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# Final Proposal

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*The Center for Sustainable Landscapes for The Phipps Conservatory and Botanical Gardens – Pittsburgh, PA*

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Construction Option

Advisor: Dr. Robert Leicht

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Penn State AE Senior Thesis

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## **Executive Summary**

The *Final Proposal* presents four analyses that will be presented in the final thesis report studying the construction of the Center for Sustainable Landscapes. Each analysis will provide insight into improving efficiency both directly and indirectly in the construction industry through project delivery method, constructability, value engineering, and schedule acceleration.

### **Analysis 1: Avoiding Traditional Delivery Methods on Publicly Funded Projects**

Developing a decision tree for project developers will facilitate the use of more progressive delivery methods on publically funded jobs, leading to an indirect increase in project efficiency. Currently, Pennsylvania’s contractor law stipulates the selection of a contractor be based on the lowest bid. The objective of this analysis is to develop a decision tree that can be used by owners and developers who desire to implement progressive projects delivery methods on publicly funded project in the state of Pennsylvania. The decision tree will be versatile enough so that it can be generically applied to projects receiving public funding and clearly illustrate to the user an alternative, if one exists, to using design-bid-build and hard bid.

### **Analysis 2: Alternative Design of Atrium**

An alternative design must be developed for the three-story atrium to improve constructability. The current design of the cast-in-place atrium stair is highly labor intensive. Further complicating matters, the atrium is also designed to be passively heated and cooled. The concrete stair is designed to increase the space’s thermal mass to better control the fluctuation in temperature. An alternative atrium design will be done and is expected to increase quality, safety, and constructability. By transferring the thermal mass of the stair to the walls, this design will better facilitate the use of prefabricated concrete panels, and thus reduce construction costs. In addition, using a metal structure for the stair will have significant schedule and construction cost benefits.

### **Analysis 3: Redesign of Mechanical and Electrical Distribution of Raised Access Floor**

An alternative HVAC and electrical distribution system must be designed and planned for implementation as a substitute for the raised access floor system currently specified. The raised access floor system imposed a number of additional costs to this project and only added a marginal amount of value. The removal of the raised access floor and relocation of under floor utilities is anticipated to result in substantial direct and indirect cost savings with minimal affects on schedule, sustainability, and overall project value.

### **Analysis 4: Schedule Acceleration through Façade Redesign**

A schedule acceleration plan must be developed for construction of the Center for Sustainable Landscapes to accommodate for unforeseen delays in the project’s schedule. This will be done by designing a prefabricated structural insulated panel system as an alternative façade assembly to accelerate the schedule. The alternative façade system’s construction is expected to be less labor intensive and quicker than the alternative metal stud framing. The original construction is anticipated to take a total of four weeks; the new construction method will attempt to reduce this duration to one week.

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**Project Background**

The Phipps Conservatory, located in Pittsburgh PA, is expanding its campus and educational facilities with the construction of its new Center for Sustainable Landscapes. Built in 1893, the neighboring Phipps Conservatory and Botanical Gardens is a cultural icon to the greater Pittsburgh area. Phipps has been noticing sizable growth and an increase in national and international attention, as it was the host for the opening dinner of the 2009 G-20 Summit. With this surge of attention, the conservatory has invested in a campus wide development focused on increasing its national image. Figure 1 shows a bird's eye perspective of the campus, the Center for Sustainable Landscapes is the building located in the middle of the image.

Phipps is expanding to offer more educational services by constructing a 3-story, 24,350 square foot mixed use classroom and research building. The most significant owner expectation for the project is that the building is built environmentally consciously by keeping sustainability a top priority. The Center for Sustainable Landscapes is attempting to meet the Living Building Challenge issued by the ILBI, and the Sustainable SITES certification issued by the Sustainable Sites Initiative. By meeting the Living Building Challenge objectives, the building will also exceed LEED Platinum certification. As a result, the biggest challenge faced by this project is the successful achievement of all 3 prestigious sustainable goals. Once complete, this building is designed to operate on net-zero energy as well as net-zero water on an annual basis.

The Center for Sustainable Landscapes will be a showcase for new sustainable construction materials and techniques. Some of the sustainable features include: a green roof, passive and active HVAC systems, onsite power generation, onsite gray and black water retention, a building automation system for the control of dynamic building elements and power consumption, and a intensive effort on using locally available new and reclaimed building materials. Due to the heavy emphasis on sustainability, significant increases in upfront construction costs were seen in exchange for lower life-cycle and operation costs. Figure 2, shows the passive flow of air through the atrium.

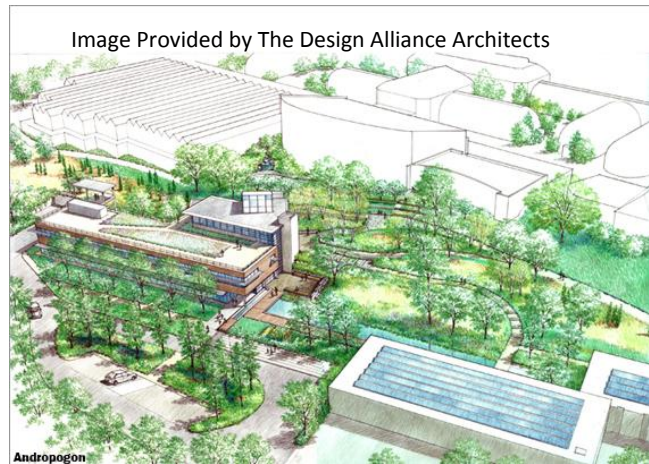


Figure 1 - Bird's eye perspective of the Phipps Conservatory and Center for Sustainable Landscapes.



Figure 2 – Building section explaining the natural ventilation of the passively designed atrium.

Sustainable challenges aside, the construction of the Center for Sustainable Landscapes does not present a large amount of additional challenges for the Turner Construction team. The Phipps Conservatory is a relatively experienced owner that allows the project schedule to be flexible to changes. As a result, the project's duration of approximately a year, from April 2011 to April 2012, is manageable for the highly qualified Turner Construction. Traditional construction and contractual practices used on the project include: construction of a cast-in-place concrete substructure and structural steel superstructure, the project delivery method used was design-bid-build with a lump-sum contractual agreement. The project budget is approximately ten million dollars, a portion of which being public funding. The Turner Construction staff that is managing the project consists of three full time onsite personnel and two office managers. Figure 3, is an image of the project's concrete and steel superstructure.

Aside from weather, there are few externalities affecting work on this project. Site access and size are suitable for the scale of the building footprint and project. The site that the project inhabits was almost vacant, and thus no phased or dual occupancy requirements are needed. Minor inconveniences include the relocation of a few select utilities and the demolition of a small portion of an existing small onsite warehouse.



Figure 3 - Concrete and steel superstructure taken September 7, 2011.

## **Analysis 1: Avoiding Traditional Delivery Methods on Publicly Funded Projects**

### Problem Identification

Currently there are laws in Pennsylvania that stipulates the selection of a contractor based on the lowest bid. This is enforced by the Pennsylvania Department of General Services, which requires publicly funded projects to be competitively bid, typically under the traditional design-bid-build delivery method. This delivery method, which was used on this project, contractually limits the project from innovation and the implementation of technology. Moreover, this delivery method does effectively incentivize the contractor to minimize schedule and cost growth.

### Proposed Solution

To develop a usable decision tree that can be used by owners and developers who desire to implement progressive project delivery methods on publicly funded project in the state of Pennsylvania.

### Research Methods

To complete this research, a greater understanding of the legislation and its implications will be gained by interviewing experienced industry members. This problem will be approached from the perspective of the general contractor as well as the owner. The industry professionals that will be interviewed are listed under *Resources* below. Once the legislation is fully understood a decision tree will be developed.

- Gathering information/Literature Review
- Conduct Contractor and Owner Interviews
- Compare and Analyze Data
- Define underlying problem
- Develop Solution
- Summarize Results

### Resources

- Department of General Services Literature
- Dr. Thomas
- David Zartman – General Contractor
- Mike Arnould
- John Bechtel Penn State OPP
- James Hostetler – Director of Construction and Design at Bucknell University
- Pennsylvania Project Developer
- Associated Builders and Contractors

### Anticipated Results

The decision tree developed will be versatile enough so that it can be generically applied to projects receiving public funding and clearly illustrate to the user an alternative, if one exists, to using design-bid-build. It is believed that not all circumstances will have a solution as the competitive bidding laws in Pennsylvania are narrowly construed and strictly enforced. Once complete, this tool is intended to be used by the Penn State Office of Physical Plant.

## Analysis 2: Alternative Design of Atrium

### Problem Identification

Holistically, the Turner construction team has done an adequate job constructing the Center for Sustainable Landscapes as per plan and specification. However, when considering a smaller more localized portion of the building like the atrium, improvements to design and constructability can be made. Changes that could have improved constructability without sacrificing value should have been considered during design. As a result, an alternative design and construction method should be used for the three-story atrium to improve constructability. The current construction of the cast-in-place atrium stair is highly labor intensive and slow, because it requires the unique forming and casting of each tread and riser around a radius and column that must be formed and cast concurrently. Further complicating matters, the atrium is also designed to be passively heated and cooled. The concrete stair is designed to increase the space's thermal mass to better control the fluctuation in temperature.

### Proposed Solution

In order to improve constructability without negating the spaces passive design, an alternative design will be developed that transfers the thermal mass from the stair to the atrium walls. This alternative design will incorporate a steel stair that can be rapidly assembled as well as concrete wall panels that can be easily mounted to atrium walls.

### Solution Method

- Develop a atrium computer model
- Conduct AE Structural Faculty Interviews
- Conduct Specialized Contractor Interview
- System Design and Design Review
- Feasibility Study and Cost Estimation
- Summarize Results

### Resources

- Precast Concrete Supplier
- AE Structural Faculty
- Applicable Design Literature

### Anticipated Results

The alternative atrium design and construction is expected to increase quality, safety, and constructability. By transferring the thermal mass of the stair to the walls, this design will better facilitate the use of prefabricated concrete panels, and thus reduce construction costs. In addition, using a metal structure for the stair will have significant schedule and construction cost benefits. The original cast-in-place stair design is anticipated to take a total of 4 weeks; the alternative stair design will offer a sizeable reduction in schedule. Furthermore, these design alterations will attempt to match the cost of the original system. Ultimately, alterations made to the design will be aesthetically pleasing and not compromise the passive design of the atrium.

### **Analysis 3: Redesign of Mechanical and Electrical Distribution of Raised Access Floor**

#### Problem Identification

An alternative HVAC and electrical distribution system will be designed and planned for implementation as a substitute for the raised access floor system currently specified. The raised access floor system imposes a number of secondary changes to a project that result in substantial cost gains, with little value added. One of the most significant externalities imposed by the raised access floor is the addition of both direct and indirect increases in building size and strength. The addition of the raised access floor directly increases the dead load on the floor and columns as well as inadvertently increasing the height of the building as a result of the redundant plenum space. This increase in scale affects all aspects of the building, most notably cost. Furthermore, this system requires additional coordination, has a lower constructability when compared to alternative traditional systems, and can be more expensive to maintain as a clean plenum space.

#### Proposed Solution

Increasing the value and constructability of the project will be done by redesigning the above ceiling plenum space to accommodate the utilities that are currently designed to reside beneath the raised access floor.

#### Research Methods

The design of the alternative HVAC and electrical distribution system will be based on *MEEB*, *Mechanical and Electrical Equipment for Buildings*, techniques learned in AE 476, and other pertinent resources.

- Gathering information/Literature Review
- Conduct Specialized Subcontractor Interview
- Alternative System Design
- Summarize Results

#### Resources

- HVAC Design Specialist
- AE Faculty, Licensed Electrical Engineer
- Applicable Literature - 2008 NEC

#### Anticipated Results

The removal of the raised access floor and relocation of under floor utilities is anticipated to result in substantial direct and indirect cost savings with minimal affects on schedule, sustainability, and overall project owner value. The most substantial cost savings are anticipated to be a result of the over reduction in building height by approximately 2 feet, in addition to the removal of the raised flooring system cost entirely. One of the challenging aspects of removing the raised floor plenum will be matching the accessibility of electrical outlets in the floor of the room. Solutions to this problem will likely involve in-slab electrical outlets, or a less desirable wire mold alternative. As a result of the changes, a schedule reduction is anticipated. This reduction however will likely not impact the overall construction duration of the job.



## Analysis 4: Schedule Acceleration through Façade Redesign

### Problem Identification

A schedule acceleration plan must be developed for construction of the Center for Sustainable Landscapes to accommodate for unforeseen delays in the project's schedule. Moreover, this plan will attempt to recuperate approximately 10-15% of the activities scheduled duration. Since unforeseen weather delays occur more frequently prior to a project reaching the *watertight* milestone, schedule acceleration implemented prior to this point will be the most valuable. The most opportune activity that could be changed to increase value and accelerate the schedule is the redesign of the exterior wall assembly to facilitate offsite prefabrication and rapid onsite construction.

### Proposed Solution

This will be done by planning the use of a prefabricated structural insulated panel system as an alternative façade assembly. This façade assembly will be pre-engineered and self-supporting, thus requiring no increases to the existing structural frame. Pieces will be delivered to the site with factory cut openings and assembled by a small crane and crew. Unit sizing will attempt to maintain a comparable weight to the original façade to avoid increase the capacity of the foundation.

### Solution Method

The design of the structural insulated panel system will be based on the Structural Insulate Panel Association's *Engineered Design Guide*. This assembly will be then quantified, priced, and scheduled to reduce the duration of the original façade construction activity duration by a minimum of 10-15%.

- Gathering information/Literature Review
- Conduct Specialized Supplier Interview
- Alternative System Design and Design Review
- Feasibility Study
- Summarize Results

### Resources

- AE Faculty
- Experienced Industry Professional on SIP design
- Contact Murus SIPS for pricing and scheduling

### Anticipated Results

The alternative façade system's construction is expected to be less labor intensive and quicker than the alternative metal stud framing. The original construction is anticipated to take a total of four weeks; the alternative structural insulated panel construction will attempt to reduce this duration to one week. One potential drawback to this alteration is the lead time required for prefabrication. In addition, the structural insulated panel system will provide an increased thermal barrier and is expected to improve the heating and cooling performance of the building. This design change will add value to the project, likely at an increased cost. Additional research will determine the cost savings associated with the reduction in schedule.

## Weight Matrix

The weight matrix shown in Figure 4 illustrates the relative effort that will be placed between the four core areas of analysis. More specifically, the percentages in the table represent the time and effort that will be placed on each analysis.

<b>Figure 4</b>					
<b>Analysis Description</b>	<b>Critical Issues Research</b>	<b>Value Engineering</b>	<b>Construction Review</b>	<b>Schedule Reduction</b>	<b>Total</b>
Project Delivery Method	30%	-	-	-	30%
On-site Prefabrication	-	5%	10%	5%	20%
Distribution System Redesign	-	10%	10%	5%	25%
Façade Redesign	-	10%	5%	10%	25%
<b>Total</b>	30%	25%	25%	20%	<b>100%</b>

## Proposal Work Schedule

See Appendix B for a preliminary work schedule for the spring 2012 semester. This schedule illustrates when and briefly how the research for the analysis topics discussed will be performed in a time sensitive manner.

## Conclusion

After completing additional research, the analyses described will provide insight into improving efficiency in the construction industry both directly and indirectly. It is anticipated that developing a useable process chart for project developers will facilitate the use of more progressive delivery methods on publically funded jobs leading to an indirect increase in project efficiency. The redesigned cast-in-place atrium stair will improve constructability and safety without negating the passive thermal design of the space. In addition, it is also anticipated that the removing the raised access floor distribution system will lower the overall cost of the project without compromising its value. Finally, the redesign of the exterior wall envelope will increase the thermal capacity of the building as well as improve the project schedule.

**Appendix A:**  
**Breadth Proposal**

## Breadth Proposals:

The ensuing breadth topics demonstrate competencies in other disciplines within the curriculum of Architectural Engineering. Each of these breadths are related to, and will be performed concurrently with an analysis previously mentioned.

### **Breadth 1: Redesign of Atrium Stair**

The structural breadth that will be performed will be done in conjunction with *Analysis 2: Alternative Design of Atrium*. As previously mentioned, the current atrium stair is designed to be constructed of cast-in-place concrete. This construction method is significantly more expensive than other alternatives and is highly labor intensive. This breadth will focus on the structural design and calculations for the new atrium stair. The new stair design will be complex in that it will be done in a Caesar style. The materials used will be steel for the frame (including stringers) with precast concrete treads.

### **Breadth 2: Architectural**

Breadth 2 will also be performed on the design of the atrium stair previously discussed in Breadth 1. The stair is located in the main atrium of the building and greets guests from both the roof terrace (connected to the neighboring building) and the main entrance to the facility. The two story stair will be redesigned in a Caesar style that will match the overall motif to the building. The current stair is depicted in Figure 4. A change order has since removed the column extending from the second landing to the roof.



Figure 4 - Cross Section of Atrium. Image provided by Alliance Architects

### **Breadth 3: Mechanical**

Breadth 3 will be performed in conjunction with *Analysis 3: Redesign of Mechanical and Electrical Distribution of Raised Access Floor*. The current design specifies the use of a raised access floor system in the mixed use portion of the building. The benefits gained by this system are minimal when compared to its added cost. The current raised floor mechanical and electrical distribution system supplies approximately 17,900 SF of the building's 24,350 SF. Breadth 3 will design and size both systems to be placed in the above ceiling plenum. In-floor outlets will be either relocated to a wall, or cast into the composite floor slab.

**Appendix B:**  
**Proposal Work Schedule**

## The Center for Sustainable Landscapes - Proposal Work Schedule

Daniel Zartman - Construction Management - Advisor: Dr. Leicht

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	No Classes	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
1/9/2012	1/16/2012	1/23/2012	1/30/2012	2/6/2012	2/13/2012	2/20/2012	2/27/2012	3/5/2012	3/12/2012	3/19/2012	3/26/2012	4/2/2012	4/9/2012	4/16/2012	4/23/2012
Milestone 1 : 1/27/2012			Milestone 2: 2/13/2012			Milestone 3: 3/2/2012			Milestone 4: 3/26/2012						
Gathering Information/Literature Review									Spring Break						
Conduct Contractor and Owner Interviews															
Proposal Updated: 1/12/2012	Compare and Analyze Data														
	Define underlying problem														
	Develop Solution														
	Summarize Results														
Gathering Information/Literature Review															
Conduct AE Structural Faculty Interviews															
Conduct Specialized Contractor Interview															
System Design and Design Review															
Breadth 1:															
Breadth 2:															
Gathering Information/Literature Review															
Conduct AE Faculty Interview															
Conduct Specialized Subcontractor Interview															
Alternative System Design															
Summarize Results															
Breadth 3:															
Gathering Information/Literature Review															
Conduct Specialized Supplier Interview															
Alternative System Design and Design Review															
Feasibility Study															
Summarize Results															
Final Written Report Due: 4/4/2012												Faculty Jury Presentations		Senior Banquet 4/27/2012	

- Analysis 1: Avoiding Traditional Delivery Methods on Publicly Funded Projects
- Analysis 2: On-Site Prefabrication of Atrium Stair
- Analysis 3: Redesign of Mechanical and Electrical Distribution
- Analysis 4: Schedule Acceleration through Façade Redesign

- Breadth 1: Structural
- Breadth 2: Architectural
- Breadth 3: Mechanical

**Appendix C:**  
**MAE Material Incorporation**

## MAE Material Incorporation

The MAE course topics that are most applicable include:

- AE 572 – Project Development and Delivery Planning
- AE 598D – Legal Aspects of Engineering and Construction
- AE 570 – Production Management in Construction

The knowledge gained in AE 572 and AE 598D is directly applicable to *Analysis 1: Avoiding Traditional Delivery Methods on Publicly Funded Projects*. AE 598D provided a basic understanding of the legal doctrines, contractual relations, and construction contracts. AE 572 discussed the methods employed by owners and developers throughout the process of project development. These courses will aid in understanding the fundamental reasons why Pennsylvania’s Department of General Services restricts the use of progressive delivery methods on publicly funded projects. In addition, the course information covered will also provide a greater understanding of the benefits associated with using more progressive project delivery methods such as Design-Build.

The course material covered in AE 570 is applicable to *Analysis 2: On-Site Prefabrication of Atrium Stair*. AE 570 discussed the analysis of production systems and the application of production management tools such as the Toyota Lean Principles. This analysis will improve upon the design and construction of the atrium stair by investigating the problems in the current production system as well applying the basic principles learned in this course to improve upon it.