Team SAND

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1 Problem Formulation

1.1 Introduction

This section of the document describes the objective of the design project. A black box diagram (Figure 1-1) is used to simplify the objective statement.

1.2 Objective

The objective of this design project is to design a solution that will improve the acoustics inside the Humboldt Coastal Nature Center. The project will be centered on a list of criteria generated by the client, Friends of the Dunes.

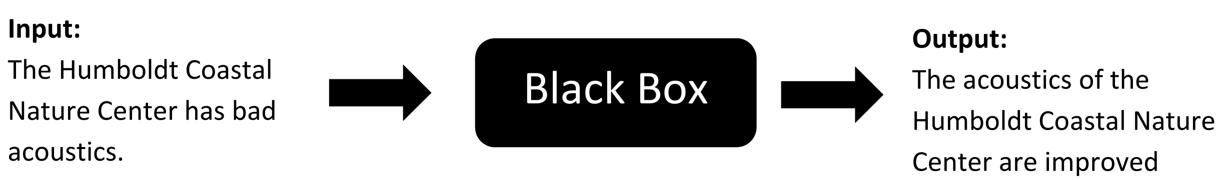

Figure 1-1: Black box model of the design objective.

2 Problem Analysis and Literature Review

2.1 Introduction to Problem Analysis

Here, Team SAND presents criteria, considerations, specifications, as well as constraints with regards to our project with the Friends of the Dunes for improving the acoustics within the Humboldt Coastal Nature Center.

2.1.1 Specifications

These are the specifications, or the minimum requirements, for the acoustic banners project. They are the following:

- The location for the acoustic banners will be at the Humboldt Coastal Nature Center in Manila, California.
- The acoustic banners will lower reverberation rate within the Humboldt Coastal Nature Center.

2.1.2 Considerations

Considerations are aspects of the project that are required to be successful and that are formulated from the specifications. The considerations are the following:

- The system naturally improves the acoustics of the Humboldt Coastal Nature Center.
- The system will be located indoors at all time
- The system will follow all California building regulations

2.1.3 Criteria

This is a list of the criteria for the acoustic dampening project. The constraints and the weight of their importance are also given.

- Safety
    - Constraints: Safe to handle and be around
    - Weight: 10
- Aesthetics
    - Constraints: Pleasing to the eye and fits in with the building's motif
    - Weight: 8
- Functionality
    - Constraints: Improves the acoustics of the room
    - Weight: 10
- Cost
    - Constraints: Stay under the $400 budget (100 from client, 300 from members), client may also be able to provide grant money for this project.
    - Weight: 3
- Durability
    - Constraints: Will remain working until the future remodel
    - Weight: 5
- Inspires
    - Constraints: People leave the facility with more awareness of “green” building methods
    - Weight: 5

- Ease of Maintenance and Installation
  - Constraints: Minimal amount of effort to install and keep functioning
  - Weight: 7

- Appropriateness
  - Constraints: Uses alternative “green” building techniques that go well with what the Friends of the Dunes believe in.
  - Weight: 7

2.1.4 Usage

The Humboldt Coastal Nature Center will be using this design to improve the acoustics throughout the inside of the Humboldt Coastal Nature Center.

2.1.5 Production Volume

The project will be designed and built once during the allotted time.

2.2 Introduction to Literature Review

The purpose of the literature review is to establish a background of knowledge which can be used for the design process. The following topics will be discussed through this section: Friends of the Dunes, client criteria, acoustics, acoustic design, building design, and materials.

2.3 Friends of the Dunes

Friends of the Dunes (FOTD) is a non-profit organization based in Manila, California. FOTD’s mission is to converse and restore coastal environments through service, education and stewardship. FOTD is working with teams from Humboldt State’s 2012 spring semester Engineering 215 class in developing designs to help FOTD achieve its goals.

2.4 Client Criteria

Our client with the Humboldt Coast Nature Center met with a member of our group on February 17th. The client wants some way to improve the acoustics in the visitor center. The client wishes for these criteria to be followed:

- Client would like the implemented design to be a light base color
- Design should Improve the aesthetic quality of the room

2.4 Acoustics

2.5.1 Sound

Sound is a vibration, in the form of a sinusoidal wave (Figure 2-1), which creates a pressure disturbance within a fluid. This fluid needs to be an elastic medium, in that it returns to its original shape after being disturbed. (Hillenbrand 2011) The rate of vibration, or frequency, determines whether the sound is audible to a listener and is measured by how many cycles of the wave occur every second. For example, a low frequency produces a low sounding noise, and if the frequency is high the sound will be high. (Hillenbrand 2011)

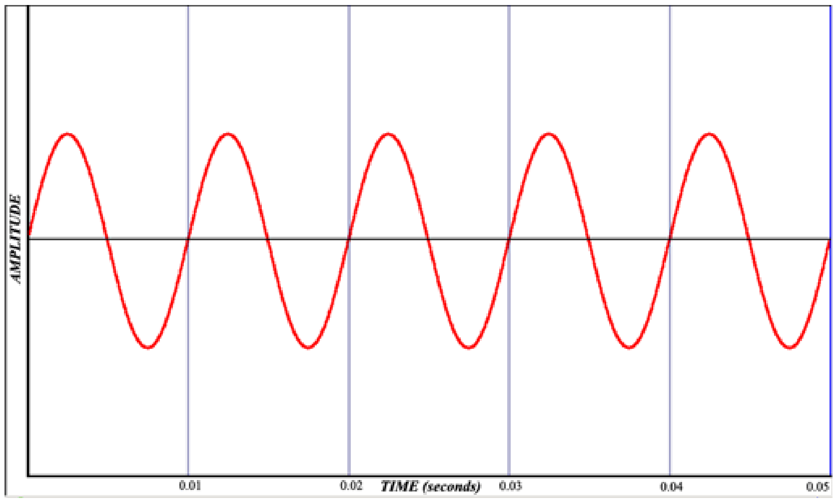

Figure 2-1: Geometric representation of a sinusoidal sound wave (Michael 2012)

2.5.2 Sound Interaction

2.5.2.1 Introduction

When a sound wave hits an object, the wave is either absorbed or reflected by the object depending on the structure of the object. In this sub-section, the differences between sound absorption and sound reflection are clarified.

2.5.2.2 Sound Absorption

When a sound wave hits an object that is not infinitely rigid, some of the wave's vibration is absorbed into the material. This contact will cause the sound wave to lose some of its energy. Depending on some properties of the object, the wave could lose more or less energy. (Howard & James 2001) For example, if the object is made of a porous material, the waves will experience more diffusion because there is more surface area for the wave to contact with inside the material.

2.5.2.3 Sound Reflection

When a sound wave hits an object, some of the energy can be reflected. This is the process that creates echoes and is mainly associated with very rigid objects. If a sound wave were to hit an immovable object, all of the energy in that sound must bounce off in the reverse direction from where it came from because the object cannot absorb any of that energy. (Howard & James 2012) In the Humboldt Coast Nature Center, their acoustic problem is most likely due to too much sound reflection.

2.6 Acoustic Design

2.6.1 Introduction

Acoustic design is utilized to counteract the many varieties of sound and it directly affects the quality of the structures. Achieving optimum acoustical design is based upon the size and shape of building and the method for dampening. This section will provide information on the acoustic design of the most common and alternative methods for dampening sound.

2.6.2 Acoustic Banners

Since the materials used in constructing most conference centers, auditoriums and gymnasiums are very hard, reverberant noise can intensify the sound in an already noisy environment. Reverberant noise is sound energy radiating from voices or other sources which impacts the surrounding hard surfaces, amplifies and then is reflected back toward the source. In these situations, acoustic banners can effectively reduce ambient noise levels by up to 10 dB, by allowing large quantities of acoustically absorptive material to be distributed throughout an area, and help provide a more enjoyable environment while enhancing the area's interior decor at the same time. (Enoisecontrol 2003)

2.6.3 Acoustic Panels

The primary element that will dictate an acoustic panel's acoustical performance is its thickness. The most prevalent fabric used to cover an acoustic panel is woven polyester, which is acoustically transparent and extremely easy to work with. The panel edges will frequently be specified to be hardened by impregnating the edge with a polyester resin or be framed with an aluminum edge molding. The fiberglass cores used in the United States today are long fibered resilient fiberglass mats that are sufficiently resilient to withstand abuse and crushing while still being able to be machined to produce a variety of edge profiles. The soft panel edges also have the ability to improve the acoustical performance due to what is termed the "edge effect"; that is to say the soft edges will also allow acoustical absorption where the panels are separated with a space between the panels. (Acoustical Surfaces)

The most cost effective way of mounting acoustical wall panels is through the use of impaling clips that are permanently mounted to the wall and then pushed into the back of the panel where they are locked into place with adhesive that wicks into and binds the glass fibers together. If by chance the panels for any reason do have to be removed, careful removal will pull some of the fiberglass from the panel back. When relocating the panel, simply locate the impaling clips in a different location. Impaling clips provide a more cost-effective approach in both materials and labor to install the panels. (Acoustical Surfaces)

2.6.4 Alternative Design

There are many other alternative ways to design methods of sound dampening. Depending on the size and amount of money you’re willing to spend, designs can range from materials made out of:

- Egg Cartons
- Foam

- Acoustic Baffles
- Acoustic Tiles
- Blankets

2.7 Building Design

The Humboldt Coastal Nature Center (Figure 2-2) was originally built in 1985 by Charles Stamp as a retirement home. The building itself isa domed earth shelter and is solidly constructed with steel beams, rebar and concrete. (Gail 2012)

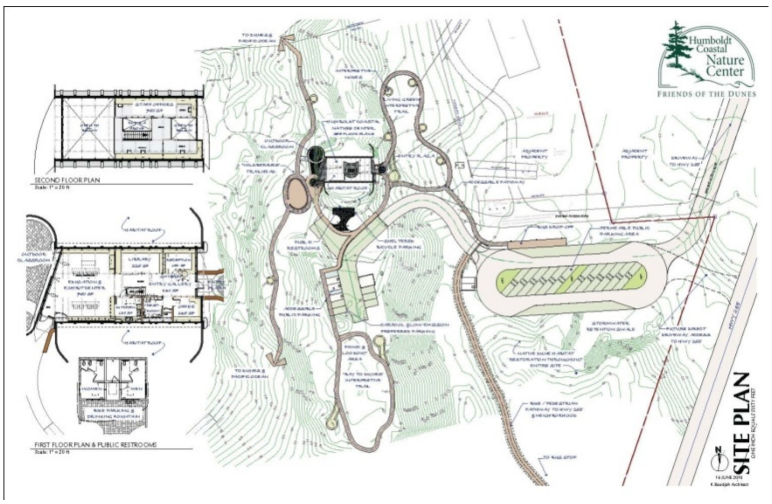

Figure 2-2: Overhead view of the Humboldt Coastal Nature Center (friendsofthedunes.org)

2.8.1 Introduction

In order to complete the task of controlling sound that is echoed in the Humboldt Coast Nature Center, materials that can possibly be used will be categorized under the criteria of being alternative, acoustic, or local materials as well as their benefits and disadvantages.

2.8.2 Alternative Materials

Green materials used in construction are designed to produce minimal amount of impact on the environment while also being safe and healthy for people to be in the vicinity of. (Mohamed and Darus 2011) These materials are often renewable such as bamboo or straw (Mohamed and Darus 2011) or recycled and therefore can reduce costs up to 30% (Dator 2010). It can be noted that some green material availability can be limited. (Knowles et al 2011) Here are some possible materials that can be used in this specific design.

2.8.1.1 Living Walls

Living Walls (Figure 2-3) are an environmental beneficial design method to improve interior structures by decreasing the noise pollution and improving the carbon footprint, indoor temperatures, and indoor air quality of a space. (Loh 2008)

Figure 2-3: Living Wall structure (Appropedia, 2009)

2.8.1.2 Ecoladrillo

A building system created by ECO-TEC utilizes non-returnable PET bottles to form structures such as retaining walls, sheds, and even homes. The bottles are used as bricks and are linked together by a mortar/ string system or framing system. (Figure 2-4) This system reduces the use of carbon building materials (wood, steel) and is its own recycling program. This system is estimated to cost less than most building materials and encourages volunteer help. (Froese 2010)

Figure 2- 4: Example of Ecoladrillo construction being used (Appropedia)

2.8.3 Acoustic Materials

Materials have different properties that can control the way sound waves are transmitted, absorbed, or reflected. (Figure 2-5) Hard materials that do not absorb sound well will cause reverberation, or the decay of sound after its source has stopped. (Cox and D'Antonio 2009) Materials with absorptive properties can be placed over these hard surfaces to reduce reverberation. (Bies and Hansen 2009) Materials that have high absorption coefficients include:

- Acoustic Tiles
- Mineral Wool
- Slag Wool
- Glass Silk
- 25 mm Wood
- Wool Cements
- Brickwork

(www.EngineeringToolBox.com, 2011)

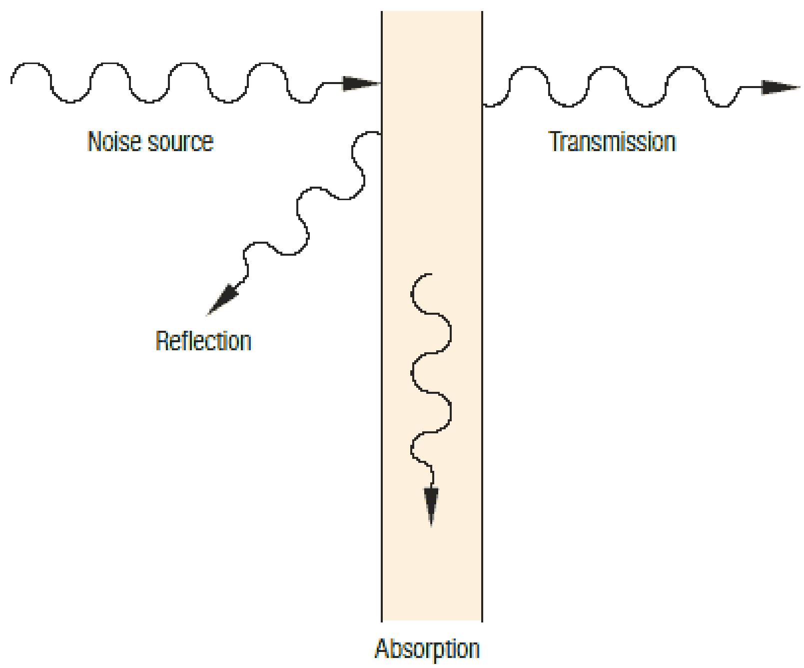

Figure 2-5: A visual representation of sound absorption (panels.kingspan.in)

2.8.4 Local Materials

Materials that can be found locally were also considered for the project because of their potential for ease of acquisition and cheaper costs.

- Wool
- Old Carpet
- Timber
- Beach Grass
- Newspaper
- Pallets
- Variety of biomass
- Vegetation and trees

3 Search for Alternative Solutions

3.1 Introduction

To produce alternative solutions for improving the acoustics of the Friends of the Dunes visitor center, a few brainstorm sessions took place. At the sessions, each solution that was proposed was reviewed with the approved set of criteria. The final set of alternative solutions consists of the most reasonable designs that were formulated in the brainstorm sessions.

3.2 Brainstorming

We as a team had three successful brainstorming sessions for formulating and developing ideas for alternative solutions. The notes from the sessions are located in the appendix of this document. For the first brainstorm session, we started with thinking of different locations in the facility that would work for either an acoustic panel or an acoustic banner. We then brainstormed on what type of materials could be used in the banners or panels. Our first brainstorm session was finished after a discussion about different designs, besides banners or panels, which could be implemented to improve the acoustics of the room.

The second and third brainstorm sessions for our team consisted of refining the list of materials, locations and other designs from the previous session. We started out with the list of materials and locations. We then refined that list down to what would be plausible designs. After this step we added the other specific designs to the list and this became our designs for the alternative solutions.

3.3 Alternative Solutions

During the brainstorming sessions, the following sixteen solutions were formulated:

- Carpet installation
- Wooly Panels
- Trashy Panels
- Grassy Panels
- Foamy Panels
- Banners hung vertically from ceiling
- Banners hung against the walls
- Banners draped across the ceiling
- Acoustic chandeliers filled with sheared wool
- Acoustic chandeliers filled with trash
- Acoustic chandeliers filled with beach grass
- Acoustic chandeliers filled with foam
- Diffusers installed on ceiling
- Plants
- White noise generator
- Acoustic chandeliers with bird shaped foam

3.3.1 Alternative Solution 1: Carpet installation

In the carpet installation solution, carpet is used to cover the concrete floors and also the low ledges that border most of the inside of the building. In the Figure 3-1, a representation of where the building would be carpeted is pictured. Carpet installation does not meet several of the specified criteria, but also excels in other aspects. Carpet is a safe material and poses no risks to the visitors or workers. Also, carpet would decrease the possibility of serious injury in case of a fall on to the floor because it would provide more cushion than the hard concrete slabs. The carpet would add to the aesthetics of the building because the concrete slabs are not pleasing to the eye. The carpet would do an excellent job at improving the acoustics because it decreases the amount of hard, sound reflecting surfaces. The carpet would also be a good sound absorber depending on its thickness and style. Carpeting, depending on where it is purchased and how it is made, can be expensive. So it would possibly not score very well in the cost criteria. Carpet, especially if it is an indoor-outdoor style, is very durable and would likely last at least until the remodel. Another criterion carpet doesn’t meet well is ease of maintenance and installation. Because the Nature Center will have foot traffic from visitors hiking the beach trails, there is a high possibility that these people would track in dirt, sand or moisture. This would pose a maintenance issue for the staff because the carpet would need to be cleaned regularly. Carpet can also be difficult to install, and considering that have desks and cubicles already inside, it would be an extensive job. Lastly, carpet would not satisfy the inspiration category well or the appropriateness category either. Both rely on green building materials and it would be difficult to implement that into something like carpet.

Figure 3- 1: The Carpet Installation uses carpet to improve the acoustics in the inside of the building. The carpet is installed on the entire concrete floor of the building and also on the ledges that surround most of the room. In the figure the shaded areas are where carpet would be located. This figure only represents a small portion (the west portion of the building) of what would actually be covered by the carpet. The carpet would cover most of the horizontal surfaces of the building along with all sides of the ledge

3.3.2 Alternative Solution 2: Wooly Panels

The Wooly Panels solution is custom made acoustic panels filled with unused sheared wool and installed at head height. Figure 3-2 illustrates theses panels installed on the western half of the facility because the other half has desks and other structures situated against the wall. The panels would be located at a general head level height because most of the sound that reverberates throughout the building is generated from speech which is produced at head height. The sound waves would travel, in theory, from the person to the wall parallel to the ground. Since this is the first contact point for the sound waves, placing panels in that area would significantly reduce the energy of the sound wave before it had time to reflect off any other surfaces. Wooly Panels fits well with the designated criteria.

The panels would be safe for the visitors and the staff because they would not be mounted high enough to pose as an injury risk if a panel fell from events such as earthquakes. The safety risks associated with sheared wool are unclear, however it would seem as though there would not be any serious risks. Wooly Panels would offer an aesthetic improvement to the building. These panels will be wrapped in a colored fabric that matches the motif of the building and local environment. Wooly Panels would be a good solution to the acoustic trouble of the building because of the location of the panels and the wool that fills the panels. The main cost factor for Wooly Panels would be the price of the wool. Even though the wool would go unused anyway, there are a lot of panels to fill with the material. Wooly Panels would have no trouble fulfilling the durability aspect of our criteria because there are a very limited number of problems to be considered with just general wear over time. By using wool, the Wooly Panels would achieve the inspiration criteria as well as the appropriateness criteria. Wool is an excellent alternative material because it would have just been discarded by the workers. Since Wooly

Panels are only mounted at head level the installation would go easily and also if the panels needed maintenance, they are easily reached.

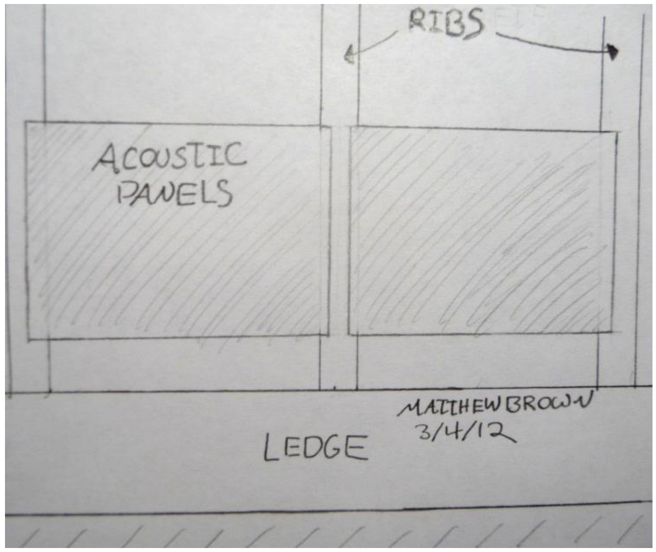

Figure 3- 2: Wooly Panels improves acoustics by absorbing the sound waves that hit the panel. The panels are installed at average head height in order to maximize sound absorption. The panel frames will be filled with unused sheep's wool and then the panels will be wrapped in a fabric that's color will match the motif of the room and will also add to the sound absorption.

3.3.3 Alternative Solution 3: Trashy Panels

The Trashy Panels solution is custom made acoustic panels filled with solid trash or recyclables, or any combination of both, and installed at head height. Figure 3-3 illustrates theses panels installed on the western half of the facility because the other half has desks and other structures situated against the wall. The panels would be located at a general head level height because most of the sound that reverberates throughout the building is generated from speech which is produced at head height. The sound waves would travel, in theory, from the person to the wall parallel to the ground. Since this is the first contact point for the sound waves, placing panels in that area would significantly reduce the energy of the sound wave before it had time to reflect off any other surfaces. Trashy Panels fits well with the designated criteria.

The panels would be safe for the visitors and the staff because they would not be mounted high enough to pose as an injury risk if a panel fell from events such as earthquakes. The trash or recyclables inside the panels would not be harmful and as precautionary measures, the contents would be sorted to make sure nothing clearly hurtful is put in the panels. Trashy Panels would offer an aesthetic improvement to the building. These panels will be wrapped in a colored fabric that matches the motif of the building and the local environment. Trashy Panels would be a good solution to the acoustic trouble of the building because of the location of the panels and the trash or recyclables that fill the panels. There are not any apparent high costs to implement Trashy Panels. The most costly part would either be the costs of building the frame, or the fabric covering, or the mounting apparatus. Trashy Panels would have no trouble fulfilling the durability aspect of our criteria because are a very limited number of problems to be considered with just general wear over time. By using trash or recyclables, the Trashy

Panels would achieve the inspiration criteria as well as the appropriateness criteria. Trash or recyclables are an excellent alternative material because if it is trash, it is much better than being moved to a landfill and if it is recyclables, the materials are being recycled in a different way. Since Trashy Panels are only mounted at head level the installation would go easily and also if the panels needed maintenance, they are easily reached.

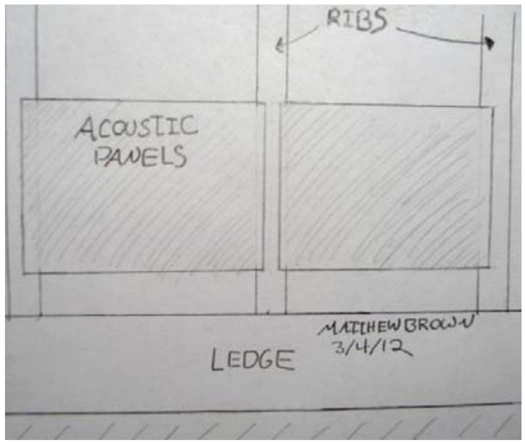

Figure 3- 3: Trashy Panels improves acoustics by absorbing the sound waves that hit the panel. The panels are installed at average head height in order to maximize sound absorption. The panel frames will be filled with either recyclables or trash, or some combination of both, and then the panels will be wrapped in a fabric that's color will match the motif of the room and will also add to the sound absorption.

3.3.4 Alternative Solution 4: Grassy Panels

The Grassy Panels solution is custom made acoustic panels filled with beach grass that is collected from the local dunes and installed at head height. Figure 3-4 illustrates theses panels installed on the western half of the facility because the other half has desks and other structures situated against the wall. The panels would be located at a general head level height because most of the sound that reverberates throughout the building is generated from speech which is produced at head height. The sound waves would travel, in theory, from the person to the wall parallel to the ground. Since this is the first contact point for the sound waves, placing panels in that area would significantly reduce the energy of the sound wave before it had time to reflect off any other surfaces. Grassy Panels fits well with the designated criteria.

The panels would be safe for the visitors and the staff because they would not be mounted high enough to pose as an injury risk if a panel fell from events such as earthquakes. The safety risks associated with beach grass is unclear, however it would seem as though there would not be any serious risks. Grassy Panels would offer an aesthetic improvement to the building. These panels will be wrapped in a colored fabric that matches the motif of the building and the local environment. Grassy Panels would be a good solution to the acoustic trouble of the building because of the location of the panels and the grass that fills the panels. There are not any apparent high costs to implement Grassy Panels. The most costly part would either be the costs of building the frame, or the fabric covering, or the mounting apparatus. Grassy Panels would have no trouble fulfilling the durability aspect of our criteria because are a very limited number of problems to be considered with just general wear over time. By using beach grass, the Grassy Panels would achieve the inspiration criteria as well as the appropriateness criteria. Beach grass is an excellent alternative material because it is already being removed from the local dunes and the Friends of the Dunes are looking for ways to dispose of it. Since Grassy Panels are only mounted at head height, the installation would go easily. Also, if the panels needed maintenance they are easily reached.

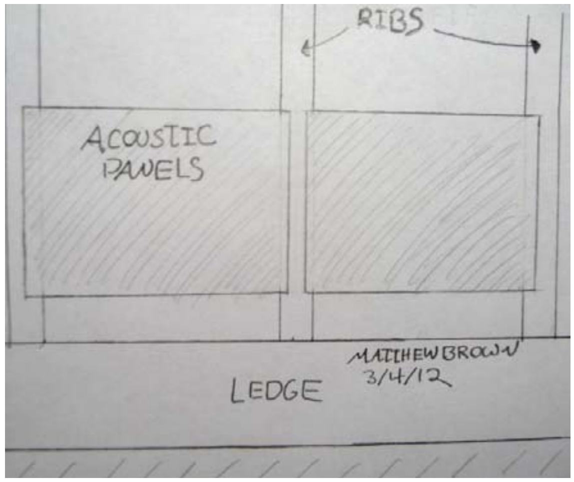

Figure 3- 3: Grassy Panels improves acoustics by absorbing the sound waves that hit the panel. The panels are installed at average head height in order to maximize sound absorption. The panel frames will be filled with the collected beach grass from the local dunes and then the panels will be wrapped in a fabric that's color will match the motif of the room and will also add to the sound absorption.

3.3.5 Alternative Solution 5: Foamy Panels

The Foamy Panels solution is custom made acoustic panels filled with scrap foam and installed at head height. Figure 3-5 illustrates theses panels installed on the western half of the facility because the other half has desks and other structures situated against the wall. The panels would be located at a general head level height because most of the sound that reverberates throughout the building is generated from speech which is produced at head height. The sound waves would travel, in theory, from the person to the wall parallel to the ground. Since this is the first contact point for the sound waves, placing panels in that area would significantly reduce the energy of the sound wave before it had time to reflect off any other surfaces. Foamy Panels doesn't completely fulfill the designated criteria.

The panels would be safe for the visitors and the staff because they would not be mounted high enough to pose as an injury risk if a panel fell from events such as earthquakes. The safety risks associated with scrap foam is unclear, however it would seem as though there would not be any serious risks. Foamy Panels would offer an aesthetic improvement to the building. These panels will be wrapped in a colored fabric that matches the motif of the building and the local environment. Foamy Panels would be a good solution to the acoustic trouble of the building because of the location of the panels and the foam that fills the panels. The cost associated with Foamy Panels has the possibility of being relatively high. Unless there is scrap foam available locally for free or a low cost, the foam could be ordered online from several businesses who specifically sell scrap foam. However, the cost of ordering the foam would be high. Foamy Panels would have no trouble fulfilling the durability aspect of our criteria because there are a very limited number of problems to be considered with just general wear over time. Scrap foam is not an impressive “green” building material so Foamy Panels has trouble fulfilling the inspiration criteria and the appropriateness criteria as well. Since Foamy Panels are only mounted at head height, the installation would go easily. Also, if the panels needed maintenance they are easily reached.

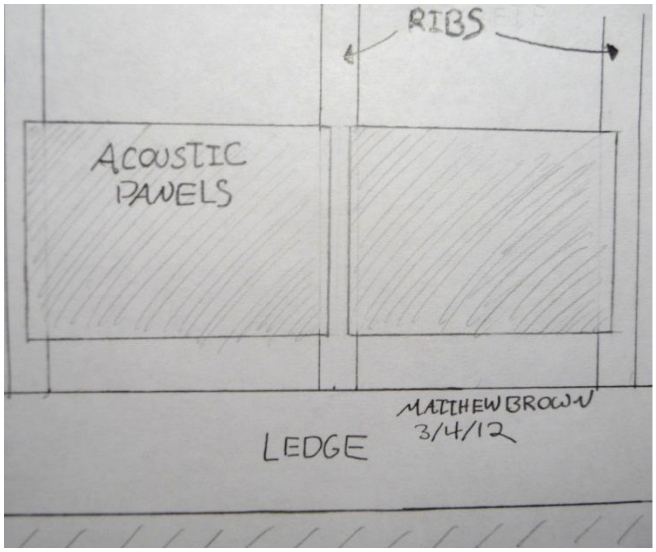

Figure 3- 5: Foamy Panels improves acoustics by absorbing the sound waves that hit the panel. The panels are installed at average head height in order to maximize sound absorption. The panel frames will be filled with scrap foam and then the panels will be wrapped in a fabric that’s color will match the motif of the room and will also add to the sound absorption.

3.3.6 Alternative Solution 6: Vertically Attached Banners

The vertically attached banners are constructed with wooden frames filled with a sound absorbing material and a fabric cover. These materials were chosen to absorb the most sound. Since the nature center is built in a half-circle shape, the banners are specifically placed at different heights so they can dampen the sound that is reverberated at different angles. In Figure 3-6, the placement of the banners is pictured and labeled. Banners 1-3 and 10-12 are the longest vertical banners that cover the distance from the bottom of the hanging lights to the top of the concrete ledge on both sides. They absorb most of the horizontal sound due to the fact the main sound source is people. Banners 4, 5, 8, and 9 are attached higher up on both sides that acoustically cover from the top of the light fixtures to where they are bolted into the ceiling. These banners absorb and act as a barrier to the sound that is usually reflected back down to the floor due to the half-circle shape of the building. Banners 6 and 7 are the shortest vertical banners and they hang from the square wooden ceiling. They eliminate any remaining sound that is reflected from the other banners.

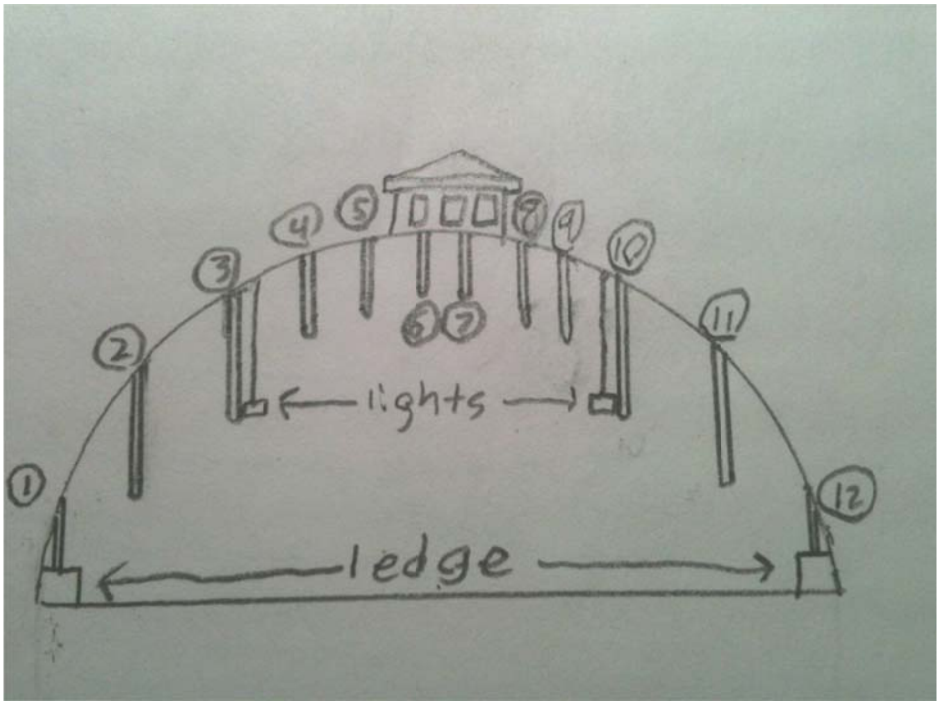

Figure 3- 6: Vertically attached banners improves acoustics by absorbing the sound waves that hit the banners. The banners labeled (1-12) are installed at different heights in order to maximize sound absorbtion from all angles. The wooden banner frames will be filled with a sound absorbing material and then the panels will be wrapped in a fabric that's color will match the motif of the room and will also add to the sound absorption.

The Vertically Attached Banners meet the safety criterion by following government regulations and is safe to be around or handle. The functionality criterion is met by improving the acoustics of the nature center and reduces the reverberation rate. The appropriateness criterion is met by utilizing environmentally friendly building techniques such as, building with local redwood and local recycled materials. The cost criterion is met by staying under the $400 budget previously set by the team. The construction of the banners meets the durability criterion by utilizing wooden frames and a fabric cover to hold all the fillings.

3.3.7 Alternative Solution 7: Horizontally Attached Banners

The Horizontally Attached Banners are constructed with wooden frames filled with a sound absorbing material and a fabric cover. These materials were chosen to absorb the most sound and since the nature center is built in a dome shape, the banners are specifically placed at different heights so they can dampen the reverberated sound at different angles. In Figure 3-7, the placement of the banners is pictured and labeled. Banners 1, 2, 6, and 7 are the lowest and are bolted into the wall. Their position will absorb whatever sound that is refracted off the curved shape of the walls. Banners 3, 4, and 5 are closer to the top of the dome and will dampen most of the vertical sound from sources along the middle of the nature center.

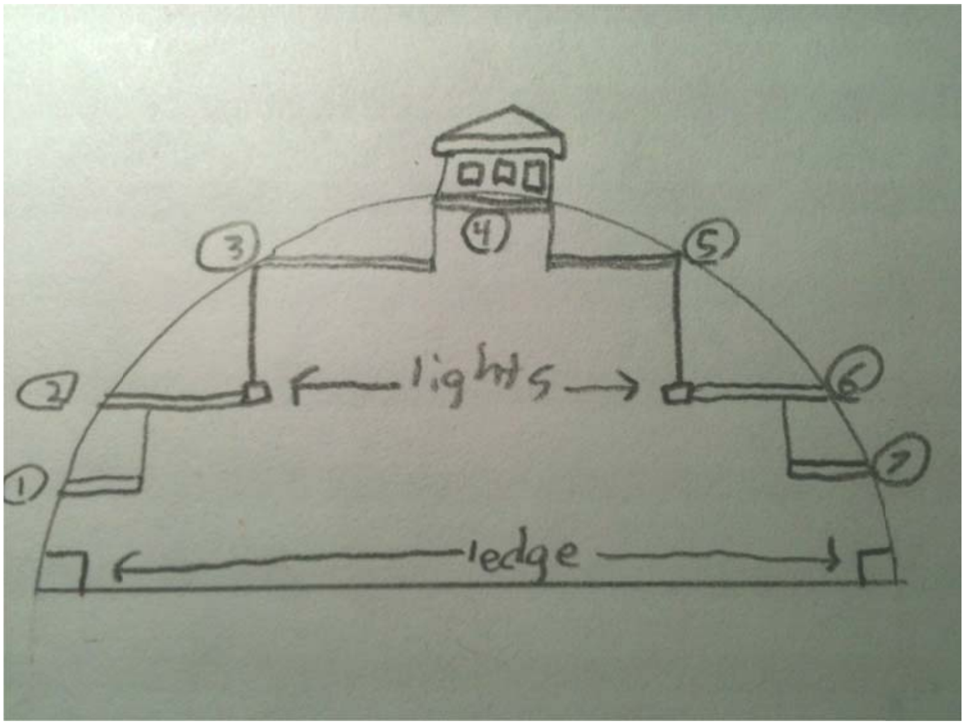

Figure 3- 7: Horizontally attached banners improves acoustics by absorbing the sound waves that hit the banners. The banners labeled (1-7) are installed at different heights in order to maximize sound absorbtion from all angles. The wooden banner frames will be filled with unused sheep's wool and then the panels will be wrapped in a fabric that's color will match the motif of the room and will also add to the sound absorption.

The Horizontally Attached Banners meet the safety criterion by following government regulations and is safe to be around or handle. The Functionality criterion is met by improving the acoustics of the nature center and reduces the reverberation time. The appropriateness criterion is met by utilizing environmentally friendly building techniques such as, building with local redwood and local recycled materials. The cost criterion is met by staying under the $400 budget previously set by the team. The construction of the banners meets the durability criterion by utilizing wooden frames and a fabric cover to hold all the fillings.

3.3.8 Alternative Solutions 8: Banners against the Walls

The Banners that will be attached to the walls will be constructed with wooden frames filled with an acoustic absorbing material and a fabric cover. These materials were chosen to absorb the most sound and since the nature center is built in a dome shape, the banners will be built with a curve so they can be flush with the walls of the building. In figure 3-8, the placement of the banners is pictured and labeled. The blue indicates the placement of the banners and to show how close they are to the walls. This design will ensure that there is no space for sound to reverberate off the walls and will absorb sound from a source at any angle.

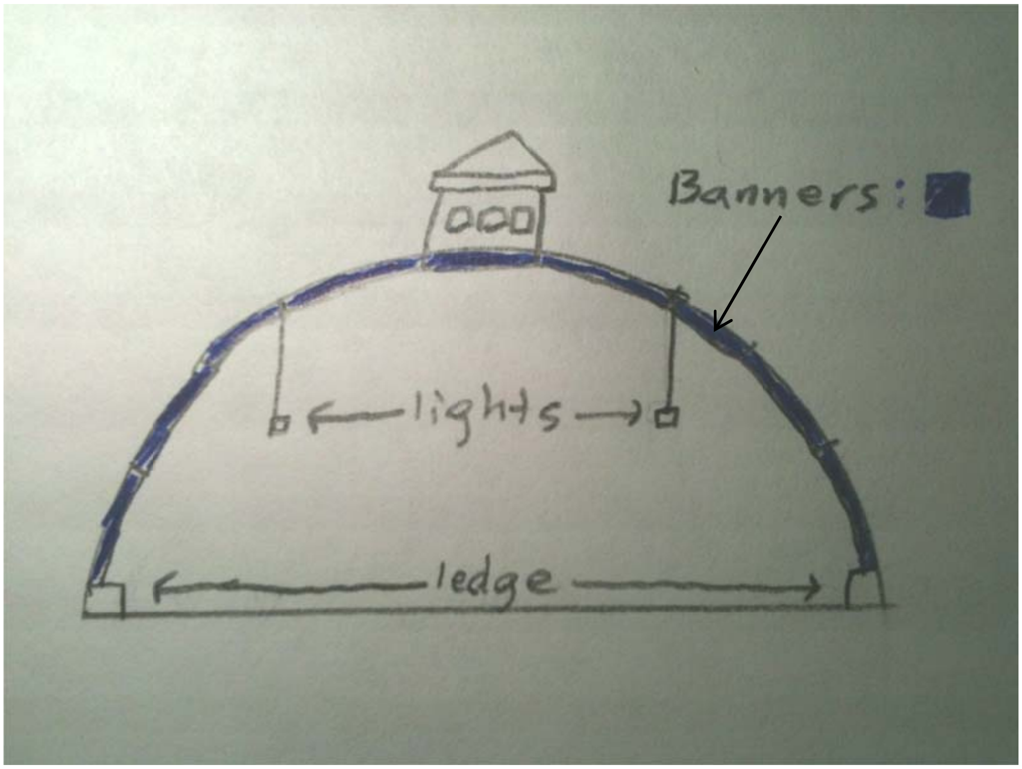

Figure 3- 8: Banners agaisnt the Walls improves acoustics by absorbing the sound waves that hit the banners. The banners (blue) are installed agasint the walls in order to maximize sound absorbtion from all angles and eliminate reverberated sound. The wooden banner frames will be filled with unused sheep's wool and then the panels will be wrapped in a fabric of color that matches the motif of the room.

The banners against the walls meet the safety criterion by following government regulations and is safe to be around or handle. The functionality criterion is met by improving the acoustics of the nature center and reduces the reverberation time. The appropriateness criterion is met by utilizing environmentally friendly building techniques such as, building with local redwood and local recycled materials. The cost criterion is met by staying under the $400 budget previously set by the team. The construction of the banners meets the durability criterion by utilizing wooden frames and a fabric cover to hold all the fillings.

3.3.9 Alternative Solutions 9: Draping Banners

The banners that will be draped to the walls will be constructed with wooden frames filled with an sound absorbing material and a fabric cover. These materials were chosen to absorb the most sound and since the nature center is built in a dome shape, the banners will be draped from the opening in the ceiling and the lights, so that the least amount of space is taken up. In figure 3-9 the placement of the banners is pictured and labeled. The banners will absorb unwanted sound from any angle by itself; in addition the shape and space created in between the ceiling and the banner, will act as an acoustic diffuser as well. This diffuser will work by dampening echoes and reflections from various sources.

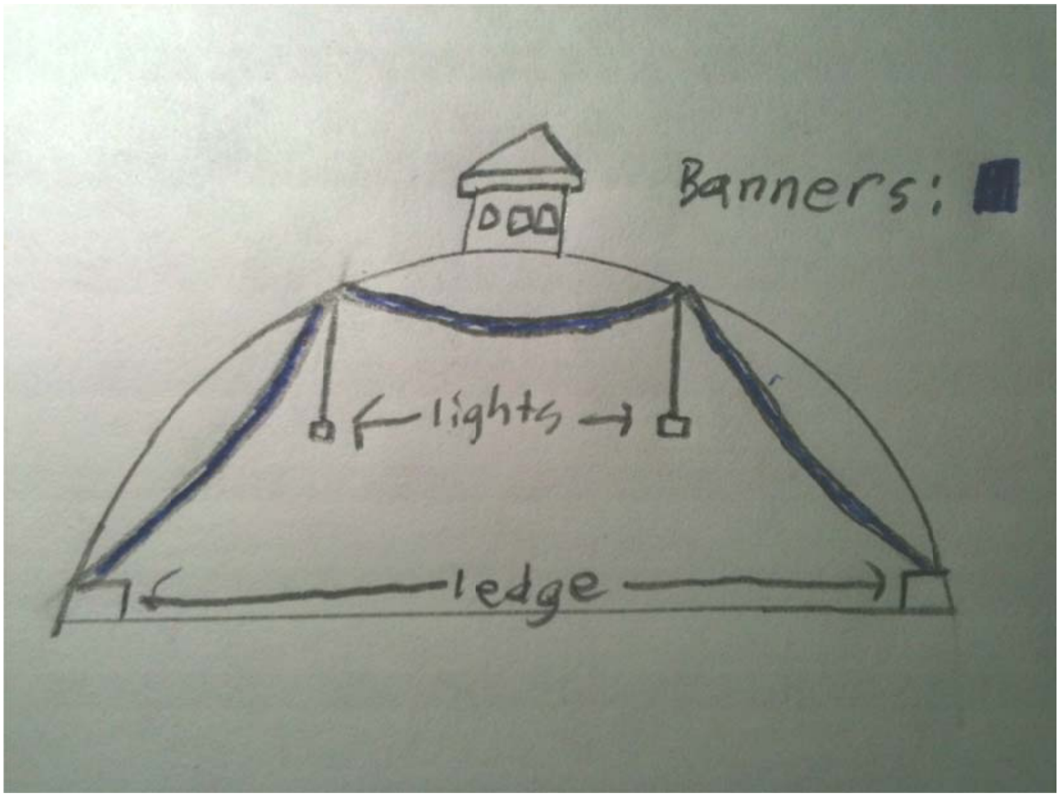

Figure 3- 9: Draping Banners improves acoustics by absorbing the sound waves that hit the banners. The banners labeled (blue) are draped from the ceiling and where the lights are bolted into the wall in order to maximize sound absorbtion from all angles. The wooden banner frames will be filled with unused sheep's wool and then the panels will be wrapped in a fabric that's color will match the motif of the room and will also add to the sound absorption.

The Draping Banners meet the safety criterion by following government regulations and is safe to be around or handle. The functionality criterion is met by improving the acoustics of the nature center and reduces the reverberation time. The appropriateness criterion is met by utilizing environmentally friendly building techniques such as, building with local redwood and local recycled material. The cost criterion is met by staying under the $400 budget previously set by the team. The construction of the banners meets the durability criterion by utilizing wooden frames and a fabric cover to hold all the fillings.

3.3.10 Alternative Solution 10: Frame Built Acoustic Chandelier - Trash Fill

Frame Built Chandeliers - Trash Fill is an aesthetically pleasing yet effective design. Acoustic chandeliers are a specific form of acoustic dampening systems that are smaller than acoustic banners. As shown in Figure 3-10 and Figure 3-11 the frames are built with one by two inch boards. The frames are three dimensional prisms such as a rectangle or octagon. The system is filled with trash to cause the inside of the chandeliers to replicate porous like qualities which is very efficient at sound absorption. The frame is covered in a fabric held on by staples. (Figure 3-12) The fabric will maintain good aesthetics, contain the trash, and also contribute to the sound absorption. The chandeliers will be hung with a thin cable which can either be hung from the building's already existing light fixtures or bolted to the roof itself. The cable will be attached to the chandeliers by running the cable through the chandelier frame via two drilled holes. This system should be a relatively cost effective due to many aspects, but mostly because of the use of cheap materials. Maintenance after the chandeliers are installed should be low with cleaning once or twice a year.

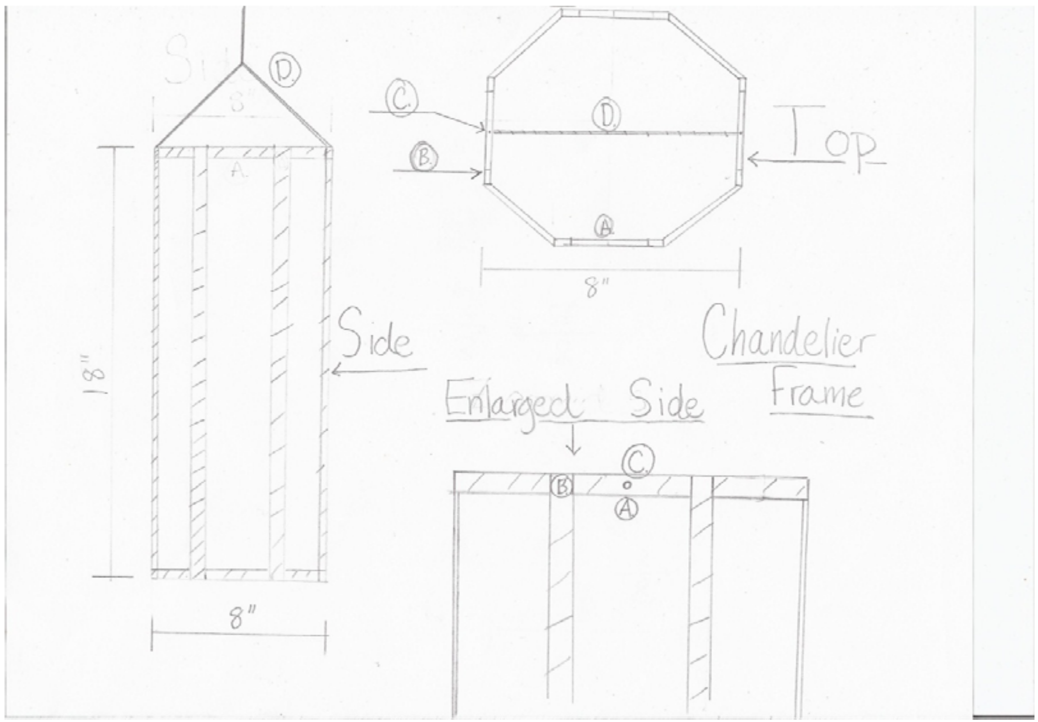

Figure 3- 10: The Octagonal Chandelier Design is more complex but has more aesthetic value. The letters in the figure refer to A. 1x2 inch top board of the frame. B. The vertical 1x2 inch board with the length of 18 inches. C. The drilled hole for the suspension cable to run through it. D. The suspension cable running through the frame. Note that either frame design can be filled with any solution filling.

3.3.11 Alternative Solution 11: Frame Built Acoustic Chandelier - Foam Fill

Frame Built Chandeliers - Foam Fill is an aesthetically pleasing yet effective design. Acoustic chandeliers are a specific form of acoustic dampening systems that are smaller than acoustic banners. As shown in Figure 3-10 and Figure 3-11 the frames are built with one inch by two inch boards. The frames will be a three dimensional prisms such as a rectangle or octagon. The frame will be filled with foam such as Styrofoam, floral foam, or packing material to cause the inside of the chandeliers to replicate porous like qualities which are very efficient at sound absorption. The frame is covered in a fabric held on by staples. (Figure 3-12) The fabric will keep good aesthetics, contain the foam, and also contribute to the sound absorption. The chandeliers will be hung with a thin cable which can either be hung from the building's already existing light fixtures or bolted to the roof itself. The cable will be attached to the chandeliers by running the cable through the chandelier frame via two drilled holes. This system should be a relatively cost effective due to many aspects, but mostly because of the use of cheap materials. Maintenance after the chandeliers are installed should be low with cleaning once or twice a year.

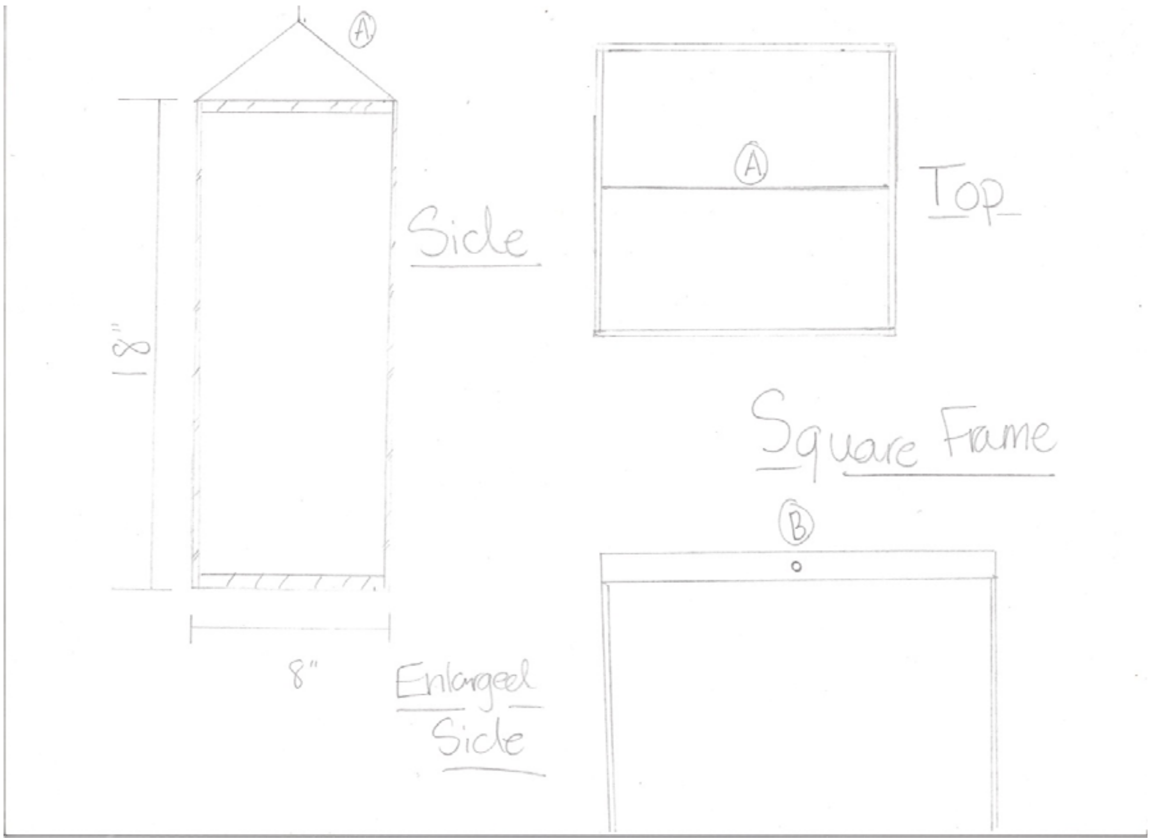

Figure 3- 11: The Rectangular Chandelier Design is the much simpler of the two but is not as interesting to the eye. The letters in the drawing refer to A) The suspension cable running through the frame system and B) The drilled hole for the suspension system.

3.3.12 Alternative Solution 12: Frame Built Acoustic Chandelier - Beach Grass Fill

Frame Built Chandeliers- Beach Grass Fill is an aesthetically pleasing yet effective design. Acoustic chandeliers are a specific form of acoustic dampening systems that are smaller than acoustic banners. As shown in Figure 3-10 and Figure 3-11 the frames are built with one by two inch boards. The frames are three dimensional prisms such as a rectangle or octagon. The frame will be filled with beach grass to cause the inside of the chandeliers to replicate porous like qualities which are very efficient at sound absorption. This fill will also demonstrate the reusable and broad potential of beach grass after it has been removed from the dunes. The frame is covered in a fabric held on by staples. (Figure 3-12) The fabric will keep good aesthetics, contain the grass, and also contribute to the sound absorption. The chandeliers will be hung with a thin cable which can either be hung from the building's already existing light fixtures or bolted to the roof itself. The cable will be attached to the chandeliers by running the cable through the chandelier frame via two drilled holes. This system should be a relatively cost effective due to many aspects, but mostly because of the use of cheap materials. Maintenance after the chandeliers are installed should be low with cleaning once or twice a year

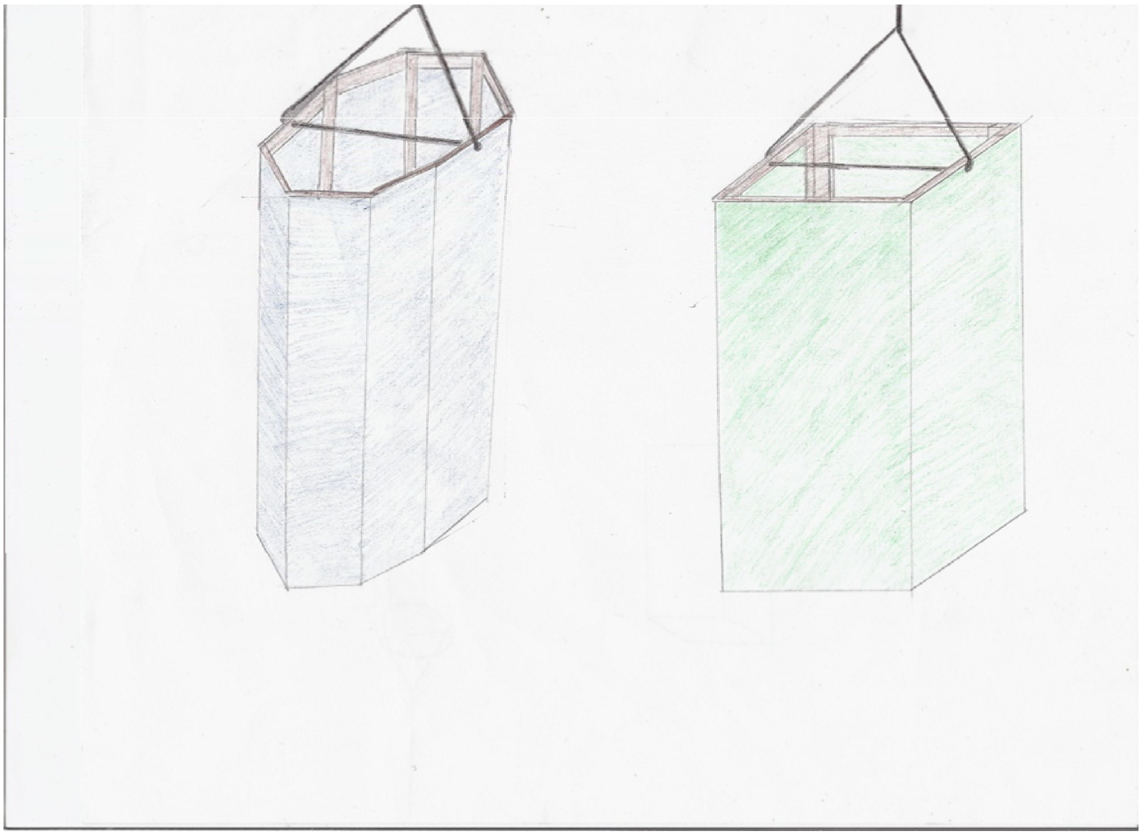

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Figure 3- 12: These are the Octagonal and Rectangular Chandelier Designs concept drawings. The octangular on the left and square on the right. Note both frames are covered with frabric and have the suspension cable strung through the. Both are ready for the asseration of the porous material in the middle of chamber of the frame.

3.3.12 Alternative Solution 13: Frame Built Acoustic Chandelier - Wool Fill

Frame Built Chandeliers- Wool Fill is an aesthetically pleasing yet effective design. Acoustic chandeliers are a specific form of acoustic dampening systems that are smaller than acoustic banners. As shown in Figure 3-10 and Figure 3-11 the frames are built with one by two inch boards. The frames are three dimensional prisms such as a rectangle or octagon. The frame will be filled with wool to cause the inside of the chandeliers to replicate porous like qualities which is very efficient at sound absorption. The wool used for the fill will be local unwanted wool from local ranchers who have no use for it due to its low grade. The use of the wool will demonstrate the use of green methods and recyclable materials. The frame is covered in a fabric held on by staples. (Figure 3-12) The fabric will keep good aesthetics, contain the wool, and also contribute to the sound absorption. The chandeliers will be hung with a thin cable which can either be hung from the building's already existing light fixtures or bolted to the roof itself. The cable will be attached to the chandeliers by running the cable through the chandelier frame via two drilled holes. This system should be a relatively cost effective due to many aspects, but mostly because of the use of cheap materials. Maintenance after the chandeliers are installed should be low with cleaning once or twice a year.

3.3.13 Alternative Solution 14: Placing Strategic Plants Within the Room

Placing Strategic Plants Within the Room is a simple but great design because it requires no construction, improves air quality and improves the acoustics of the room. Ideally large indoor plants can be placed throughout the room to increase the amount of objects to absorb sound waves that are being reverberated within the nature center. Plants can be placed around the floor within planters and pots or grown up on the walls. (Figure 3-13) Large plants that would work well and that would look natural with the center include Norfolk Island Pine, Pacific Wax Myrtle, and possibly beach grass. The cost of this system is dependent on how many plants should be purchased. The overall maintenance would be high due to watering and fertilizing the plants and that would also drive the cost of the system up especially if it is kept for a long period of time.

Figure 3- 13: A drawing of the small conifer Norfolk Island Pine which can grow from six to fifteen feet tall. Although not a native plant in Northern California, its conifer attributes lend it to blend in well and look natural within the region. The simple drawing on the right is a rough floor plan of the nature center. The letters within the figure refer to the front door A. and back door. B. The green dots are possible location for large floor plants.

3.3.9 Alternative Solution 15: White noise generator

The White Noise Generator (Figure 3-14) produces ambient or textured sounds with no perfect beat or measure. Most common electronic machines produce some sort of white noise, for instance refrigerator's hum and a video game system has a fan that produces a constant sound in airspace that we classify as white noise because it becomes background noise that we tune out. White noise also occurs on a very wide spectrum in nature. Rain water hitting a surface and ocean waves crashing to land are the most general cases of natural white noise. At the Humboldt Coastal Nature Center white noise generators can be beneficial to the acoustic environment within their facility.

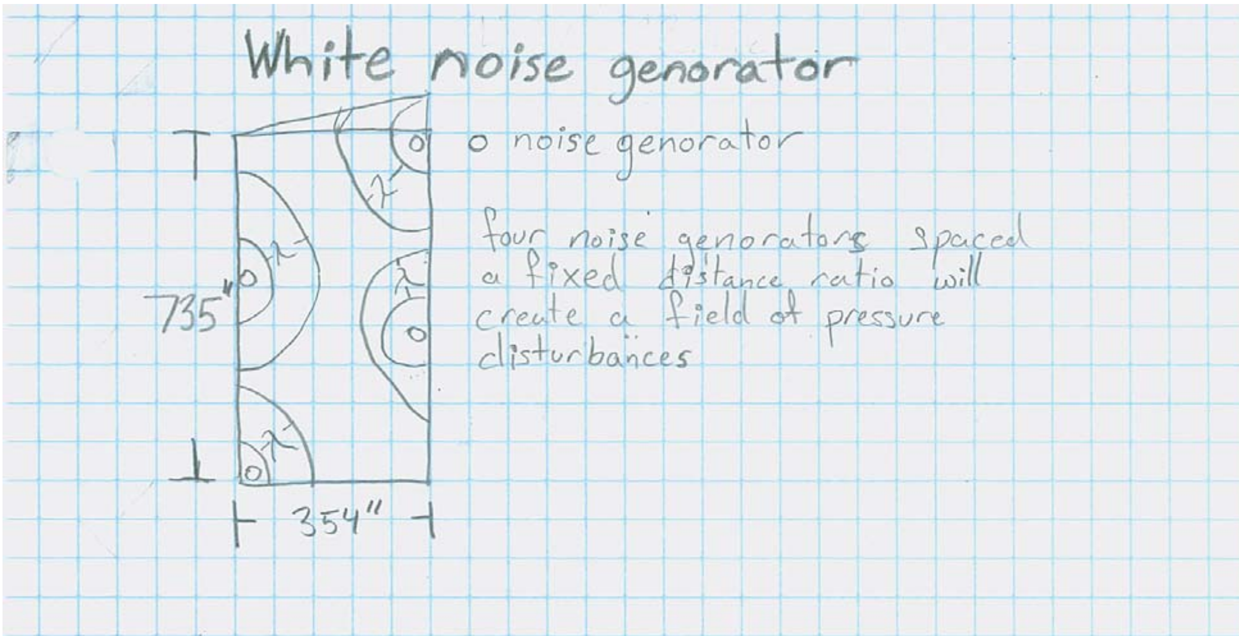

Figure 3- 14: The White Noise Generators are shown producing one pulse of sound. All solid obstacles are ignored for this rendition. In this example, there are four strategically placed white noise generators that will create a field of pressure disturbances in the room.

These devices are to be placed approximately three hundred and seventy inches from one another at the walls of the building, and are to mirror the placing of noise generators at the side opposite. This solution is safe, as long as people are not eating or drinking within several feet of the generator or its power outlet. White noise generators are easy to maintain. They will not add to the visual aesthetics of the space, but they are inspirational in that visitors to the Humboldt Coastal Nature Center will have nature sounds to accompany their visit. This is a quick installation solution.

3.3.10 Alternative Solution 16: Acoustic Chandelier Bird

An Acoustic Chandelier Bird (Figure 3-15) is an effective way to improve the acoustics in the space it occupies. An acoustic chandelier acts as a barrier between the floor and the ceiling for exited air molecules. When noise is projected from a speaker, that noise is not only going to the listener, but it is traveling high and low, and bouncing from every surface it meets. The Friends of the Dunes building is parabolic, and this special curved shape allows for sound waves to bounce more violently than in a standard rigid-cubic shape room. A chandelier is an obstacle for the sound to travel through and around. The aim of the acoustic chandelier is to stun visitors and dampen reverberation. The specifications for this specialized chandelier are given in Figure 3-15.

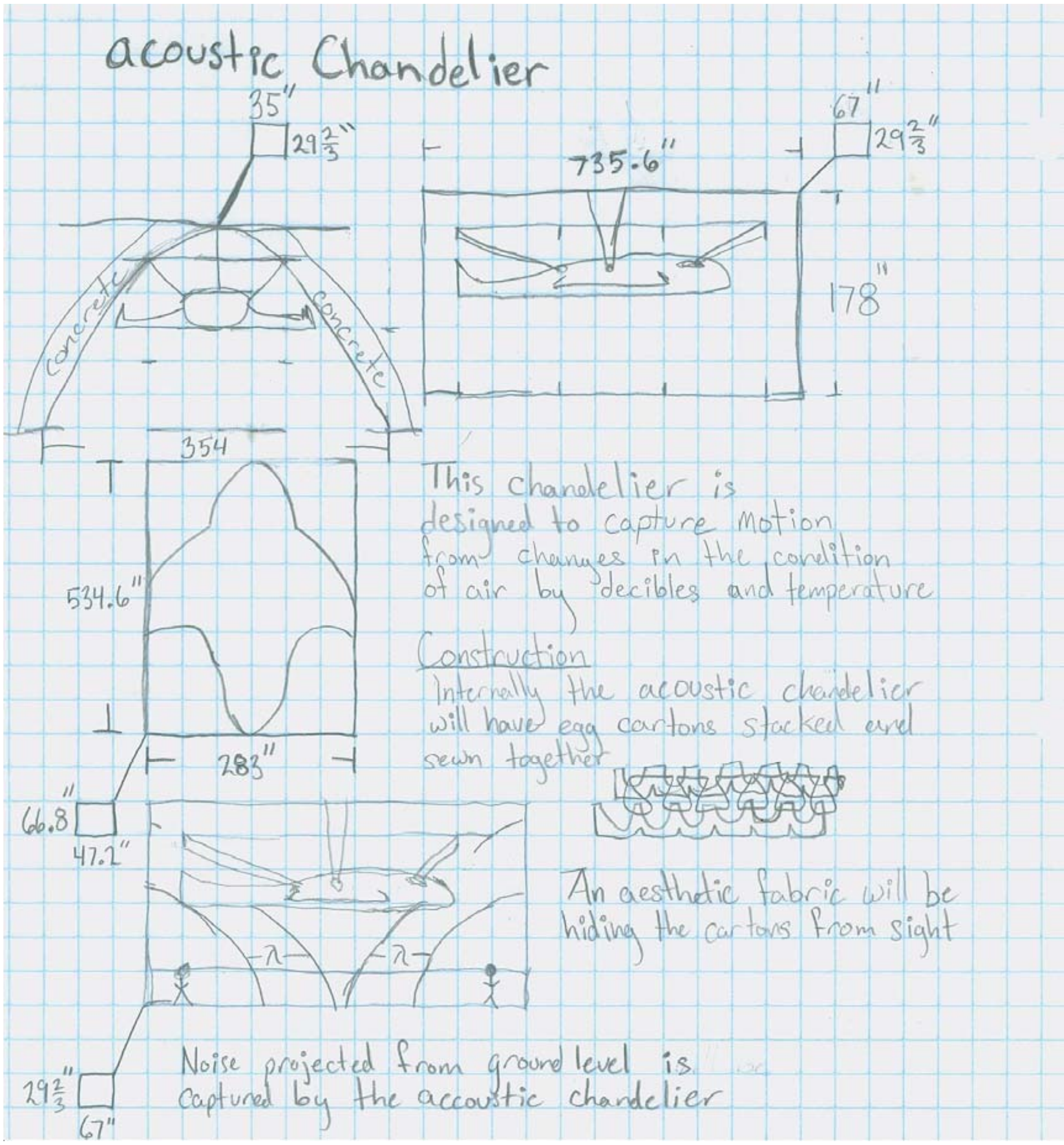

Figure 3- 15: Acoustic Bird is approximately 2,000 cubic inches and will occupy much of the overhead space. The bird will be hung from the ceiling with several cables that are fixed the walls of the building. Internally, the chandelier will be made from sewn together egg cartons and then covered in a fabric that would match the natural plumage of a native bird.

4 Decision Process

4.1 Introduction

Section 4 describes the process by which the final design decision was made. The criteria are further defined and the Delphi Method is used determine which alternative solution is the best design. The Delphi Method is a tool for weighing a set of criteria against individual solutions.

4.2 Criteria

These are the criteria that were stated in Section 2. These criteria were used to evaluate the alternative solutions of Section 3.

Safety- The solution poses no health or injury risk to the visitors or the staff of the Humboldt Coast Nature Center.

Aesthetics- The solution should fit with the motif of the Humboldt Coast Nature Center and be visually pleasing to the staff and the visitors.

Functionality- The solution should be effective at improving the acoustics of the building.

Cost- The cost of the solution must be below the budget that was set by the group members and the client.

Durability- The solution must be able to withstand general wear and tear until the future remodel of the interior of the building.

Inspiration- Visitors of the Humboldt Coast Nature Center should leave more enlightened about the possibilities of building with “green” materials after observing the solution.

Ease of Maintenance and Installation- The solution should require minimal effort by the staff and the group to be installed and kept clean and functioning properly.

Appropriateness- The solution should coincide with the environmental principles of the Friends of the Dunes organization.

4.3 Solutions

This is a list of the alternative solution explained in Section 3.

- Carpet installation
- Wooly Panels
- Trashy Panels
- Grassy Panels
- Foamy Panels
- Banners hung vertically from ceiling
- Banners hung against the walls
- Banners draped across the ceiling
- Acoustic chandeliers filled with sheared wool
- Acoustic chandeliers filled with trash
- Acoustic chandeliers filled with beach grass
- Acoustic chandeliers filled with foam
- Plants

- White noise generator
- Acoustic chandeliers with bird shaped foam

4.4 Decision Process

To identify the best possible solution, we used the decision matrix known as the Delphi Chart. (Table 2) The first step of the process is to weigh each criterion based on importance on a scale of 1 to 10, 10 being the highest and 1 being the lowest. (Table 1) The group decided on these ratings by comparing one criterion to another and deciding which was the most important, then the next most important and so on until we found the least important. The next step is using another scale of 0 to 50 for the possible solutions. A rating of 50 would be given for the best solution for that specific criterion. The group's decision process for this step was again rating the solutions against one another to find which criterion fit best, then what fit next best and so on. The final step in the decision process is to then multiply each criteria rating to its corresponding solution rating. Then the multiplied scores are added and the greatest total value is the final solution. (Table 2)

Table 1: Weighted Criteria

Criteria	
List	Weight
Safety	10
Aesthetics	8
Cost	3
Durability	5
Inspiration	5
Ease of Maintenance and Installation	7
Functionality	10
Appropriateness	7

Table 2: Delphi Matrix

Criteria		**Alternative Solutions** (0-50 high)				
List	Weight (0-10 high)	Carpet Installation	Wooly Panels	Trashy Panels	Grassy Panels	Foamy Panels
Safety	10	45 / 450	40 / 400	40 / 400	40 / 400	40 / 400
Aesthetics	8	40 / 320	40 / 320	40 / 320	40 / 320	40 / 320
Cost	3	10 / 30	30 / 90	30 / 90	30 / 90	25 / 75
Durability	5	30 / 210	45 / 315	45 / 315	40 / 280	45 / 315
Inspiration	5	0 / 0	45 / 225	45 / 225	45 / 225	35 / 175
Maintenance and Installation	7	10 / 70	40 / 280	42 / 294	42 / 294	40 / 280
Functionality	10	40 / 360	42 / 378	42 / 378	42 / 378	42 / 378
Appropriateness	7	5 / 45	45 / 405	45 / 405	45 / 405	40 / 360
		1485	2413	2427	2392	2303

Table 2: Delphi Matrix

Criteria		Alternative Solutions (0-50 high)				
List	Weight (0-10 high)	Vertically Attached Banners	Horizontally Attached Banners	Banners Against The Walls	Draping Banners	Frame Built Acoustic Chandelier- Trash Fill
Safety	10	40 / 400	40 / 400	40 / 400	40 / 400	35 / 350
Aesthetics	8	45 / 360	45 / 360	35 / 280	35 / 280	40 / 320
Cost	3	30 / 90	30 / 90	30 / 90	30 / 90	35 / 105
Durability	5	45 / 315	45 / 315	45 / 315	45 / 315	45 / 315
Inspiration	5	25 / 125	25 / 125	25 / 125	25 / 125	45 / 225
Maintenance and Installation	7	35 / 245	35 / 245	35 / 245	35 / 245	30 / 210
Functionality	10	45 / 405	45 / 405	45 / 405	45 / 405	25 / 225
Appropriateness	7	40 / 360	40 / 360	40 / 360	40 / 360	45 / 405
		2300	2300	2220	2220	2155

Table 2: Delphi Matrix

Criteria		Alternative Solutions (0-50 high)					
List	Weight (0-10 high)	Frame Built Acoustic Chandelier - Foam Fill	Frame Built Acoustic Chandelier - Beach Grass Fill	Frame Built Acoustic Chandelier - Wool Fill	Plants Within Room	White noise generator	Acoustic Chandelier (Bird)
Safety	10	35 / 350	35 / 350	35 / 350	50 / 500	50 / 500	30 / 300
Aesthetics	8	40 / 320	40 / 320	40 / 320	50 / 400	50 / 400	50 / 400
Cost	3	30 / 90	35 / 105	35 / 105	20 / 60	10 / 30	15 / 45
Durability	5	45 / 315	40 / 280	45 / 315	20 / 140	45 / 315	45 / 315
Inspiration	5	35 / 175	45 / 225	45 / 225	25 / 125	10 / 50	45 / 225
Maintenance and Installation	7	30 / 210	30 / 210	30 / 210	15 / 105	35 / 245	30 / 210
Functionality	10	25 / 225	25 / 225	25 / 225	30 / 270	45 / 405	45 / 405
Appropriateness	7	40 / 360	45 / 405	45 / 405	45 / 405	30 / 270	50 / 450
		2045	2120	2155	2005	2215	2350

4.5 Final Decision

The Delphi Chart indicates that the alternative solution of trashy acoustic panels would be the overall best fit for an acoustic dampening system for the Humboldt Coastal Nature Center. The design is affordable and reuses unwanted material, therefore is cheap and demonstrates alternative environmentally friendly methods. The panels will only be installed at head height and would not be a hazard if a panel should happen to fall due to an earthquake. Along with the panels, several acoustic banners will be hung horizontally in the facility. These extra banners will aid in the overall acoustic dampening qualities of the design.

5 Specifications

5.1 Introduction

Section 5 of this document describes the solution outlined in Section 4. Each aspect of the solution will be described such that the design is completely understood. This section will also cover the costs associated with the design. Costs such as materials, design time, and possible time in the future spent maintaining the solution is estimated and documented. The procedure to build the solution is outlined in detail and the results of the solution are explained.

5.2 Description of Solution

The solution chosen for the client is the combination of acoustic panels and acoustic banners in the Humboldt Coastal Nature Center. This solution will most likely be the best design to improve the acoustics of the building. Figure 5-1 gives a clear view of the panels and the banners.

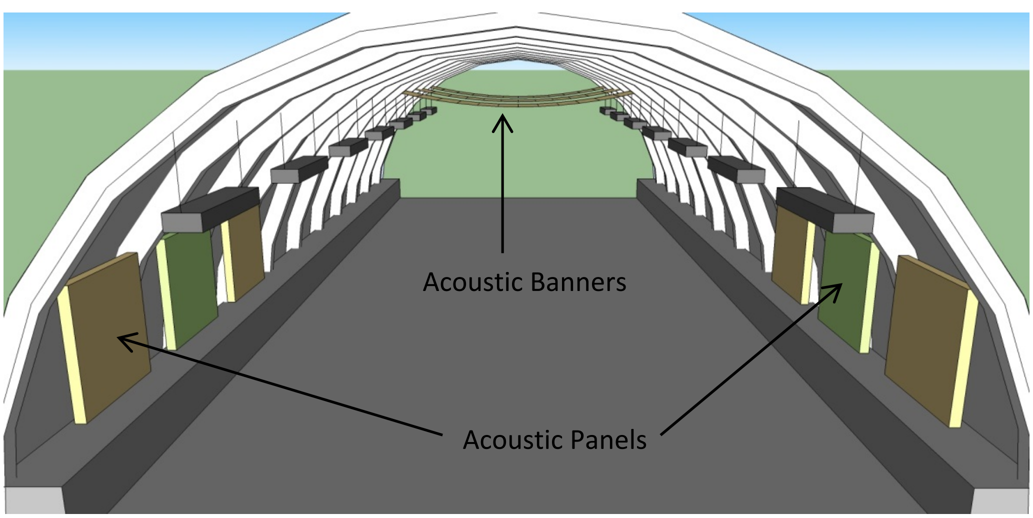

Figure 5-1: A Google SketchUp drawing of the Humboldt Coastal Nature Center with the acoustic banners and panels installed. The panels are located on west half of the room where it is a very open floor plan. The Banners are strung by the same mounts used for the light fixtures. Drawn by Matthew Brown.

5.2.1 The Acoustic Panels

The acoustic panels have a surface area of four square feet and are constructed out of 2 by 4's, fabric, newspaper, and chicken wire. The frame of the panel is constructed out of four 2 by 4's (Figure 5-2). Dimensioned 2 by 4's sold at lumber yards are actually 1.5 by 3.5 inches. Once the frame is constructed, the fabric is stretched over the front face of the frame and folded over into the inside and then stapled to the frame. (Figure 5-3) The inside of the frame is then filled with recycled newspaper. Chicken wire is then placed on the back side of the panel and will act as a truth window to the contents inside of the frame. (Figure 5-3) The next step in the process is the wall mounts. (Figure 5-4) One "L-Bracket" is bolted into the wall; this is what the panels will be secured to. In order to secure the panel to the bracket, a bolt is put through the top of the frame and then through the bracket. The bolt will then be held with a single nut.

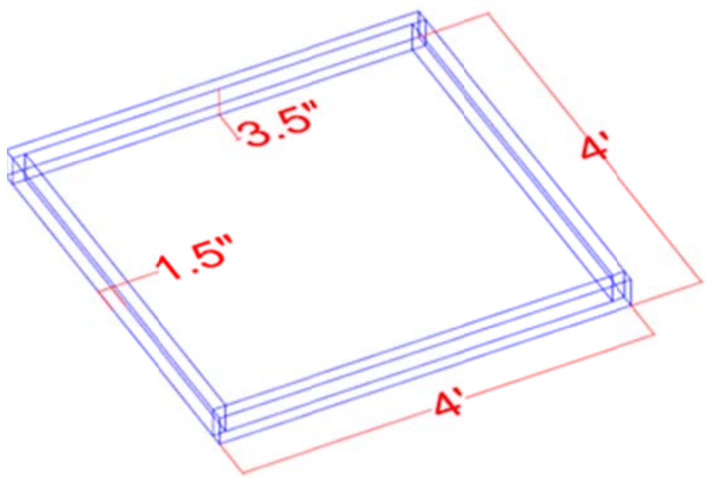

Figure 5- 2: AutoCAD drawing of one of the acoustic panel frames. Drawn by Matthew Brown

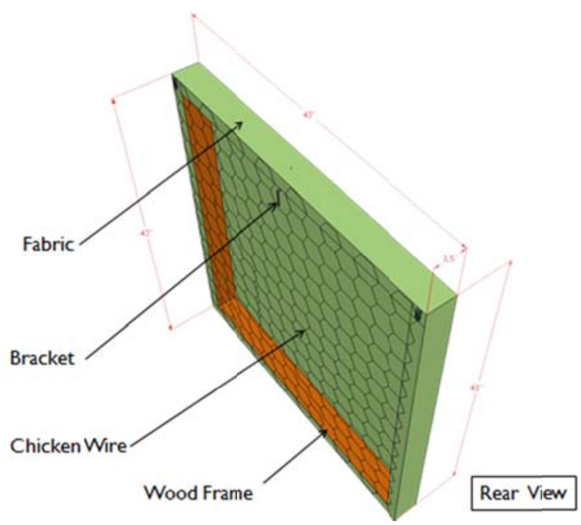

Figure 5-3: Google SketchUp drawing of a finished panel, but with no contents inside. Drawn by Cole Humphrey.

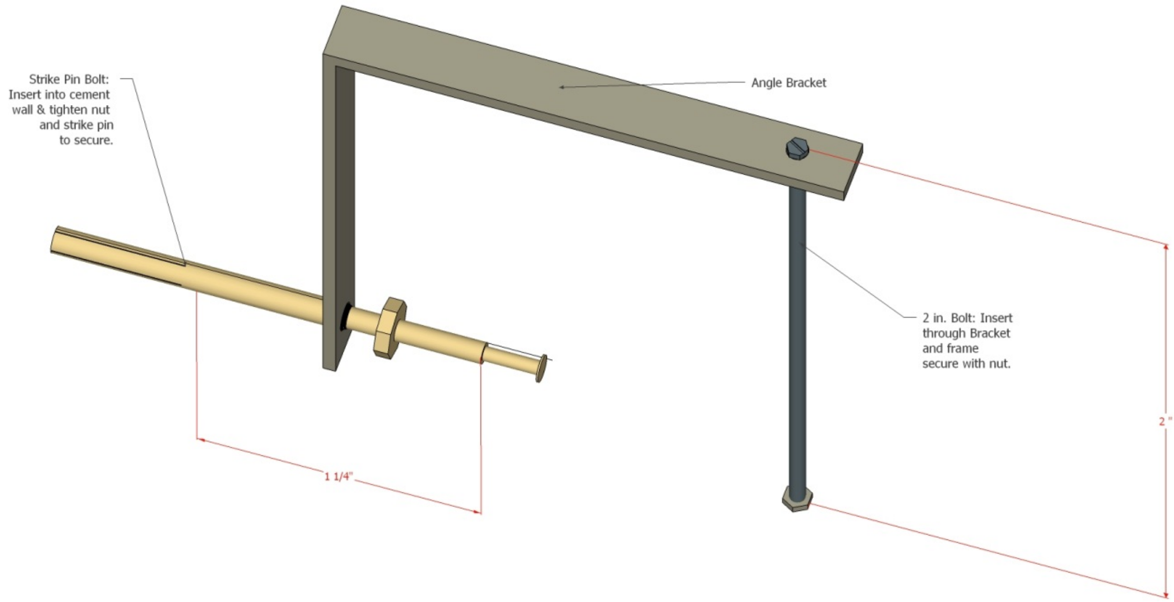

Figure 5-4: Google SketchUp drawing of the mounting system for the acoustic panels. Drawn by Cole Humphrey

5.2.2 The Acoustic Banners

The acoustic banners will each be 20 feet long and 60 inches wide and will be attached to the mounts that the light fixtures hang from. The banner's fabric will be long rolls of burlap. To increase the thickness of the banners, there will be two lengths of burlap for each banner. The long edges of the fabric will be folded over onto itself and then secured. This fold will allow for the banners to maintain their aesthetics because the condition of the fabric edges is poor. The mounts for the banners are the next step in the building process (Figure 5-5). The ends of the banners will be folded a few times over a four foot long piece of plywood. The fabric is then stapled to this piece of wood. Because the plywood is only four feet long and the width of the fabric 60 inches, there will be some extra fabric on either side of the wood. This excess fabric will be folded over onto the top of the wood; by doing so the frayed edges of the fabric are hidden, thus improving the aesthetics of the banners. Two holes are drilled into each piece of wood for cables to be put through them. Each cable is then attached to itself, after being weaved through the hole, with an adjustable cable clamp. By making this part of the cable's length adjustable, it means that the banner can have a specific hanging length. The other end of the cable is attached to the light fixture mount in the ceiling.

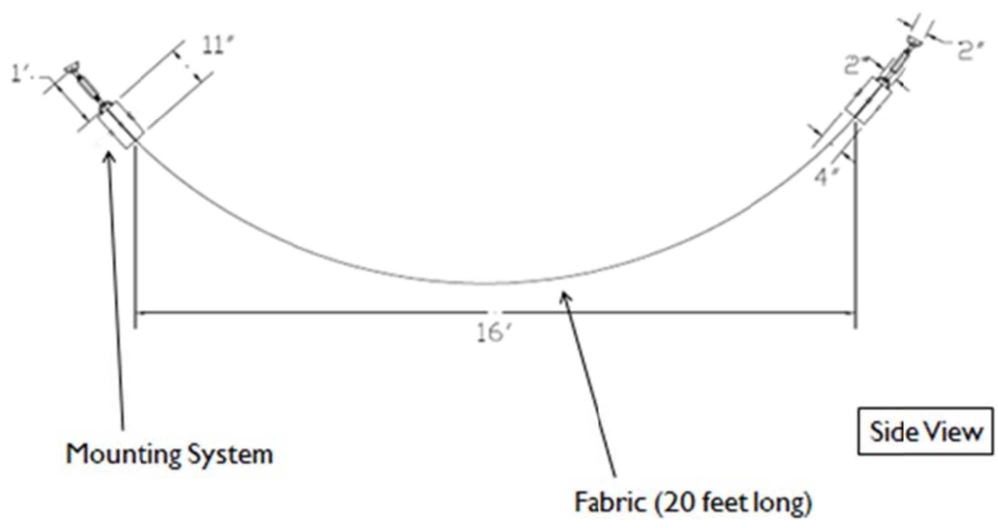

Figure 5-5: AutoCAD drawing of the acoustic banners and their mounting system. Drawn by Michael Harrow

5.3 Cost

The cost of this design project is provided in three sections: design cost, materials cost, and maintenance cost.

5.3.1 Design Cost

The design cost is the sum of the total hours that team SAND has put into for each phase of this project. In Figure 5-6, the distribution of the hours spent on this project is indicated using a pie chart. The majority of the time was used up in phase 2 and the least in phase 3.

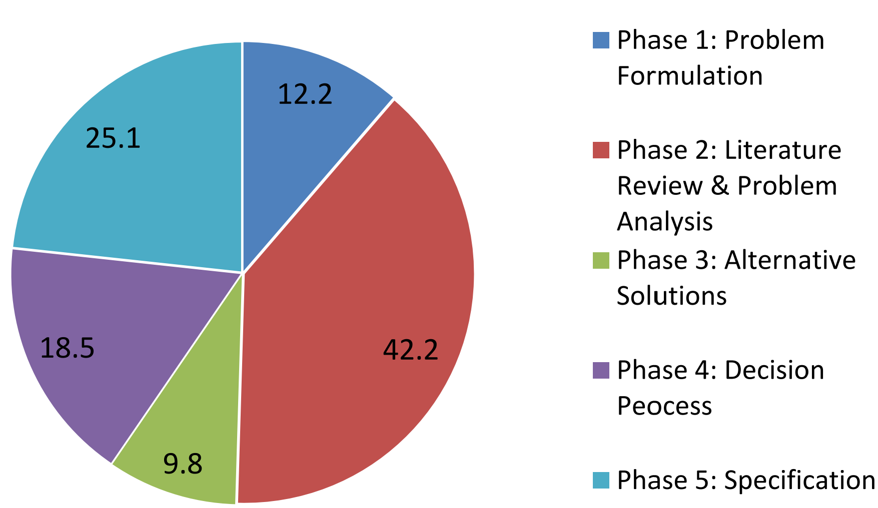

Figure 5-6: Documented hours spent for project**.**

5.3.2 Materials Cost

The materials used to complete our acoustic panels and banners are listed in Table 3. From construction to installation, the total amount spent was $225.11. The majority of the money from the team's budget was spent on the burlap fabric because it is the most crucial part of the panels/banners and because it improves the acoustics of the Humboldt Coastal Nature Center.

Table 3: Cost of materials for the project

Materials	Use	Quantity	Project Cost ($)	Projected Project Cost ($)
Burlap	Panels/Banners	54 yards	$158.87	$158.87
Strike Anchors	Panels	12	$7.74	$7.74
Angle Brackets	Panels	8	$10.00	$10.00
2" Bolts	Panels	6	$1.50	$1.50
Lumber (2x4)	Panels	24	$0.00	$54.00
Cable Clamps	Banners	24	$12.00	$12.00
Newspaper	Panels	30 ed.	$0.00	$12.00
Chicken Wire	Panels	2'x25'	$25.00	$25.00
Lumber (plywood)	Banners	1'x4' (6)	$0.00	$20.00
Cable	Banners	50'	$10.00	$10.00
		Total	**$225.11**	**$311.11**

5.3.3 Maintenance Cost

Because the banners are hung from the ceiling and the panels are attached to the walls, there will be little to no interaction with them; therefore they won't require that much maintenance besides an inspection and cleaning every couple months. As shown in Table 4, the maintenance costs will be relatively low. The projected cost per year totaled out to be $48 for the cost of labor.

Table 4: Maintenance cost for the project

Maintenance Tasks	**Frequency**	**Projected Cost/Year ($)**
Banners	every two months	$24
Panels	every two months	$24
	Total	**$48***

*Projected maintenance cost calculated at a $12/hour wage

5.4 Instruction for Implementation and Use of Model

5.4.1 Introduction

This section contains directions for implementation of the constructed acoustic improvement solution.

5.4.2 Acoustic Banners

First a fabric must be selected. It needs to be durable, preferably thick and/or soft to help with sound absorbance. Fabric is then cut to appropriate length for the interior ceiling of the structure. One by two inch boards that are four feet long are then installed at the end of the banner. The ends of the fabrics are folded over these boards. The edges of the fabric are also folded over onto the boards so as not to show the parts of the fabric that were cut because these edges are frayed and not aesthetically pleasing. The boards then have two holes drilled through them. A length of cable is put through each individual hole and then attached back to itself with an adjustable cable clamp. The cable clamp is adjustable so that the length of the cable can be changed to customize how low the banners hang. The cable is then attached to the ceiling via already existing mounts or attached to concrete anchors (if ceiling is made of concrete). For more details of solution refer to section 5.2.2

5.4.3 Acoustic Panels

First it should be noted that the solution's size is dependent on the size of room and the magnitude of reverberation within the room. The frame is constructed with two by four inch boards cut to whatever length desired. The frame can either be rectangular or square. The front and outer edges of the frame are covered with the selected fabric (it can be the same fabric as the banner material or different). The fabric is then tucked on the inside of the frame and stapled into place. The fabric should be taut over the front of the frame. A porous material that has good sound absorbing qualities is then used to fill the panel; trash, wool, cotton, paper, or foam is suitable for this. The material is retained within the frame with chicken wire that is stretched over the rear of the panel and stapled into place. The panel is then hung using a concrete anchor placed into the wall and then attached to an L-bracket for the panel to rest on. For more details of solution refer to section 5.2.1

5.5 Results

Using custom built acoustic panels and banners is an effective way to improve the acoustics within the Humboldt Coastal Nature Center. The addition of our design decreases the amount of solid concrete wall that is exposed in the facility. This creates an environment where sound waves have less of a chance to be reverberated. However, our design still leaves much of the concrete uncovered. A way to increase the amount of sound absorption is to introduce more of the acoustic panels and banners.

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6 Appendices

Appendix A: Brainstorm Notes

Material and Location Combinations

1) Carpet on floor and ledge
   * Probably not
2) Head level panels filled with...
   - Sheered wool
   - Trash
   - Foam
   - Beach grass
   - Sand? (very Heavy)

   ...That is covered with fabric/carpet
3) Banners with fabric Hung...
   - Verically
   - Draped
   - Against the wall
4) Acoustic Chandeliers Hung from ceiling made with...
   - Wood frame filled and covered
     - Carpet - fabric - Wool - foam - trash - Be
       - Clothes - Sand - Birds

Alternative Solution Brainstorm

Location
- Head level Panels
- Hanging from the walls
- Ceiling
- Light Fixtures (vertical & strung between)
- Hanging from ceiling
- Floor
- Ledge

- Materials
  - Living wall (Plants)
  - Balsa wood with stuff inside
  - Carpet
  - Unused wool
  - Trash (Egg cartons, ecodillo kinda thing)
  - Beach grass
  - Fabric
  - Second hand store clothes
  - Sand
  - Foam extras

- Other
  - White noise generator
  - Sound traps / diffusers Built in
  - Different locations
  - Acoustic Chandeliers