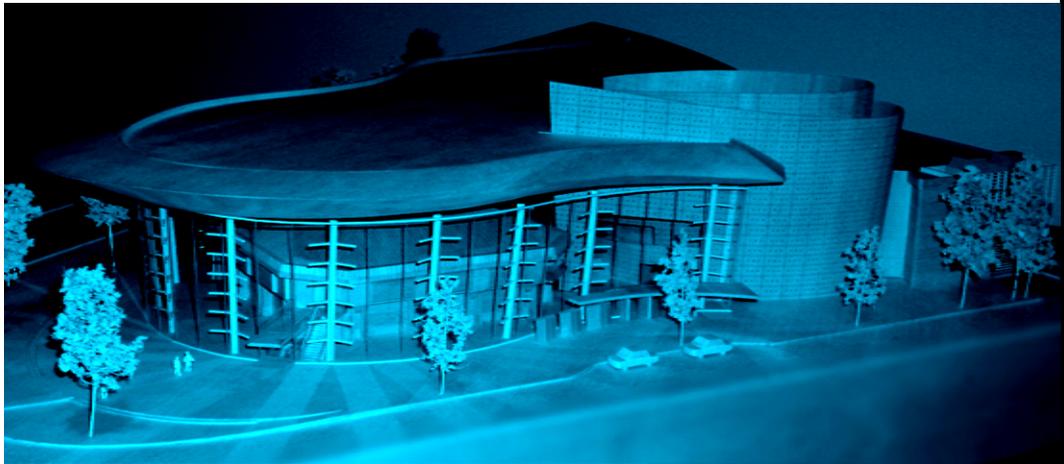


Final Proposal

[Arena Stage]

Washington, DC



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Executive Summary

This Final Proposal serves as an outline for the research and analyses that I plan to conduct in the spring semester. The four analysis areas include:

Analysis I: Eliminate Slope of Curtain Wall

Currently the curtain wall glazing is on an inverted 4 degree slope and runs along a serpentine comprised of multiple radii. There are several sections of glass that are trapezoidal instead of rectangular because of the gradual increase in unit size due to the slope of the wall. Very few are the exact same size and shape, which has caused the glazing to be very expensive. In this analysis, the slope of the glazing will be eliminated and then redesigned to have more uniform unit sizes. This is expected to not only lower the cost of the system, but also decrease the time to install the system.

Analysis II: Redesign Curtain Wall Support

By eliminating the slope of the curtain wall, but maintaining the slope of the columns, this will create the illusion that the entire system is sloped. This is being done so that the curtain wall can remain consistent with the Cradle Theatre which is also on a 4 degree slope. However, this results in the timber structural support no longer being harmonious with the glazing. This analysis consists of redesigning the layout of the timber support arms, muntins, and aluminum plates and calculating the carried loads to make sure that the new system can still meet the structural tolerances that the wall was originally designed to withstand.

Analysis III: Application of Photovoltaic Panels

Theater complexes usually consume large amounts of energy due to their large open spaces and high ceilings which can result in excessive heating and cooling. Since *Energy and the Economy* is a critical industry issue that was discussed at the PACE Roundtable, this analysis will enhance Arena Stage with the application of solar tracking panels to employ the use of solar/renewable energy. Although a high upfront cost is expected for the material and installation of this system, is likely that it will increase the life-cycle cost of the building.

Analysis IV: Application of Off-Peak Cooling

The current HVAC design utilizes (2) 375 ton centrifugal chillers to meet the required cooling demand loads. In commercial buildings, chillers usually consume more energy than any other single piece of equipment. This analysis will explore the implementation of an off-peak cooling (OPC) mechanism. Specifically, thermal-energy (ice) storage tanks will be designed in order to work in conjunction with the chillers and decrease the amount of energy they consume. Again, a high upfront cost is expected, but it could potentially allow for a decreased chiller size, will produce energy savings, and will eliminate some of the noise experienced by tenants since they operate during off-peak hours.

At the end of this document, a weight matrix is provided to illustrate the distribution of time and effort among the proposed analyses as well as a summary of the proposed breadth topics. Also incorporated is a calendar which is a week by week summary of the spring 2009 semester with completion dates for each of the analyses discussed above.

A. Background

Arena Stage is a performing arts theater complex that is located on the corner of Sixth Street and Main Avenue in Southwest Washington, DC. Main Avenue SW is a busy street that runs the length of the Washington Channel and terminates at the Tidal Basin with the intersection of 17th Street and Independence Ave. The site has an awkward triangular shape and is adjacent to several residential high-rises to the north and east.

In 1999, Arena Stage decided to build a new facility and, instead of relocating to a new site, the Board of Trustees chose to remain in their waterfront location. By staying in the original location, the theater became a part of the city's Anacostia Waterfront Initiative (AWI). The goal of the initiative is to make the Southwest DC Waterfront a more alluring section of the city and join the ranks as a leading attraction. It is currently the city's number one economic development priority. The new Arena Stage is a crucial part of the city's revitalization, just like the New Nationals Ballpark which was one of the first major movements.

The rebirth of Arena Stage, called The Next Stage Campaign, involves a massive renovation of the original Fichandler and Kreeger theatres complete with modern amenities, updated décor, enhanced acoustics, and brand new building equipment. Also, an additional space called the Cradle is being added to promote the writing and production of new American plays. New office and rehearsal space is being built in the Back of House region atop a new one-story parking garage located below grade.

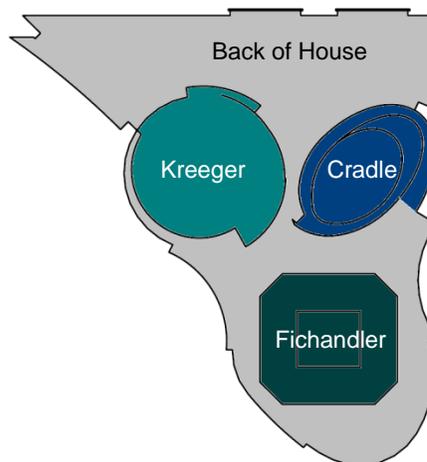


Figure 1: Schematic floor plan of Arena Stage

Clark Construction Group, LLC was awarded the construction contract in May of 2007 for the 200,000 square foot project costing approximately \$125 million. Construction began in January of 2008 and is scheduled to complete in June 2010.

B. Analysis I: Eliminate Slope of the Curtain Wall

Depth

Problem Statement:

One of the most problematic features of the project is the 45' tall curtain wall. The glazing is on an inverted 4 degree slope and the wall is a serpentine comprised of multiple radii. It is sectioned off into 12'x6'-4" insulated glass frames which weigh approximately 850 pounds per unit. There are several sections of glass that are trapezoidal instead of rectangular because of the gradual increase in unit size due to the slope of the wall. The use of multiple radii also results in size variance amongst the glazing units. Very few are the exact same size and shape. The glass is hung from the ceiling by stainless steel cables which are supported by wide flange beams located in the ceiling above the lobby. Finally, the load is passed off to the parallam timber columns which have a cast ductile-iron caps and bases.

As one of the main design features of Arena Stage, the curtain wall is a very extravagant and expensive component. The custom cut glazing units greatly increase the cost of glass portion of the curtain wall. According to the detailed estimate performed in Technical Assignment 2, the curtain wall costs approximately \$3,925,000, or \$143.15 per square foot of glazing.



Figure 2: Curtain wall similar to Arena Stage (image provided by StructureCraft Inc.)

Proposed Solution:

Eliminate the 4 degree slope of the curtain wall, but maintain the tilt of the wood columns to provide the illusion that the entire system is sloped. By keeping the wood columns sloped it would keep the system consistent with the Cradle Theatre, which also sloped 4 degrees vertically.

Solution Method:

In order to perform this analysis, a full understanding of the current system would need to be achieved. Obtaining a full set of shop drawings of both the glazing and structural systems is necessary. The exact number of custom units would need to be determined and converted to the non-sloping alternative. Once the new number and size of the

units was calculated, a new glazing estimate could be performed and compared to the original design.

This adjustment would not only alter the design and manufacturing of the curtain wall, but will affect its installation as well. Being educated in how the system is installed will allow for a better study of its effect on the schedule. Using historical performance logs of both of the structural and glazing contractors and working with them to determine a realistic time deduction for this potentially simpler system would then be completed.

Resources:

- StructureCraft Inc.
- Icon Exterior Building Solutions
- Glazing Mock-up design/Test procedure narrative
- Structural wind load testing and tolerance narrative

Expected Outcome:

The trapezoidal glazing units would be eliminated and more uniform units could be manufactured in their place, therefore reducing the overall cost of the glazing. It is also expected that this will significantly reduce difficulty of construction, resulting in an accelerated schedule. Also, this would have little architectural impact since the tilted wood columns would provide the illusion that the entire system was somewhat sloped, which is also concealed by the overhang of the roof.

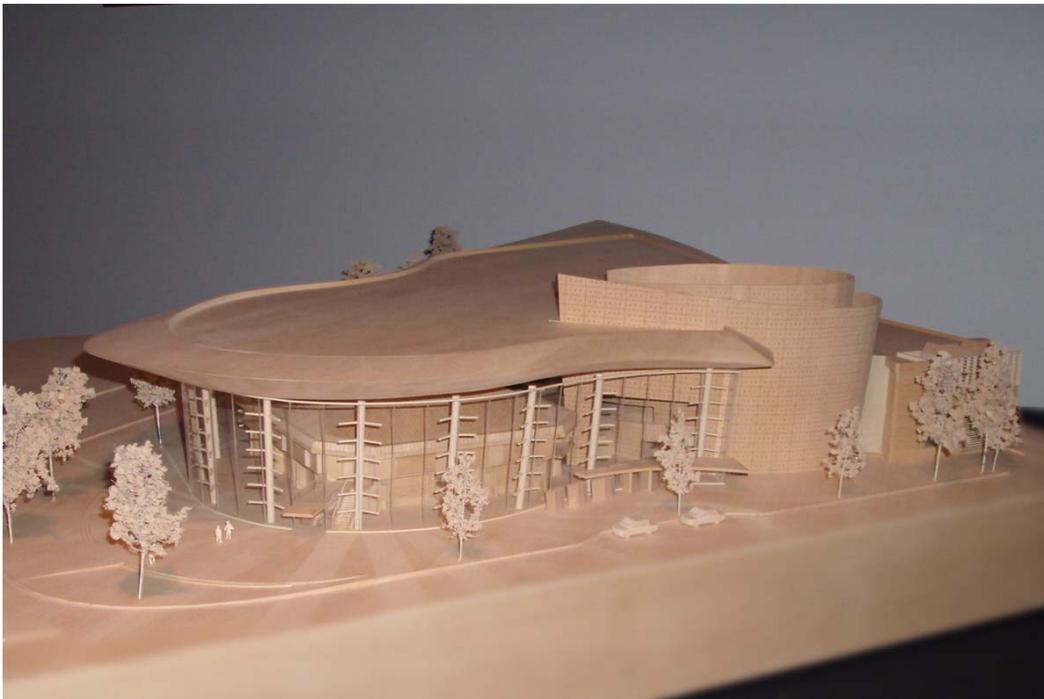


Figure 3: Current (2008) Model showing the roof overhang

C. Analysis II: Redesign Curtain Wall Support

Structural Breadth

Problem Statement:

By taking away the slant of the curtain wall, but maintaining the slope of the columns, the timber structural support is no longer going to be harmonious with the glazing.

Proposed Solution:

Reconfigure and redesign the structural support system to be consistent with the new curtain wall design.

Solution Method:

The support arms are going to have to be elongated to reach the new location of the glazing (see Figure 5). The muntins may also need to move depending on the new sizes of the glazing units. Similarly, the stainless steel cable that carries the bulk of the dead load of the glass will also be adjusted to run vertically plumb. In order to properly connect the cable, muntins, and support arm, the aluminum plate location will be adjusted as well. New calculations of the structural loads carried by each component will be performed to make sure that the new system can withstand all loads and tolerances, or will be redesigned to do so. A new cost estimate can then be performed.

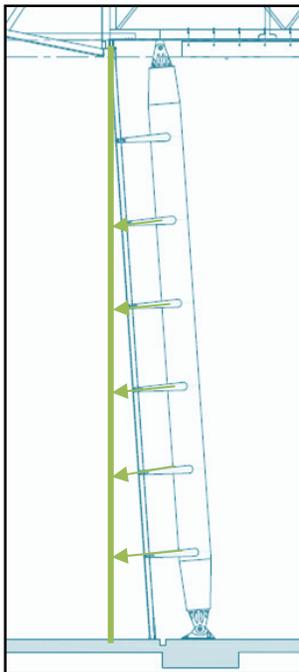


Figure 5: Section of the curtain wall without the 4 degree slope and extended support arms



Figure 4: This detail shows the connection of the support arm and muntins to the aluminum plate and the intersection of the support cable with the aluminum plate

Resources:

- StructureCraft Inc.
- Icon Exterior Building Solutions

Expected Outcome:

The change to the current structural system will have a higher initial cost due to the new sizes of the timber components. However, this higher upfront cost will be minimal compared to the amount of money that will be saved by making the glazing of the curtain wall more uniform. Also, the increase in customization of the timber structure will not have a huge impact in coordination since all of the timber columns can be expected to have the same number, types, and sizes of structural arms, muntins, and plates.

D. Analysis III: Application of Photovoltaic Panels

*[Critical Industry Issue Analysis]
Sustainability Breadth*

Problem Statement:

Since Arena Stage is not striving to achieve LEED certification, little was done in regard to the environment or energy consideration. Theatre complexes usually consume large amounts of energy due to their large open spaces and high ceilings which can result in excessive heating and cooling. Since *Energy and the Economy* is a critical industry issue that was discussed at the PACE Roundtable, it would be wise to enhance Arena Stage with the application of sustainable systems. This will reveal areas where Arena Stage may have been able to be a little more energy conscious and increase the life-cycle cost of the building.

Proposed Solution:

The use of solar tracking panels to implement the use of solar/renewable energy.

Solution Method:

Research the availability of sunlight on the site in order to propose a location where PV panels could be installed in order to optimize solar gain without drastically affecting the aesthetics of the building. Examining the sun path in Washington, DC and the effects of the shade from surrounding buildings will also be necessary. Finding a material provider and experienced PV installer from the area would be pivotal for this addition. Once these preliminary studies are done, the size and number of solar panels can be determined. A calculation can be performed to see what types of energy savings could be expected and compare them to projected energy consumption of the building (if available). The cost and time associated with adding the system would be produced as well.

Resources:

- EDSGN 498A: *Solar Electrical System Design and Construction* (spring 2009 course)
- Penn State Professors knowledgeable in sustainable design
- PACE Industry Professionals
- Online research

Expected Outcome:

Although a relatively high upfront cost is expected, by collecting solar radiation from the sun and converting that energy to electricity, the operating costs of the theater complex can be reduced, therefore reducing the life-cycle cost of the building.

E. Analysis IV: Application of Off-Peak Cooling

*[Critical Industry Issue Analysis]
Mechanical Breadth*

Problem Statement:

Again, design considerations for Arena Stage were not focused around energy saving measures. The current design utilizes (2) 375 ton centrifugal chillers to meet the required cooling demand loads. In commercial buildings, chillers usually consume more energy than any other single piece of equipment.

Proposed Solution:

Implement an off-peak cooling (OPC) mechanism such as a thermal-energy (ice) storage tanks in order to work in conjunction with the chillers and decrease the amount of energy they consume.

Solution Method:

First, consultation with a mechanical contractor would need to occur in order to assess the feasibility of this application. Then the building cooling loads would need to be calculated in order to figure out exactly how much energy is being consumed by the current system. As with the PV trackers, finding a material provider and experienced storage tank installer from the area would be necessary. Once adequate research is performed on OPC systems, a specific type of storage tank could be chosen and an installation location around the building could be selected. Using the calculated cooling loads, the size and quantity of tanks could then be determined. Finally, an energy saving analysis could be performed and a suggestion could be made to decrease the size of the chillers. The cost and time associated with adding the system would be produced as well.

Resources:

- Southland Industries
- HVAC Basis of Design
- Penn State Professors knowledgeable in sustainable design
- Online research

Expected Outcome:

Again, a relatively high upfront cost is expected, OPC is expected to considerably reduce the required performance of the chillers and a potential resizing of the units could be a result. This will lower the energy consumed by the chillers and, therefore, reduce the life-cycle cost of the building. Also, by producing ice during off-peak hours, any noise produced by the system is not experienced by the tenants and the noise from the chillers is expected to be reduced since they are not required to work as hard.

F. Conclusion

Arena Stage is a complex project that has undergone several changes since the inception of its design almost eight years ago. Through value engineering measures, it has been stripped of all frivolous features in order to meet its very tight budget which is limited by the donations made to the Next Stage Campaign.

Although there are several problematic features on the project, the four analyses listed above were chosen due to my interest in the topics and knowing that I will enjoy performing the research. Also, the educational value of the research and analysis that I will be completing will be beneficial to my future career in industry. Analysis I and II involve the curtain wall system which, since I obtained this project, has been my favorite design component of Arena Stage. The adjustment of system is expected to cost less money and increase the project schedule. Although minor structural implications are expected, it is a reasonable adjustment that has the opportunity to drastically simplify the entire system and decrease the overall cost.

Analysis III and IV deal with the critical industry issue *Energy and the Economy* that was discussed at the PACE Roundtable. I feel that this is a very important issue to be aware of and understand that there are ways to decrease, or counter, the amount of energy a building consumes. Although photovoltaic panels and ice storage tanks are mechanisms that cost a lot of money up front, they not only add value to the building, but they have the ability to decrease the life-cycle cost of the building, which often gets overlooked. By educating the owner in this area of importance, they could become willing to spend the extra money in the beginning in order to save money in the long run.

G. Weight Matrix

The weight matrix shown in Table 1 illustrates the distribution of time and effort among the proposed analyses.

Table 1: Weight Matrix

Description	Research	Value Engineering	Constructability Review	Schedule Reduction	Total
Curtain Wall Slant	-	10%	15%	10%	35%
Parallam Timber Columns	5%	10%	5%	-	20%
PV Panels	10%	15%	-	-	25%
Off Peak Cooling	10%	10%	-	-	20%
Total	30%	40%	20%	10%	100%

H. Appendix I: Breadth Excerpts

Breadth I: Redesign Curtain Wall Support

As a depth topic, the 4 degree slope of the curtain wall glazing is going to be eliminated, but the slope of the columns is going to be maintained, to give the illusion that the system is still sloped. However, the timber structural support is no longer going to be harmonious with the glazing. To resolve this, the structural support system will be reconfigured and redesigned to be consistent with the new curtain wall. The support arms are going to have to be elongated to reach the new location of the glazing. Since the stainless steel cables are going to be moved, the muntins and aluminum connection plates will be relocated to properly intersect all of the components. New calculations of the structural loads carried by each component will be performed to make sure that the new system can withstand all loads and tolerances, or will be adjusted to do so. The change to the current structural system will have a higher initial cost due to the new sizes of the timber components. However, this higher upfront cost will be minimal compared to the amount of money that will be saved by making the glazing of the curtain wall more uniform. Also, the increase in customization of the timber structure will not have a huge impact in coordination since all of the timber columns can be expected to have the same number, types, and sizes of structural arms, muntins, and plates.

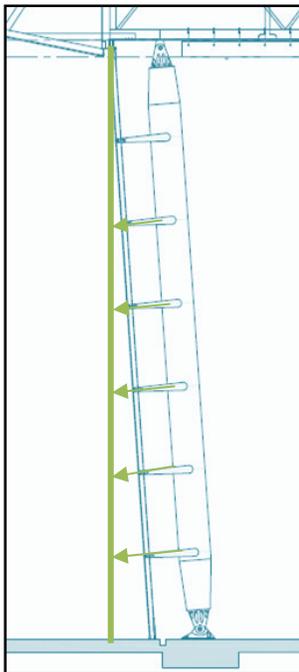


Figure 7: Section of the curtain wall without the 4 degree slope and extended support arms



Figure 6: This detail shows the connection of the support arm and muntins to the aluminum plate and the intersection of the support cable with the aluminum plate

Breadth II: Application of Photovoltaic Tracker Panels

Since Arena Stage is not striving to achieve LEED certification, design considerations were not focused around energy saving measures. Theatre complexes usually consume large amounts of energy due to their large open spaces and high ceilings which can result in excessive heating/cooling. Since *Energy and the Economy* is a critical industry issue that was discussed at the PACE Roundtable, the use of solar tracking panels to implement the use of solar/renewable energy is a way to counter Arena Stage's energy consumption. Researching the availability of sunlight, proposing a location for installation, examining the sun path in Washington, DC and the effects of the shade from surrounding buildings will all be necessary. After finding a material provider and installer from the area, the size and number of solar panels will be determined. Energy savings will be calculated to see what types of energy savings could be expected. The cost and time associated with adding the system would be produced as well. Although a relatively high upfront cost is expected, by collecting solar radiation from the sun and converting that energy to electricity, the operating costs of the theater complex can be reduced, therefore reducing the life-cycle cost of the building.

Breadth III: Application of Off-Peak Cooling

The current mechanical system utilizes (2) 375 ton centrifugal chillers to meet the building's cooling demand loads. In commercial buildings, chillers usually consume more energy than any other single piece of equipment. Implementation of an off-peak cooling (OPC) mechanism such as a thermal-energy (ice) storage tanks working in conjunction with the chillers can decrease the amount of energy they consume. After consulting with a mechanical contractor, the building cooling loads will be calculated to determine exactly how much energy is being consumed by the current system. After finding a material provider installer, research will need to be performed on OPC systems. Once a specific type of storage tank is chosen and an installation location is picked, the size and quantity of tanks will be determined. Finally, an energy saving analysis will be performed and, potentially, a suggestion could be made to decrease the size of the chillers. The cost and time associated with adding the system would be produced as well. Again, a relatively high upfront cost is expected, but OPC is expected to drastically reduce the required performance of the chillers and smaller chillers could potentially be used. This will lower the energy consumed by the chillers and, therefore, reduce the life-cycle cost of the building. Also, by producing ice during off-peak hours, any noise produced by the system is not experienced and the noise from the chillers is expected to be reduced since they are not required to work as hard.

I. Appendix II: Spring 2009 Timetable

Tables 2 – 5 show a week by week summary of the spring 2009 semester and target dates for the completion of each of the analyses discussed above.

Table 2: Production calendar for January 2009

JANUARY 2009						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				1	2	3
4	5	6	7	8	9	10
WINTER BREAK						
11	12	13	14	15	16	17
Obtain curtain wall shop drawings Speak with subcontractors about the adjustment						
18	19	20	21	22	23	24
Establish layout with new uniform glazing size Perform new glazing estimate						
25	26	27	28	29	30	31
Obtain installation instructions and historical performance logs Determine schedule reduction						

Table 3: Production calendar for February 2009

FEBRUARY 2009						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
Analyze load applications of the system Design schematic layout of the timber supports, perform structural load calculations						
8	9	10	11	12	13	14
Design final support system Create new structural drawings and details, determine structural cost impact						
15	16	17	18	19	20	21
Perform research on DC sun path, analyze shade fun surrounding buildings Find potential locations for installation of PV panels						
22	23	24	25	26	27	28
Find a material provider/installer, choose install location Size PV panels and determine quantity						

Table 4: Production calendar for March 2009

MARCH 2009						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
Calculate energy savings, compare to building operation cost Cost and installation estimates						
8	9	10	11	12	13	14
SPRING BREAK						
15	16	17	18	19	20	21
Consult with Southland about OFC Perform research on ice storage systems, Find a material provider/installer						
22	23	24	25	26	27	28
Choose install location, calculate cooling loads Determine size and quantity of tanks						
29	30	31				
Calculate energy savings, compare to building operation cost, cost and installation estimates						

Table 5: Production calendar for April 2009

APRIL 2009						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
Extra time to fix problematic areas or get caught up						
5	6	7	8	9	10	11
Prepare Presentation and Final Report						
12	13	14	15	16	17	18
FINAL THESIS PRESENTATIONS						
19	20	21	22	23	24	25
26	27	28	29	30		