

AE Senior Thesis

Phoenixville Area Middle School: Final Proposal

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Executive Summary

This proposal contains areas of focus that will be researched throughout the following semester. Each of these areas was selected based on the conditions of the project, including such factors as location, delivery method, and design. The common themes that are the basis of the research to be conducted in these areas include: Critical Industry Issue Research, Value Engineering Analysis, Constructability Reviews, and Schedule Acceleration Scenarios. The proposed changes and future findings associated with them are not a negative reflection on the project team's efforts on this job. They are simply a way to examine current issues and ideas by applying them to a project under construction. The analysis areas are broken down and described below.

Alternative Delivery Method

The multiple prime, design-bid-build system typical of state-funded projects is seeing a decline in use in recent projects. The rise of BIM and sustainable systems has given rise to an integrated design-build approach to project organization. This area will cover the changes that would occur had the project team been structured this way, including different roles, responsibilities and lines of communication. Characteristics of successfully run projects using this method will be identified.

Alternative Heat Pump System

The current mechanical system uses water source heat pumps. This was identified in the value engineering process as a place that could achieve higher total value with a more efficient system in place. Geothermal heat pumps will be examined in this section, along with cost, schedule, and constructability concerns. LEED rating will also be addressed in this section, as a cost analysis involving government compensation for silver-rated buildings will be conducted.

BIM Application to Analysis and Planning

BIM use for design analysis and construction planning will be identified for its potential benefits. The uses for multiple and single prime delivery methods will be examined.

Modular Classroom Design

The potential schedule reductions resulting from the modular classroom design will be researched. Trade involvement and responsibility will be used to explain feasibility on this particular project.

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Technical Analysis 1: Alternative Delivery Method

Problem Identification

As required by the Pennsylvania Separations Act, the Phoenixville Area Middle School employs a multiple prime design-bid-build delivery method. An agency construction manager acts as the owner representative, and seven prime contracts were issued rather than the minimum four. While historically this system has been seen as a way to limit construction costs with lower contractor fees, the law mandating multiple prime contracting has recently been criticized for the fiscal and administrative burden it places on the owner. A growing trend within the construction industry is the use of a more integrated delivery method, utilizing a design-build approach. The benefits of this system stem from the increase in communication and involvement of all project team members. By applying this approach to the middle school project, the school district will receive better value for the money spent on construction.

Background Research Performed

As technology and sustainable building systems have played a larger role in the design and construction of buildings, the integrated structure for delivering projects has become increasingly common. The reasons for using this system do not typically include lower construction costs; the benefits are in the quality of design and the long term use of the building. Despite the law concerning multiple prime contracting, school districts can apply for exemption from this requirement. In doing so, they can choose a delivery method they determine to be the most cost effective. Some state funded projects have done this for large, logistically challenging projects. Others did so based on past problems they had with the traditional delivery method. By utilizing a single prime, design-build approach for this project the school district may achieve better value for the money spent on construction.

The research for this analysis area will focus on the application of a single prime, design build delivery method to this project. The shifting of risk, responsibility, and communication amongst members of the project team that comes with the transition to this method will be described and contrasted to the current system.

Potential Solutions

By thoroughly examining the methods and benefits of the design-build approach, the application of this system can be evaluated for the conditions of this project. The findings may result in the conclusion that this would have been a better delivery method for the new middle school. On the

other hand, the project may not possess the features that make the integrated approach worth using. It is possible that the requirements for exemption are not satisfied.

Analysis and Research Methods

Other recently constructed projects that have successfully used this design-build system will be studied to identify a successful organization structure. The benefits of early contractor involvement in designing systems will be evaluated by researching data from other construction projects. To establish a better understanding of the benefits of this delivery method, the opinions of a wide range of industry professionals will be obtained. The process of applying for exemption from the Pennsylvania Separations Act will be researched to identify any requirements.

Expected Outcome

The anticipated result of this research area will be that an alternative delivery method will provide the owner with an overall higher quality product. While the degree to which changes in the way the project is delivered are made may vary based on project conditions, the focus on long term value over lower construction costs will bring higher satisfaction to the school district.

Technical Analysis 2: Alternative Heat Pump System

Problem Identification

An energy efficient design was a focus of the owner and project team from the early planning stages of the project. As an educational institution, the school district felt responsible to set the right example for the students they educate and the community they serve. Economics was the other major driving force with the past and projected spikes in energy costs. Typically budget constraints are a limiting factor in school projects, making upfront costs a more significant concern. The school district declined the option to achieve LEED Certification largely based on this issue. However, state funded projects are eligible to receive compensation for LEED Silver certification, and this project was right at the minimum of points for this rating on the scorecard.

School buildings generally are in use for fifty years, creating a promising opportunity for long term savings potential. Given the cold climate of Eastern Pennsylvania throughout the school year, heating represents a large portion of the building's energy consumption. The Phoenixville Area Middle School was designed with a mechanical system incorporating water source heat pumps. This design is a relatively efficient system, but it does not necessarily guarantee the best value for the school district over the life cycle of the building. By substituting in higher efficiency heat pumps into the system, the school district potentially can save enough on energy costs long term to justify increases in construction costs. Along with energy cost savings, the government compensation would be an added offset to the costs of this system. The additional efficiency would mean a higher overall reduction in consumption, scoring more points on the LEED scorecard and ensuring a silver rating. This area will include a breadth study on the energy use of each system.

Background Research Performed

A discussion at the PACE Roundtable Conference was based around energy management in buildings. A key point from this discussion was the importance of life cycle analysis in design. During the value engineering process on the middle school the mechanical system was targeted. The agency construction manager on the project, Reynolds Construction Management, believed that geothermal heat pumps were a better option than the water source. However, the school district wanted to lower construction costs, and rejected this option.

Potential Solutions

As previously described, this research will be used to determine the short and long term costs of the geothermal heat pumps compared to the currently designed water source. This will then be used to determine if this alternative makes sense economically. Ultimately, the possible outcomes will be that the long term payback makes the new system a better alternative, or that the current system is a better value. LEED silver compensation will also be included. The geothermal system will be evaluated both as with and without this compensation.

Analysis and Research Methods

A breadth study on the efficiency of the geothermal and water source heat pumps will calculate energy consumption differences of each system. The results will be used a part of this analysis. The methods of research for this portion are organized below by the different parts of this topic.

Cost Analysis

Assuming a fifty year building life cycle, the current and projected cost of energy will be used to calculate an approximate value for long term costs. Energy costs will be research based on the current and projected rates determined by expert analysis. Costs on construction will be done through research of past projects and consultation of mechanical contractors.

Construction Concerns

The changes in schedule, logistics, and sequencing of the proposed system will be researched by consulting mechanical contractors. Both the contractor for the project and contacts made at PACE Roundtable will be utilized for their expertise.

LEED Certification

The LEED points will be identified by examining the scorecard requirements and consulting with the construction manager on the project. Using the feasibility study done by the project team and including the changes in heat pump design, the compensation will be determined and used in the cost comparison. Additional efforts required by the project team will be addressed in the construction concerns portion.

Expected Outcome

The geothermal heat pump system is expected to provide better total value than the existing design. The construction manager thought this was the better choice during the planning period of the project despite the school district's decision. The additional efficiency of the system will make LEED silver certification attainable, and the associated compensation and long term savings will make this decision an economically feasible choice.

Technical Analysis 3: BIM Application to Analysis and Planning

Problem Identification

The implementation of modeling software was limited on the Phoenixville Area Middle School. According to the architectural firm, Gilbert Architects, the only areas it was used was for the architectural and structural design. This was then used for school board presentations, facility manager communication, and creating construction documents. Multiple prime contracting structures make building information modeling (BIM) difficult to utilize since it is unclear who is responsible for leading and coordinating the process. The design of the middle school itself does not present extreme logistical or sequencing issues that would require model use for planning. However, opportunities exist on the project for BIM use to improve the processes involved with the design and construction process.

Background Research Performed

Modeling software is versatile in its application to a variety of trades and processes. These are listed in the BIM Execution Guide created by Penn State University. While all of these uses do not apply to this project, certain areas have potential for improving the overall quality of the final product. The complete list is listed below:

Building Maintenance Scheduling	Design Authoring
Building Systems Analysis	Engineering Analysis
Asset Management	Sustainability Evaluation (LEED)
Space Management and Tracking	Code Validation
Disaster Planning	Design Reviews
Record Modeling	Programming
Site Utilization Planning	Site Analysis
Construction System Design	Phase Planning (4D Modeling)
Digital Fabrication	Cost Estimation
3D Control and Planning (Digital Layout)	Existing Conditions Modeling
3D Coordination	

The potential areas of application that have potential to bring positive results to this project are those regarding design analysis and construction planning. Building systems analysis with regard to the mechanical system would have provided a better means of comparison in the value engineering process. In terms of construction planning, using software for MEP 3D

Coordination as well as some form of phase planning (4D modeling) would allow for the fine tuning of the mechanical layout and construction planning. If a modular classroom design were to be used, BIM would facilitate a more detailed plan.

Potential Solutions

The use of modeling software for the previously listed areas could prove to be valuable in providing extra detail and data. Positive impacts such as increased building system efficiency and lowered problems in construction would make its application practical. However, given that the current delivery method is multiple prime, the added hassle associated with BIM use would be greater than that of single prime. Its inclusion in the project may only be practical had the middle school been structured differently.

Analysis and Research Methods

Due to the relatively short period that modeling software has been used as a means of communication amongst team members, there is not much in terms of data that can provide quantitative research for this analysis. However, potential uses and the opinions of professionals will provide the bulk of research for this subject. Mechanical contractors, general contractors, owners and construction managers will be interviewed on a combination of the following topics:

- How BIM was applied to the previously mentioned focuses
- Requirements of all project members in terms of BIM input
- Benefits seen through use
- Problems encountered through use
- Areas that are better than others for application
- Difficulties of multiple prime BIM use

Expected Outcome

The delivery method of the Phoenixville Area Middle School project may restrict the practicality of BIM on the project. However, the areas its use will be explored may prove to be useful for the project team. The use of the software may demonstrate the potential for options that are not available unless it is used on a project.

Technical Analysis 4: Implementing a Modular Classroom Design

Problem Identification

The classrooms of the new middle school represent a significant portion of the building space and schedule. Each one of these rooms has its own HVAC and lighting controls, casework, heat pump, and things such as finishes and glazing that require multiple trades to do work in one area. Each of these rooms is similar in design and size on the project. By creating a way to make these repetitive rooms quicker and simpler, the project can progress more quickly and the overall completion time will drop. One method of accomplishing this task is in developing a modular classroom.

Background Research Performed

Modular rooms are typically used for projects that have several identical rooms and are working with a focus on shortening duration. While using this method can increase costs due to transportation costs, the reduction in schedule can drop the costs of other areas and offset this problem. In order to make this work, the different trades that do work within the room must be coordinated completely so no on site problems are encountered. This is difficult with the multiple prime delivery method since communication and leadership is lacking compared to that of single prime. However, by specifying which trades will do work for the modular room it can be applied to some extent on this project.

Potential Solutions

The degree to which the duration of the classroom construction decreases will vary based on the design of the modular room. Based on the trades identified, the amount of schedule reduction may or may not make the modular application worthwhile. If it does prove practical on this project, it may be useful on other projects done by the construction manager on the job.

Analysis and Research Methods

The benefits and typical applications of modular rooms will be examined by researching other projects that implemented this tactic. Focuses will include types of buildings, trades included, constructability challenged, and changes to cost and schedule. The requirements and limits of contractors in both single and multiple prime settings will be identified as well. This research will be based on other projects, professional interviews, and any literature on the topic.

Expected Outcome

While the delivery method of the project limits the extent to which a modular design can be implemented, some form of modular work can help to reduce the schedule.

Analysis Weight Matrix

The areas of analysis previously described will cover different topics critical to any proposed change to a construction project. These are research, value engineering, constructability review, and schedule reduction. The manner in which each analysis area included these core aspects is detailed in the following table.

Description	Critical Issue Research	Value Engineering	Constructability Review	Schedule Reduction	Analysis Total
Project Delivery	10%	-	-	-	10%
Geothermal Heat Pumps	10%	20%	10%	-	40%
BIM Application	10%	-	-	10%	20%
Modular Classroom	-	10%	10%	10%	30%
Core Topic Total	30%	30%	20%	20%	100%

Timetable

Do to the volume of research necessary for an in depth study of these areas, a well-defined schedule will be important in remaining on track to complete this work. An early estimation of the semester is provided in Appendix B.

Conclusions

Investigating each of these areas will allow an investigation of current industry trends and changes through their application to a project under construction. The goal of this research is not to find errors and problems within the existing Phoenixville Area Middle School; the project team has done a quality job in delivery the project on schedule, on budget, and satisfactory to the owner. The point of these proposed changes is more to examine how the changes in methods and practice seen in today's construction culture can be applied to this specific project. Any findings that show an opportunity to benefit the project team in anyway can be used by them.

Appendix A

Breadth Topic: System Analysis of Geothermal Heat Pump Alternative (Mechanical)

This area will cover the difference in energy efficiency of the proposed geothermal heat pump system compared to the current water source system. This analysis is necessary for the cost comparison described in analysis area two. This study will be done to a somewhat limited extent since accuracy is not required as much as a relative comparison. In order to accomplish this, energy evaluation programs will be used with basic building geometry. The exact program to be used will be chosen based on those available to students at Penn State University. The control system and any other significant issues will be researched through consultation with established mechanical contractors.

Breadth Topic: Modular Classroom Design (Mechanical/ Architectural)

The modular design of the classrooms presents an opportunity for schedule reduction on the project. In order to evaluate the extent to which this will affect the project, a design must be developed in order to establish the requirements and complexities. The trades involved will impact manner in which the room is constructed. Logistics such as transportation and construction will be evaluated and reflected in the design. The research will be based on that other projects did given the conditions and requirements faced.

Appendix B

