate/detract from the goals of the owner?**

Saving Money!

3. **What ideas for value engineering were considered but not implemented?**

GENERAL:

The purpose of AE Senior Thesis is to identify various challenges and potential opportunities to improve the design, construction and delivery of our chosen building. Technical analyses will be performed on each area to propose alternative methods and/or potential solutions to improve the project delivery.

Is there anything specific to this project that you would like me to focus my research on? This could be anything similar, but not limited to:

- **Schedule Reduction (Sequencing/Phasing of project)**
- **Sustainable Features (Green Roof, Façade, MEP Systems, Materials)**
- **Design/Approval/Execution Process**
- **Achieving LEED Rating** → Cost driven... Limited by Existing
- **Electrical/Mechanical/Structural System Design**
- **BIM/Modularization/Preconstruction/Prefabrication/Mockups** (Virtual)

· Collaboration Issues → utilized pretty well... 4D scheduling ~

* TOUR W/ Rick!!?

- Collaboration Issues: Design-Assist b/c healthcare & MEP
  Cost & schedule

Design after phase I

Extra Material Dumped back Grays Woods

Hand cutted

APPENDIX B

Value Engineering Log

Alexander Building Construction Co.

Geisinger Gray's Woods
Potential Value Engineering Options

April 12, 2012

	Description	Targeted Amount	Accepted	Rejected	Under Study	Comments
	CONSTRUCTION COST SUMMARY					
	Estimated Construction Cost:					
	Site	$ 2,010,051				
	Parking Deck	$ 3,012,300				
	Building	$ 17,653,354				
	General Conditions, Insurance, C.M. Fee	$ 2,637,526				
	Construction Subtotal	$ 25,313,231				
	Design/Estimating Contingency	$ 400,000				
	Construction Contingency, 5%	$ 1,153,690				
	Subtotal	**$ 26,866,921**				
	Add Alt: Rear Entrance Canopy	**$ 177,310**				
A	**Total Estimated Construction Cost**	**$ 27,044,231**				
	Project Budget Target for Construction Costs	**$ 26,649,990**				
	Current Construction Overage	**$ 394,241**				
B	**Accepted Adjustments / V.E Items**	**$ (216,931)**				
	Revised Construction Overage (i.e., Rear Entrance Canopy)	**$ 177,310**				
	Revised Construction Total (A+B)	**$ 26,827,300**				
	DETAIL OF POTENTIAL COST SAVINGS					
	General Items					
	Division 2000 - Sitework					
1	GOH Bid Alt. - Use on-site soils for backfilling behind west elev. concrete wall at garage (vs. 2A modified) - $30,000 Deduction				Included	
2	GOH Bid Alt. - At segmental retaining wall behind existing cooling tower, keep bottom 4' of existing wall to remain (vs. demo. in its entirety). Determination to be made at time of wall removal.				TBD	
3	GOH Bid Alt. - Change concrete equip. pad detail 5/S5.1 for emerg. generator to "oxygen tank pad detail" on dwg. C15.				$ (2,200)	
4	GOH Bid Alt. - Place and grade excess soils at rear waste lot (vs. 95% compaction).				$ (20,000)	

Geisinger Gray's Woods
Potential Value Engineering Options

	Description	Targeted Amount	Accepted	Rejected	Under Study	Comments
5	GOH Bid Alt. - At the garage, change perimeter foundation drain detail (ref. 18/S5.1) with drain board/ perforated pipe/2B stone to American Wick Drain (AWD) combination drain footing which eliminates the need for the 2B's and geotextile.				TBD	
6	Change formed concrete footings to trench pour - Garage		$ (65,470)			
7	Change formed concrete footings to trench pour - Bldg.		$ (49,811)			
	Division 3000 - Concrete					
1	JC Orr Bid Alt. - Change formed concrete footings to trench pour at garage		$ (3,321)			
2	M&M Bid Alt. - Change formed concrete footings to trench pour at bldg.		$ (13,700)			
	Division 4000 - Masonry					
1	Caretti Bid Alt. - Change continuous 16 Ga. stainless steel closure at exterior sills to 26 Ga. (ref. A3.4.4).				$ (2,400)	
2	Caretti Bid Alt. - Change spray foam sealant at exterior window & louver heads to 4" rigid insulation board (ref. typ. 6/A3.4.4).				$ (4,500)	
3	Caretti Bid Alt. - Delete TotalFlash drainage mat detail at exterior window & louver heads (ref. 6/A3.4.4).				$ (5,400)	
4	Exterior windows to be inset vs. flush (ref. 6/A3.4.4). EwingCole to provide details. Note: This may be an added cost.				TBD	
	Division 5000- Metals					
1	Altoona Bid Alt. - Delete 192 LF of roof screen framing (from Col. L/15 to SW Stair located @ Col. F.7/16.4)		$ (55,923)			
	Division 6000 - Wood & Plastics					
	Division 7000 - Foundation Waterproofing					
1	Change the building foundation waterproofing from the Cetco UltraSeal BT Bentonite / Cetco Envirosheet waterproofing system (ref. 1/A3.4.4) to bituminous damproofing where the floor height is at or above the finish grade. The SE corner of the building to remain as designed for 84 LF.				$ (9,000)	
2	Delete the 2" rigid insulation protection board at the building foundation waterproofing (ref. A3.4.3).				$ (3,800)	
3	Delete the Cetco Aquadrain 15X drainage mat at the building foundation waterproofing.				$ (4,300)	

Alexander Building Construction Co.

Geisinger Gray's Woods
Potential Value Engineering Options

April 12, 2012

	Description	Targeted Amount	Accepted	Rejected	Under Study	Comments
	Division 7000 - Roofing					
1	Marcon Bid Alt. - Change roof insulation from avg. 4" min. (avg. R-54.26) to avg. 2" min (avg. R-41.56).			$ (33,300)		
2	Marcon Bid Alt. - Change roof insulation from avg. 4" min. (avg. R-54.26) to avg. 2.5" min using revised layout.			$ (36,160)		
3	Marcon Bid Alt. - Change roof insulation from avg. 4" min. to avg. 1.5" min. at South/East Canopy.			Included		
4	Marcon Bid Alt. - Change roof insulation from avg. 4" min. to avg. 1.5" min. at Rear Entrance Canopy.			$ (1,200)		
5	Marcon Bid Alt. - Change sloped metal roof from 22 Ga. 3 coat Kynar to 20 Ga. 2 coat Kynar to match GW-1.				$ (3,060)	
6	Marcon Bid Alt. - Change white TPO fully-adhered roof system to .060 ballasted EPDM with sloped roof steel.				$ (40,000)	Includes $25,000 add for increasing height of exterior wall and $10,000 add for sloped steel
7	Marcon Bid Alt. - Change white TPO to EPDM.				No Change	
8	Change protection board under membrane from 1/2" primed dense deck to 1/4" unprimed dense deck.				$ (6,530)	
9	Delete 1/2" primed dense deck protection board under membrane in its entirety.			$ (36,105)		
10	Reduce the extent of tapered roof insulation by sloping the roof steel. EwingCole to review.				TBD	
	Division 7000 - Metal Panels					
1	Marcon Bid Alt. - Change composite aluminum panels from insulated to non-insulated at the metal panel roof eaves.			$ (4,100)		
2	Marcon Bid Alt. - Change composite aluminum panels to standard core panels per flame spread specification at South/East Canopy.		$ (6,350)			
3	Marcon Bid Alt. - Change composite aluminum panels to standard core panels per flame spread specification at Rear Entrance Canopy.		$ (8,600)			
4	Change composite aluminum panels from 3 coat to 2 coat Kynar.				$ (600)	
	Marcon Bid Alt. - Delete 192 LF of roof screen panels (from Col. L/15 to SW Stair located at Col. F.7/16.4)		$ (13,756)			
	Division 8000 - Curtainwalls, Windows, Entrances					
1	Nittany Bid Alt. - Change Kawneer 1600UT center glaze curtainwall system to Kawneer 1600 (same as GW-1 front set)			$ (9,934)		
2	Nittany Bid Alt. - Change Kawneer 451UT storefronts to Kawneer 451T (same as GW-1 front set)			Included		
3	Nittany Bid Alt. - Change one pair interior doors from thermal to standard.			Included		
4	Nittany Bid Alt. - Change fire rated non-wire glass from Fireglass Firelite Plus to an alternate.				TBD	

Geisinger Gray's Woods
Potential Value Engineering Options

	Description	Targeted Amount	Accepted	Rejected	Under Study	Comments
5	Nittany Bid Alt. - For lead glass, EwingCole to select from a standard list of common sizes (vs. custom sizes). Nittany to provide list of sizes.				TBD	
	Division 9000 - Finishes					
	Division 10000 - Specialties					
	Division 15000 - Fire Protection					
	Division 15000 - Plumbing (details to be evaluated)					
1	PVC underground piping				TBD	
2	Evaluate fixture package for savings				TBD	
3	Waterless traps vs. trap primers				TBD	
4	Use pro-press on domestic water piping				TBD	
	Division 15000 - HVAC (details to be evaluated)					
1	Revise ATC for controllers and scope issues (ATC under Owner budget)				TBD	
2	Verify harmonic filters vs. line filters on VFD's				TBD	
3	Relax duct leak testing to sample sections				TBD	
4	Fiberglass transfer ducts (review GW-1 existing conditions)				TBD	
5	Relax duct spec. from 4" to 2" after VAV's				TBD	
6	Revise duplex basket strainer and pump suction diffusers				TBD	
7	Revise AFS at branch ducts to fan-evaluator style				TBD	
8	Delete pump inertia bases				TBD	
9	Delete RH coils at interior VAV boxes on 1st floor				TBD	
10	Use pro-press on copper piping 2-1/2" and smaller				TBD	
11	Simplify duct routing				TBD	
12	Evaluate duct barrier wrap and sound attenuators (confirm GW-1 existing conditions)				TBD	
13	Evaluate equipment buyout				TBD	
14	Evaluate vibration spec for all piping				TBD	
	Division 16000 - Electrical (details to be evaluated)					
1	Delete concrete for ductbank conduits except for 12 KV and under roadways				TBD	

Alexander Building Construction Co.

Geisinger Gray's Woods
Potential Value Engineering Options

April 12, 2012

	Description	Targeted Amount	Accepted	Rejected	Under Study	Comments
2	Delete rebar from ductbanks except under roadways				TBD	
3	Compare cost of fiber reinforced concrete instead of rebar				TBD	
4	Reduce 5" conduits to 4" conduits				TBD	
5	Change encased HV conduit to DB PVC				TBD	
6	Reduce site lighting conduit from 1-1/2" to 1"				TBD	
7	Delete mimic bus on switchboards				TBD	
8	Change panels w/ 100 MCB more than 30 ckts from 225 bus to 100A bus				TBD	
9	Aluminum vs. copper feeders (service conductors, switchboards, gen., panelboards)				TBD	
10	Eliminate bypass isolation feature on ATS				TBD	
11	Eliminate walk in enclosure on Gen (add access platform to outdoor enclosure)				TBD	
12	Delete FAS in conduit				TBD	
13	Review dimming - Lutron vs. GE or eliminate dual level switching				TBD	
14	Add ground rods to site lighting				TBD	
15	Confirm fixture support on ceiling grid and seismic are not cost issues				TBD	
16	Revise emerg. system branch wiring from EMT to HCF MC				TBD	
17	Add SCC coordination and arc flash study				TBD	
18	Change linear fixtures to Prudential				TBD	
19	Change decorative downlights				TBD	
20	Change bathroom wall slot to lay-in type				TBD	
21	Propose alternate corridor fixtures				TBD	
22	Evaluate and reduce scope of nurse call system				TBD	
23	Use MPLS rather than boxes at tele/data stubs				TBD	
	Total Potential Cost Savings		$ (216,931)	$ (120,799)	$ (101,790)	

APPENDIX C

PACE Roundtable Notes

Student Name George Andonic

Session 1: Topic: Information Mgmt for the workforce

Research Ideas:

1) Use of electronic documents & Ipads on jobsite
   - Limited by workforce experience (Paper vs. electronic)
   - Computer stations in field w/ easy user interface

2) Developing virtual models to obtain critical design information from end users
   - → Improve design process and reduce delays in construction
   - → Later used by workforce for construction!!

Session 2: Topic: Modularization & Prefabication

Research Ideas:

1) Prefab Exterior Wall Components / MEP Systems
   - Exterior Brick Walls
   - Curtain Wall in North facade?
   - → Hallways (long, manageable sets)
   - → Med gas piping?

2) Modularization of 2nd floor office spaces?
   - Repetitive Layout
   - Out of site & shipped in!!

Session 3: Topic:

Research Ideas:

1)

2) Not Applicable to this Roundtable!!!

Industry Member: John O'Keefe

Key Feedback: *Which research topic is most relevant to industry? What is the scope of the*

Prefabrication

New + Renovation: On corridors
- Cable tray
- Sprink
- EL
- Fire

offsite → flow in

Coord b/w M,E,

Quality, cost, schedule, $$

Prefab similar rooms. (eg,
↳ Repeated (sink, drains, etc.)
Wall sections??

Preinspected??

Prefabrication → Environment ✓
↳ OR temporary (pour slab)

Material to warehouse = transportation

- Full BIM Model with visualization
- End users
  ↳ Benefits coordination

Change orders
↓
Big Dis

Suggested Resources: *What industry contacts are needed? Is the information available?*

Info mgmt for workforce
- David Musser → Gilbane (BIM coordinator)
- Chuck Tomasco → Truland Systems Co.
- Dan Kerr → Burns Mechanical

Prefab + Modularization
- Andy Rhodes → Southland
- Chuck Tomasco → Truland Systems Co.
- John O'Keefe → Clark Construction Group