PHEONIXVILLE AREA MIDDLE SCHOOL

Professor: Dr. Robert Leicht

Technical Report 3

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Executive Summary

Technical Report 3 focuses on the decision making and planning that went into the delivery of the Phoenixville Area Middle School. Through interviews with members on the Agency Construction Management Team, Reynolds Construction, in-depth personal insight of the planning and construction process helped to identify several aspects of the building. The members interviewed included the Vice President and Project Manager at Reynolds. Topics discussed include the constructability issues faced in the construction process, schedule acceleration concerns and scenarios, and value engineering topics. Also included is the information obtained by attending the PACE Roundtable Conference held Novermber 9th, 2011. This experience will be applied to this project in the attempt to identify possible areas of improvement for the Phoenixville Area Middle School.

Constructability concerns on the project involved the issues with the site. Since the project is on a school campus with an active high school and middle school, safety and interference were a concern. Also, the soil conditions discovered in the geotechnical reports required decision making concerning the foundation system. In the end, it was decided to replace the existing unsuitable soil with structural fill. Finally, the sequencing of multiple trades to reach the desired duration required detailed logistic planning by the management team.

Schedule is a concern on the project since the new school must be ready for the 2012 Academic school year. The critical path follows through a series phases and trades, and is displayed in graphical form within the report. Potential for schedule acceleration was determined to be the greatest with the application of short interval production planning in the classrooms. This is possible due to their modular design.

Value engineering was important in the development of the middle school design. The schematic phase saw many changes that help bring the budget within a range that made this project possible. The areas that saw the most changes were the interior and exterior finishes, size and layout of spaces, and the building systems. In the end, these value engineering decisions made it possible to save the school district several million dollars. This was done without compromising the wishes and requirements of the owner.

A description of the sessions attended at the PACE Roundtable demonstrates the lessons learned. These will be valuable in evaluating several aspect of this project.

All the information in this report is put to use in the problems and technical analysis section. Here the areas of future research are broken down into groups: delivery method, mechanical system selection, application for LEED certification, BIM use, and SIPS for classroom planning. These were chosen based on the understand gained from interviews with the project team and the possibilities discovered at the PACE Roundtable Conference.

Constructability Challenges

The Phoenixville Area Middle School is a relatively simple building in terms of constructability. The building is only three stories with a shallow foundation, with a simple steel frame, exterior masonry walls and composite metal decking floor systems. The building site itself is open, and there are multiple access roads to the site. The site layout allowed for storage and trailers to be located north of the building footprint, out of the way of construction activities. The building site was a field prior to construction, and the surrounding areas all had been built on in some manner. No unforeseen conditions were encountered on the project. However, there were some logistical challenges that had to be dealt with.

School in Session

The building site is in a field east of the existing high school and middle school. Construction began in May of 2010, and is scheduled to be completed in May of 2012. While the project was planned to maximize work time during the summer months, the project will still be active for two school years when school is in session. Two main concerns of the owner are the safety of students, and the interference with school activities throughout the year.

Safety is always a concern on a construction site, but student safety is a concern that demands added precaution. The project team had to devise strategies to ensure students were kept away from the project site, and that vehicles entering and exiting did not endanger pedestrians. Safety fencing, which is required for any site, was placed surrounding all sides of the project with screens to block vision from inside or out. All employees on the project were screened for criminal backgrounds as required for school projects. Traffic control monitored all vehicles going in or out of the site. Temporary access roads allowed those who drove to school to access the parking lots. A site utilization plan was required for the measures taken for safety on school grounds.

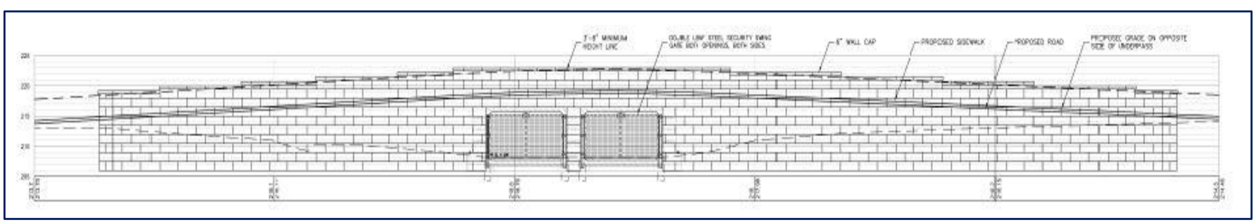

Figure 1. Temporary Pedestrian Access Ramp

To minimize the impact construction had on normal school activities, the construction planning took into account some of the requirements set by the owner. Noise control was implemented for construction activities so distracting sounds did not bother students in class. The south-eastern entrance was limited in use for deliveries since it is the bus route. Between 7 and 8 a.m.

and 2 and 3 p.m. there is no access allowed by that road. The main entrance used was the northern access point by the high school. A temporary pedestrian walkway was created that crossed over the south-eastern site access point. Many students come to school that way, and that needed to be erected during the general conditions phase.

Unsuitable Soils

The soils report completed by the geotechnical engineer stated that the tests done where the foundation of the middle school would lie had unsuitable soils for the proposed foundation. Classified as a disturbed site, the soils, or miscellaneous fill of Stratum IMF, had a significant risk of settlement and required subgrade repair. The proposed shallow foundations was footings and a floor slab, however if the designer chose to go deeper they would encounter weathered rock. This would mean using techniques such as blasting to remove it. Added to this was the risk of a fluctuating water table.

The decision was made to use soil replacement rather than redesign the foundation. While an added cost that was not anticipated by the project team, structural fill was applied where needed and compacted to the specified level. The risk of the water table was accounted for with pumps, however these turned out to be unnecessary since water was not an issue.

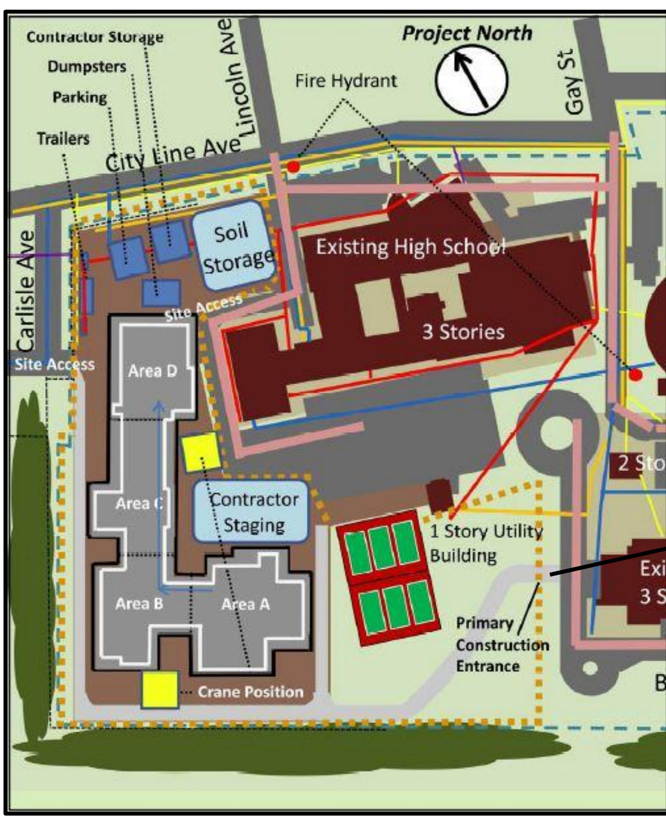

Figure 2. Site Layout during Interior Fit-out stage

The construction site at this point in the project has a complete superstructure. Staging is spaced in different areas based on trade.

Pedestrian overpass

Phasing of Construction

Despite the relatively open layout of the construction site, construction sequencing posed a logistical challenge in the later portion of construction. The schedule had to be short enough to maximize work done in summer months while ensuring completion for the 2012-2013 academic school year. In order to make this happen, sequencing had to be implemented to maximize the amount of work taking place on the project.

This was done by overlapping phases of the project that typically would not occur at the same time. The construction manager split the building into four areas, and each was given its own schedule. The excavation and foundation are relatively short in duration compared to other building features, but the MEP and interiors take the longest by far. However, they cannot start before enclosure of an area, and enclosure is dependent on the structural system. No other work can take place while the structure is being erected, as noted in the crane plan. As soon as the structure and roof went up in one region, the concrete-masonry enclosure would start work. As soon as the enclosure moved to the next area, the MEP and interior work would begin in the region. As soon as the structure began in the third part of the building, there were many trades operating at one time on site. This created logistical challenges for site layout, since the sheer numbers onsite needed storage and mobilization space. Detailed crane and site layout plans had to be developed in order to determine the manner in which contractors operated. This one done by designating areas for each trade, and getting the structural steel contractor off site as soon as possible.

Schedule Acceleration Scenarios

The schedule of the project was made to maximize work time during summer months, and had to be completed by the start of the 2012 school year. Mobilization took place in May of 2010, and construction was schedule to be completed in May of 2012. While a few months is somewhat of a wide margin for completion time, testing of the mechanical systems and move in of furniture meant that the deadline was pretty tight. The project was phased to minimize schedule time, and delays in construction could mean the building would not be completely prepared for the new school year.

Critical Path

The critical path of the Phoenixville Area Middle School is based on the sequencing of construction activities. The project was phased to allow work to occur simultaneous in different areas. These areas were designated by function, composition, and layout. They are as follows:

Area A: Gymnasium

Area B: Classrooms & Kitchen

Area C: Classroom & Library

Area D: Auditorium

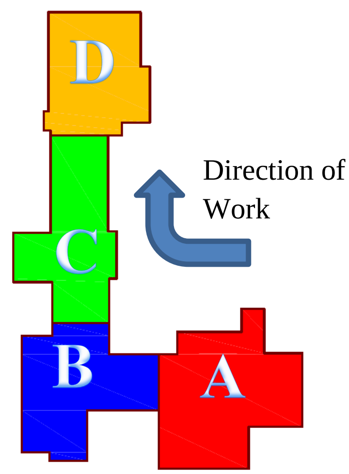

Figure 3. Building Areas

The critical path begins with site establishment. This site remains the same throughout the project in terms of layout and access. At this point the fencing, erosion control, temporary utilities and trailers, and temporary access ways area created. The bulk excavation and fill are included in this section since the foundation is shallow and does not take long to dig. The path then goes to foundations. The foundation of Area A is built first, and follows in chronological order to D. However, after the foundation of Area A is complete, the structural steel is started in that region. While the superstructure is dependent on the foundation, the activities can be ongoing at the same time in different regions. Following superstructure is enclosure with concrete-masonry units. As was the case with steel, the enclosure starts immediately after the superstructure is built. After full enclosure, interior fit-out is the next portion of the critical path. At this point, framing and MEP rough-in start in Area A, and following the path of all other trades work towards Area D. Finally, interior finishes and casework are the last part of the critical path. This finishes with the flooring and casework of the auditorium in Area D, which cannot begin until MEP and finishes inside the building area completed.

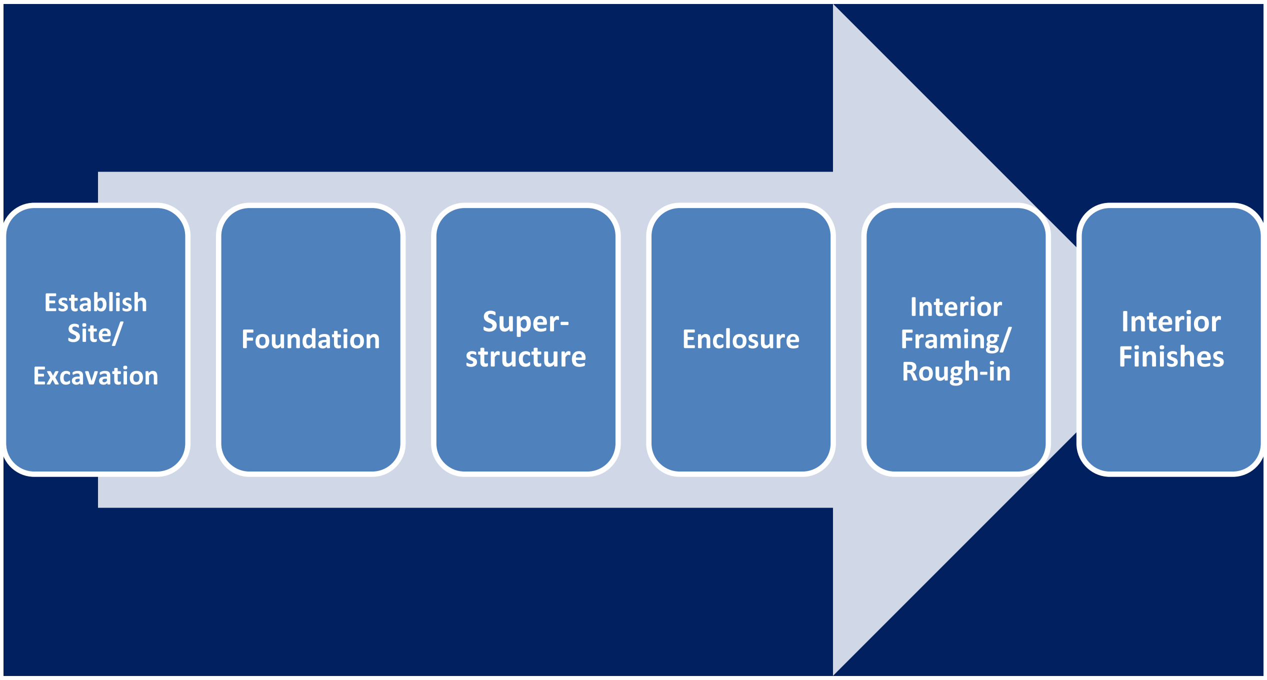

Figure 4. Representation of Critical Path Throughout Project

Acceleration Scenario

Should the schedule of the project need to be accelerated for any reason, the portion with the greatest potential for acceleration would be the interior framing, MEP rough-in and interior finishes in Area B and C. Specifically in the classrooms, these activities have a relatively long duration. They take place at similar points in the project. Their early completion would mean an earlier start on Area D work. In doing so, they would be complete earlier, and the finish and casework in Area D could be started earlier. This acceleration could be reached by implementing short interval production planning (SIPS). The modular design of the classrooms would allow this to be implemented. In doing so time could be cut down per room and the overall duration reduced.

Value Engineering Topics

The majority of value engineering done on the Phoenixville Area Middle School took place during the schematic design phase of the project. At this point in the project, the overall cost was over the school district's budget. The project team targeted several areas where scaling back and altering the design would not detract from the owner's overall satisfaction with the final product. While not all proposed changes were accepted, the school district approved many that cut costs significantly. While changes were made in all areas of the middle school, the bulk of design elements to undergo value engineering were interior and exterior finishes, dimensions and layouts of spaces, and the building systems. The cost breakdown of these alterations is listed in the sections below.

Interior and Exterior Finishes

Total Number of Changes Made: 13 **Total Amount Saved: $507,000.00**

This category contains alterations to both the dimensions and types of finishes on the interior and exterior of the building. The changes made in this area had the least impact in reducing the overall manner the building fulfilled the program developed by the owner. However, each change resulted in a relatively minor reduction in project costs. The most significant reductions of cost came from replacing ground-face concrete masonry units in the walls of the corridors with standard epoxy painted concrete masonry units, with a savings of $115,000. Also included is a reduction in height of the bathroom ceramic wall tile from six feet to five feet. On the exterior, the precast concrete window sills, heads, and bands were replaced in favor of colored ground-face concrete masonry units. Each of the items in this category is similarly themed, with a substitution or reduction of a finish in favor of a cheaper alternative. To avoid redundancies, these are not described here.

Dimensions and Layouts of Building Spaces

Total Number of Changes Made: 3 **Total Amount Saved: $1,010,000.00**

Many of the building spaces were altered during the value engineering stage in order to drop costs. While the potential for savings is much greater in this category, so is the risk of taking away from the features needed to meet the requirements of the program. Two of the main changes here include a reduction in square footage and capacity of the Auditorium and Gymnasium. The auditorium square footage dropped by 2,000 square feet, meaning 200 seats had to be removed. The gymnasium lost 1,400 square feet, with a loss of 100 seats. However, the project team and owner decided that this reduction would still provide adequate space, and resulting savings was $660,000. Also included is a reduction in all ceiling heights by eight inches, to bring it down to fourteen feet.

Building Systems

Total Number of Changes Made: 5 **Total Amount Saved: $912,000.00**

This category is comprised of changes made to the mechanical, lighting, and roof of the middle school. These items had a significant impact on project cost. However, the value engineering of the building systems had to take into account the long term costs of the building. The lifetime cost of a building is much greater that the construction costs; replacing a component of a system with a cheaper, less efficient substitute could prove more costly in the long run. This was the case when choosing to change the roofing material and modify the lighting system. A TPO single-ply membrane system was chosen to replace the modified bitumen, however this was seen as an acceptable replacement. The amount of hung pendant fixtures was reduced and more generic fluorescents were added instead. The layout of the mechanical closets containing heat pumps serving each classroom was modified to combine two in each closet. This cut the amount of doors needed while maintaining access for service. The seismic protection for the MEP system was removed, a choice that may come back to haunt the project team. However, the risks were seen as small enough to justify the $100,000 savings that came with it.

Figure 4. View of Gymnasium Courtesy Gilbert Architects

Additional Changes

Along with the previously noted value engineering modifications, further measures were taken to drop costs. The designer initially intended to specify one manufacturer for each material that could be used for the project. This was both to ensure that the correct materials were used on the project by contractors, and to make bidding on the project simpler since it was done by unit cost. However, at the suggestion of the Reynolds Construction Management, this was broadened to a range of four or five for each material. Along with this change, the specified requirements for recycled and regional content were limited for several materials to lower contractor bids.

Unapproved Items

Total Number of Changes Proposed: 4 **Total Potential Amount Saved: $1,645,000.00**

Some changes proposed during the schematic design phase for value engineering were rejected by the Phoenixville Area School District. The potential reduction in cost was not worth the loss of quality of the building. By far the most significant of these changes was the proposed switch from the water-source heat pump design to a roof-top VAV unit with hydronic heating. This change would have dropped with mechanical system $1,300,000. However, the loss of efficiency was unacceptable to the owner. An energy efficient building was a priority from the beginning, despite the decision not to pursue LEED accreditation. Also left out was the switch in finishes for the upper-floor corridors, change in floor finishes for the cafeteria, and reduction in stage size for the auditorium.

Critical Industry Issues

The PACE Roundtable is an annual event that creates an opportunity for Architectural Engineering students at Penn State University to meet and learn from professionals within the construction industry. This conference proved to be a valuable experience in gaining knowledge and insight for fifth-year thesis projects, along with establishing professional contacts whose expertise can be utilized throughout the year. The conference was structured into sessions on varying topics, with three general topics overall. These included sustainability/ green building, process innovation, and technology. Each topic had two separate seminars, and attendees chose which to attend based. Following these seminars was a panel board discussion by attending professionals concerning the effects of the current economic climate on construction companies. Finally, students broke out with individual professionals to discuss their thesis projects.

The following is a summary of key topics discussed in the presentations I attended, along with potential applications to my research on the Phoenixville Area Middle School. I chose to take part in Session 1A: Energy Management Services and Session 2B: Integrated Decisions for High Performance Retrofit Projects. My decision was based on my personal interests and the potential application of these topics to future research on my thesis project.

Session 1A: Energy Management Services

Leader: Bryan Franz

This session was based on the operation of an occupied building's systems after the completion of construction. Occupant behavior was unanimously agreed upon as the most important variable in building management, regardless of the system put into place. Facility managers operating the systems need to understand not only how they work, but also the intended uses of each one. Occupants complaining of conditions within the building cause managers to adjust systems. If a system is overly complex, often times it is misused and the promised energy savings are not reached. Simple systems are better since they are more frequently used correctly. This then gave way to a discussion on the training of operations, and the delivery method of systems in the construction process. Top down management strategies are the best way to ensure successful operation. The owner dictates an energy goal, and then works to incorporate occupants into reaching this strategy. A feature such as the dashboard system, where energy use for a given area is displayed at all times, creates awareness of energy use. An interesting concept was a competition between regions or floors of a building to use the least energy. In terms of the construction phase, the two biggest impacts on an efficient building system are the delivery method of the project, and the owner's willingness to pay more upfront for a higher quality system. An integrated delivery process is the best in designing and maintaining systems. Bringing in the contractors earlier in the design process means the best possible design can be created to suit the conditions and goals of the project. System design selection frequently occurs too late in design. The schematic phase is the best to make changes, and a specialist contractor can present the most options. Value engineering must take into account the costs of the building life-cycle versus the initial costs. Especially with the current equitable rates, a higher upfront cost often means better overall value for a project. The available options depend in large part on the owner's willingness to pay more up front. Certain owners, such as school districts, usually prefer minimum energy management goals. This is a product of tight budgets and the fear of drawing criticism from tax payers for appearing to overspend on projects. While this may be slowly changing for state-funded projects, it is the contractor's responsibility to educate the owner by showing a breakdown of costs throughout the building life-cycle. Schools are fifty-year buildings, meaning a high potential for savings on energy. Finally, load-leveling was discussed as an option for lowering energy costs. By purchasing energy at non-peak hours, or "smart purchasing", owners can optimize fuel coming into a building.

One of the topics that surprised me most about this discussion was how frequently buildings are mismanaged. Given the rapidly growing popularity of LEED certified buildings, I was under the impression that projects which implemented complex, high-efficiency elements performed much better than simple systems. However, the current LEED system does not measure after occupancy, although it was noted that this is changing. The role of building managers and occupants in energy management is overlooked since designers are not responsible for what happens after construction is completed. The use of integrated delivery processes and life-cycle analyses have potential in the future for changing the way both designers and owners look at building system design. The transition will be slower in state-funded projects than private. The required delivery method of state project means that involving the contractor earlier is currently difficult. My thesis project, the Phoenixville Area Middle School, is state-funded and faces this problem. However, the concept of higher upfront costs to achieve the greater life-cycle value is one that can be applied to it. By involving the mechanical contractor earlier in the design phase and showing the long-term cost benefit that comes with it, the school district can get better value for money spent. Contacts that I met from this session that could provide insight into this approach are Daniel Kerr and Christopher Stultz from McClure Company, a mechanical contractor.

Session 2B: Integrated Decisions for High Performance Retrofit Projects

Leader: Dr. Robert Leicht

This session was based on the best methods for decision making on renovation projects. My thesis project is new construction, but I chose this topic based on my interests in examining the delivery method used for the Phoenixville Area Middle School. The discussion began by listing the keys to successful delivery of retrofit projects. Those mentioned included reconnaissance work for existing conditions, obtaining knowledge for educated decision making, and the use of building information models for information sharing. Understanding the existing condition is important to the front end planning of the project. By knowing what will be encountered during construction, the development of the scope can be done to suit the budget. Existing documents are never accurate. An architect or engineer is required to make extensive field measurements and thoroughly inspect all features. This includes things such as existing building systems. Information can then be put into a computer model and used for information sharing throughout the project. The interaction of the different members of the design team can decide whether or not a project will be delivered successfully. This includes not only the architect and engineers, but the owner, general contractor and sub-contractors. The owner must be consulted on the purpose of the project. The life-cycle of the construction being planned influences the design of many different elements. The owner also must be consulted on the past work done on the building. The systems implemented, and the manner by which they were contracted can dictate how things will be approached in the renovation work. The interaction between the design team and the general contractors must be a well thought-out process. Every project must have a specifically designed information sharing process tailored to the specific needs of the project conditions. The leadership role is critical to decision making. Identifying who needs to know what and when and understanding how decisions affect all project members is important to avoid potential mistakes. An information sharing process can be based on past successful projects as well as those that failed. By identifying the point of failure, project teams can learn from past mistakes. Integrated project delivery is a growing trend in construction, and has many benefits for making the best possible project. This includes involving sub-contractors earlier and working with the owner to achieve best value. Sub-contractors are specialists in their respective areas, and can foresee problems that may be overlooked by the design team early on. Their expertise means more options in designing systems as well. Overall, the biggest thing taken away from this session was the need for strong communication between all parties, and the need to plan every detail of construction to give the best possible chance of success.

The most surprising part of this discussion was the lack of communication between project team parties in past construction projects. The classic delivery methods for projects create divisions amongst different members. This inevitably leads to problems when construction takes place, meaning higher costs and schedule delays which lead to disputes or even lawsuits. The integrated delivery process is something that should be required for all projects. While it may scare owners with higher upfront costs, in the end it ensures the best value for a project. It has become easier with the application of BIM, along with other communication tools such as laptops and cell phones. My thesis project is a state-funded job, meaning that the delivery method must be multi-prime design-bid-build. The contractors were not brought into the project until the design was nearly complete. Changes at this point cost much more money, and more often than not are opposed by the design team. While no significant problems have occurred in the construction of my project so far, the owner may not be getting the best value on the project. I would like to examine this specifically on the mechanical system, which implemented water-source heat pumps on the project. Contacts I met from the first session can help with examining the potential for better long-term options.

Problem Identification and Technical Analysis

Overall the Phoenixville Area Middle School project has been a success for all parties involved in its delivery. However, as is the case with any construction project, there are some areas that have potential for improvement. This does not mean those involved have done anything wrong. It means that better long-term value could have been possible had a different approach been made taken in certain areas throughout the project.

Delivery Method and Contracting

The delivery method for the Phoenixville Area Middle School is design-bid-build with multiple prime contracts, the required method for state funded projects. This form of delivery is seen as the best way to lower costs of construction. Given that school buildings are general used for fifty years, the school district may not be getting the best long-term value for their money. Contractors are not brought into the project until the design is complete.

The added benefits to the design and construction planning of systems gained from earlier consultation of contractors can have significant benefits. The research to be conducted will examine historical cost and schedule differences by examining data from past projects. Changes in project design are much easier to make in early planning phases of the project. The owner's needs may be better met without significantly increasing costs. A life-cycle analysis will be compared to construction costs to examine the potential for increased value. The benefits of contractor input in design will be a continual theme throughout each area of technical analysis.

Mechanical System Value Engineering

As previously discussed, the impact of early contractor involvement can benefit the decisions made in designing aspects of a building. The greatest potential for this is in the mechanical system design of the middle school. The owner, as is typical with school districts, was concerned with upfront costs on the project. Water-source heat pumps were chosen for the project due as a way to increase the efficiency of the HVAC system. However, installing a higher efficiency system may have made enough of an impact to warrant the increased upfront costs. My research will examine the long-term cost benefit of geothermal heat pumps over water-source. The impacts of mechanical contractors' early involvement on the cost, schedule and efficiency on mechanical systems will also be covered. This will be done by examining geothermal systems, historical data from other projects, and consulting mechanical contractors.

Application for LEED Silver Certification

LEED certification was not achieved on this project. As discovered in the previous technical report, the middle school scored highly enough on the LEED scorecard to potentially achieve a silver rating. Any state-funded project that gets a silver rating is eligible to receive state money. This compensation would come in the form of a percentage of the money spent on the project.

This research will examine the costs of attaining a LEED silver rating, and determine if the compensation from the government is enough to make certification practical. This will be done with the inclusion of the geothermal heat pumps being examined in the other technical analysis. While cost will increase with the heat pumps, the building efficiency and compensation from the government will as well.

BIM Use for MEP

BIM was not implemented on the project except for the design of the architectural and structural features. Reasons for this given by the architectural firm and construction manager were that the prime contractors did not typically use it. The Phoenixville Area Middle School has a relatively simple design, so BIM was not required to plan out difficult construction activities. However, there are many uses to utilizing BIM software. These include class detection, systems evaluation, and construction planning. My research will focus on the application of BIM to the design and construction planning of the MEP systems. The added costs of using the software will be weighed against the benefits. These include the potential for prefabrication of HVAC ductwork, clash detection, and evaluating the efficiency of MEP systems.

SIPS Application to Classroom Construction

The classrooms in the Phoenixville Area Middle School have a modular design. This makes the installation of systems simpler and allows for an efficient use of floor space. By implementing short interval production schedules (SIPS), the time to install the MEP and finishes in each room will be reduced. The classrooms represent a significant portion of the total building area. Each room has its own heat pump, controls, lighting, finishes and framing. The MEP work specifically takes a significant amount of time on the project schedule. By planning in detail the construction of the classrooms, a significant reduction in schedule may mean shortened overall project duration.