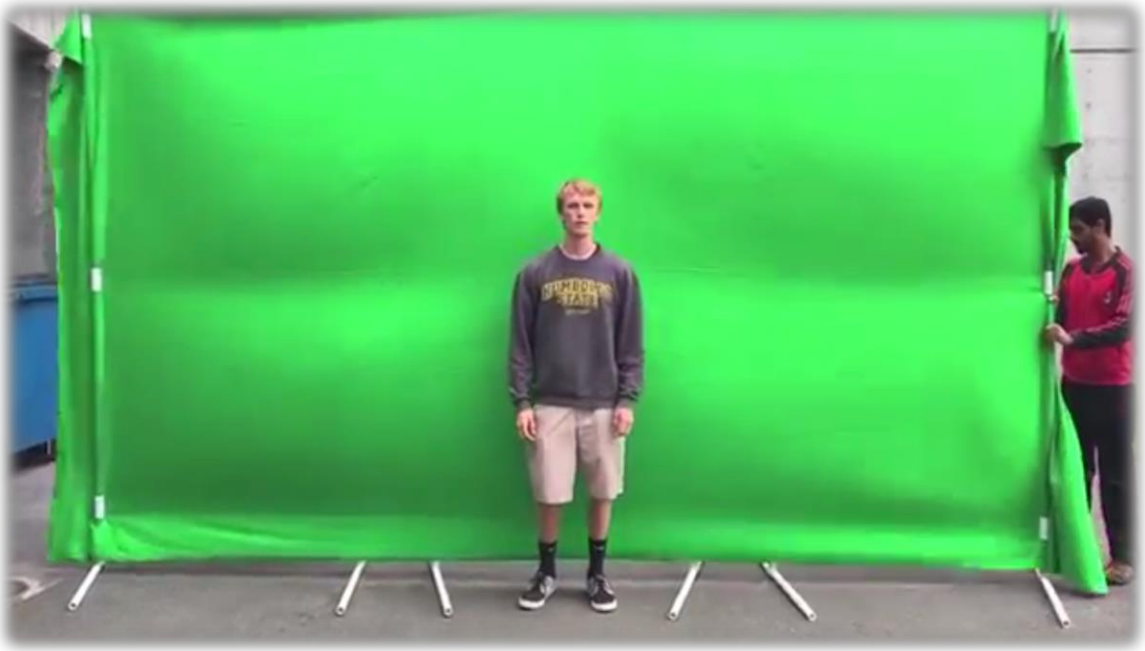
GREEN SCREEN PROJECT

Team Visual Effects
Humboldt State University, 2017 Spring Semester
215 Intro to Design, Instructor Lonny Grafman



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1 Problem Formulation

1.1 Introduction

Phase 1 provides background on the project and explains the design and building objective. Figure 1.1 is a black box diagram that visually demonstrates the objective.

1.2 Background.

Zane Middle School client representative and digital media class instructor Damon Brooks contracted the services of Team Visual Effects for the design and construction of a portable green screen apparatus for indoor/outdoor use by his students. Team Visual Effects is composed of Abdullah Alyami, Liam Dooley, Kyle Ebert, and Karl Oman, all members of Lonny Grafman's Spring 2017 ENGR 215 class at Humboldt State University.

1.3 Design Objective

The objective of Team Visual Effects is to create a portable, durable, lightweight, and user-friendly green screen that will provide a shadow-free background surface for the film and photography projects of Zane Middle School students.

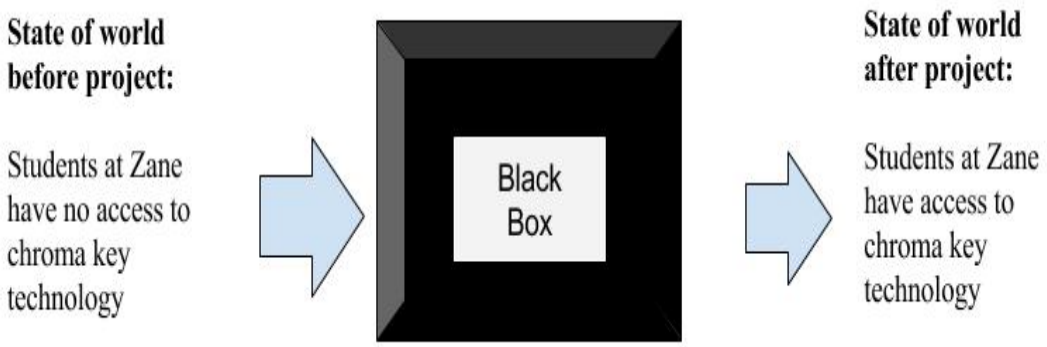

Figure 1-1: This Black Box Diagram shows a simplified version of our objective.

2 Problem Analysis and Literature Review

2.1 Introduction

The Problem Analysis and Literature Review section of the green screen design document identifies variables, constraints, and conditions discussed with the client, in addition to a body of research on topics related to the project. Design specifications, criteria, and considerations are also included in the following sub-sections, which lay the groundwork for later design work.

2.2 Specifications and Considerations

The specifications and considerations in this sub-section of the document contain the

conditions agreed upon by the client and the team members in order to achieve the desired design.

2.2.1 Specifications

The specifications are a number of conditions that the client proposed to the team members, which provide parameters for the final design product. Listed below are the design specifications that establish an achievable minimum requirement for the final design product.

- Must fit through a standard doorway while maintaining optimal screen size.
- Must be portable.
- Must have no appearance of shadows on the screen.
- Must be built to last for a long period of time.
- Must easily operate.
- Must pose no danger to students.

2.2.2 Considerations

Considerations are the overall circumstances that the team must consider throughout the building process in order to meet the client's needs. These are outlined by the following:

- The apparatus will be used indoors and outdoors.
- The apparatus will be used (and abused) by middle school students.
- The apparatus will be used by a new group of students each year.

2.3 Usage:

The screen will be used for the digital media projects of a middle school digital media class. It will be used both indoors and outdoors, and will be stored in a closet adjoining the classroom.

2.4 Criteria:

Damon Brooks, the client representative and digital media instructor at Zane Middle School, discussed requirements and constraints for the Green Screen project with Team Visual Effects in February 2017. The client's primary concerns were that the screen could fit through a standard doorway and be easily moved from place to place by students. The table below shows all client criteria and constraints related to the project. These criteria are weighted from 0-10 based on the degree of importance.

Table 2-1: Criteria

Criteria	Constraint	Weight
Portability	Fits through doors; can easily be moved	10
Cost	Under $400	9
Durability	Lasts 5 years	9
Ease of Use	Easily operated by middle schoolers	9
Degree of Difficulty (construction)	Easy to build	8
Functionality	Produces a high quality image	8
Aesthetics	Must look presentable	7

2.5 Literature Review

This section contains research on the topic of green screens and a variety of known practices concerning the design, use, and maintenance of green screens.

2.5.1 Building Materials

2.5.1.1 Wheels

Caster wheels are suitable for any application concerned with portability. They are easily installed and last a very long time. The caster wheel design is easily attachable to a frame. Caster wheels are available in different tread types and are made with different materials depending on what surface the object is resting on. The wheel surfaces are sometimes made of rubber and softer materials for applications where hardwood floors or other delicate surfaces are a part of the environment. Some caster wheels are made of hard plastic or metal to withstand constant use on rough asphalt. Wheel diameter will have a significant effect on the ride of the cart. Larger wheels contribute to a smoother ride going over bumps, while smaller wheels improve maneuverability (NelsonJameson.com, *Selecting Wheels).*

Figure 2-1:Caster Wheels, http://nelsonjameson.com/learn/sanitation-maintenance/selecting-wheels-casters/

2.5.1.2 Frame

A variety of frame materials exist on the marketplace. Wood and PVC pipe are utilized in many frame applications. The base section will have to be heavy enough to withstand the force of the green screen pulling in any particular direction. Wood is an ideal material to work with for building the base frame. Wood is easily to attached to itself with wood glue or nails and can be cut precisely and easily. PVC is a lightweight alternative that may also be considered. (www.EngineeringToolbox.com)

2.5.1.3 Green Screen Material

Green screens can be made of various materials. The screen cannot be of any color found in human skin, so that background and actor can be differentiated by editing software. Green is the most common color used because it provides a strong contrast to all human skin tones and is easiest for Chroma key software to work with. The screen material itself can be made of many different things as long as color and brightness are correct. Screens can be made of paper, vinyl, nylon or foam backed with polyester fabric. Painted walls are used in some applications. Many of these screen materials are relatively inexpensive and accessible for beginners. It is emphasized that objects and people in front of the screen cannot be similar in color at all to the screen so there is no blurring or false image projections (www.artmunsonmusic.com, Green Screen for Beginners).

Figure 2-2: Green Screen Material Options, http://artmunsonmusic.com/video-production-tips/green-screen-beginners/

2.5.1.4 PVC Pipe

PVC is a widespread and well known material and has many applications that go beyond its traditional use in plumbing. Because PVC pipe is light and flexible, it is an ideal building material for lightweight projects under low material stress. Its primary use is as a light-weight alternative to metal piping. PVC is much easier to install and carry than its metal counterpart. PVC pipe is mainly used for fluid transport, but there are also types of non-pressurized PVC pipe solely fabricated for hobby projects (www.engineeringtoolbox.com, *PVC Pipe Dimensions*)

Figure 2-3: PVC Piping, http://www.engineeringtoolbox.com/pvc-cpvc-pipes-dimensions-d_795.html

PVC Piping also comes in many different sizes and forms and can be put to many different uses depending on the size of the piping.

2.5.2 Digital Compositing Methods

There are a variety of digital methods used to achieve the compositing effect associated with green screens. All of the methods covered here use a backdrop that is easy to differentiate from the foreground subject on the basis of color. The captured image is transferred to editing

equipment that recognizes the difference in color value between the foreground and backdrop and replaces the original backdrop with one of the editor's choosing. Depending on the combination of software and hardware used to edit the footage, the techniques listed below are collectively known as Chroma keying or color-difference matting. (Foster, *Green Screen Handbook)*

2.5.2.1 Green Screening

This technique involves placing a material of uniform color value behind a foreground subject and using editing software or hardware to remove all color values that match the backdrop. The color of the backdrop varies depending on the specific conditions of the shoot, but it is often green because digital cameras are designed to have greater sensitivity to green light. This approach is used widely by professional studios and hobbyists. (Foster, *Green Screen Handbook)*

2.5.2.2 Reflective Media

This technique is nearly identical to green screening, except that the green or blue color of the backdrop is created by a ring of LED lights attached to a camera lens. The matte backdrop fabric (see figure 2-4) has a dark grey appearance under normal lighting conditions, but is covered with thousands of glass beads that reflect the colored light of the LED ring back to the camera. This creates a backdrop of uniform color matching the value of light given off by the LED ring. This approach works exceptionally well in dimly lit rooms where lighting conditions are uneven and unnatural. Reflective media does not perform well outdoors, because the LED light is often overpowered by natural light, causing problems with uniform color reflection, (Foster, Green Screen Handbook).

2.5.3 Compositing Editing Techniques

Figure 2-4: Chroma Matte, http://www.dvinfo 1

Both hardware and software approaches to digital image compositing are widely used in the film industry. These techniques are explored in the sections below.

2.5.3.1 Software

Digital compositing software uses the information captured by the camera and creates the desired matting effect. Compositing software has a variety of capabilities, including color, correction, spatial filtering, geometric transformation, image combination, matte generation, and field controls. One of the more popular options is Nuke, (see figure 2-5 below). It is manufactured by Britain's The Foundry Co, (Brinkmann, Ron. *The Art and Science of Digital Compositing*. Amsterdam: Elsevier Morgan Kaufmann, 2011. Print.).

Figure 2-5: Nuke Software, https://www.foundry.com/products/nuke

2.5.3.1.1 Alpha Compositing

Each pixel of a digitally rendered image contains RGB (see figure 2-6 below) information that represents colors contained in the original camera image. The red, blue, and green channels are individually assigned values that range from 0-1. These three values combining to create a color value for each pixel. A fourth channel, represented by the Greek letter “α”, contains information about the transparency of a given pixel (e.g. a transparent pixel has a value of zero, a solid pixel that hides its background entirely has a value of 1). Different types of matting software use this system to create high-quality mattes that couldn’t otherwise be achieved through analog means, (Porter, Thomas, and Tom Duff. "Compositing Digital Images.").

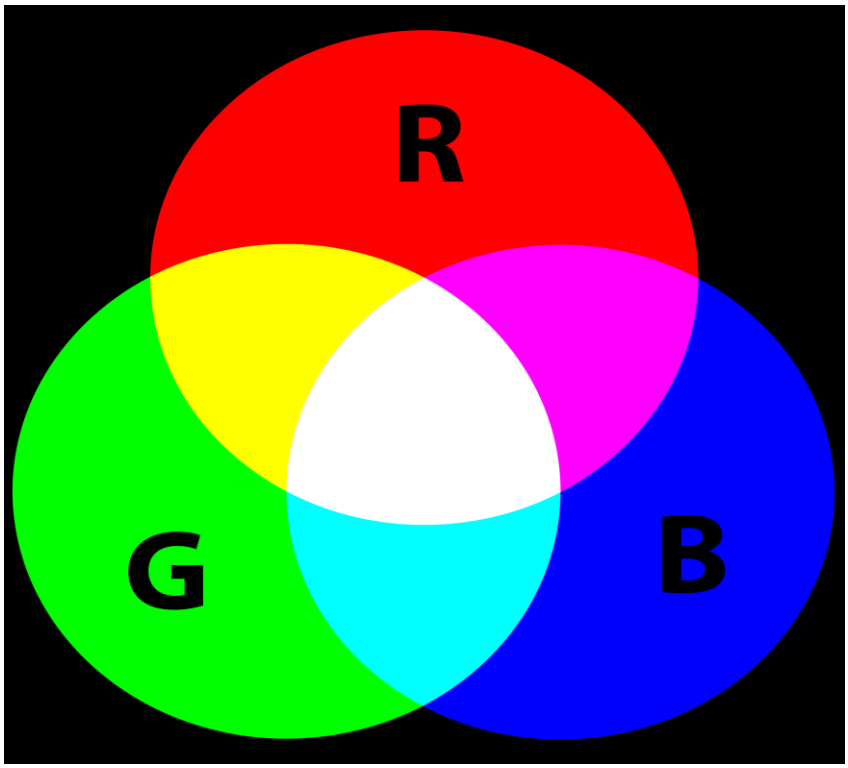

Figure 2-6: RGB, https://bpiinc.files.wordpress.com/2011/11/rgb.png

2.5.3.2 Hardware

Digital compositing hardware (see figure 2-7 below) also utilizes RGB and the alpha channel, but all processes take place in a self-contained unit. This technology is highly specialized and high cost and may not represent a practical solution for an entry-level client concerned about budget and simplicity. (<https://www.evl.uic.edu/ralph/508F98/contents.html>. <http://www.ultimatte.com/about>.)

Figure 2-7: The Ultimatte 500, http://www.ultimatte.com/ultimatte-500

2.5.4 Type of Light

Proper lighting is one of the most important components when taking pictures or videos while using either a green screen (GS) or blue screen (BS) in the background. However, lights must be placed where there is no shadow on the subject or the screen. There are many scenarios and creative ways of shooting a film, yet a few basic rules must be followed in all situations. To receive a perfect result when using a GS or BS, the following features need to be considered: the size of the studio, outdoor or indoor shooting, daylight or night shooting, the location, position, life-time, vibration, durability, cost, and cycling of the lights used. These features and

how they affect the BS, the GS, and the foreground subject will be discussed in the following subsections.

2.5.4.1 Reflecmedia LED light

As mentioned in a previous subsection, the Reflecmedia LED light (LiteRing) is composed of small green lights that are placed around the lens of the camera (see Figure 9 and 10). According to Jeff Foster, LiteRing reflects a green LED light back into the camera that creates a perfect green background behind the subject, increasing the quality of the outcomes (Jeff Foster, pg.154). With LiteRing, the location of the screen can affect its performance; the Reflecmedia LED light won't work well if placed in a very bright studio or outside in the sun (Jeff Foster, pg.154). The subject cannot wear shiny jewelry or reflective objects because of their reflective properties. If light is reflected back towards the camera from the subject, the subject will appear distorted in the edited image. Reflecmedia LED Light is a fast, low cost, and easy way of creating a green background. Image quality is sacrificed to some extent. (Jeff Foster, The Green Screen Handbook).

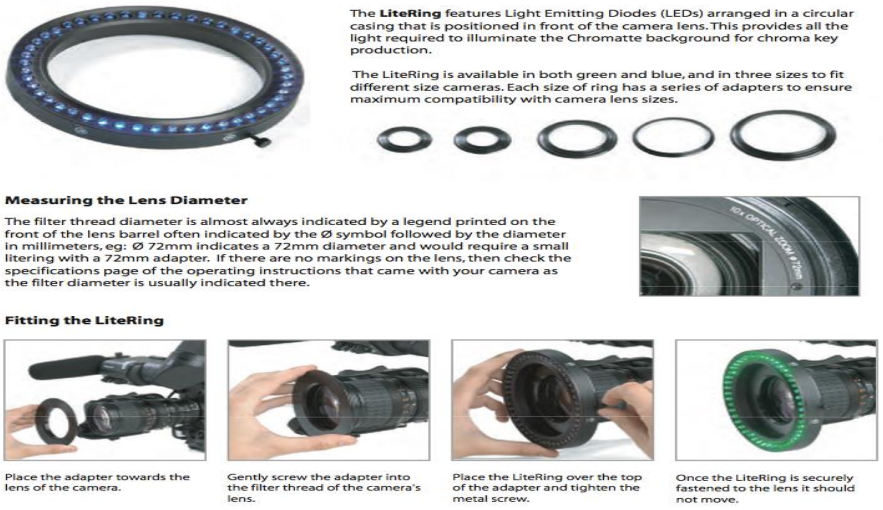

Figure 2-8: Reflecmedia LED Light, http://www.lennonbus.org/index.php?/blog/posts/working_with_chromatte_by_reflecmedia_-_a_simpler_green_screen/

Figure 2-9: Reflecmedia LED Light, http://www.provideocoalition.com/scopebox_reflecmedia_greenscreen_shoot/

2.5.4.2 Kino Flos

Kino Flos are known for their flexibility, which makes them suitable for traveling during smaller projects. Additionally, the lighting intensity of Kino Flos is easily adjusted. The user can experiment with Kino Flos lighting in two ways: 1.) by taking out or adding more light tubes, and 2.), by lowering the light intensity. There are two types of Kino Flos: BarFlys (see Figure 2-10) and Diva 400s (see Figure 2-11). In his experiments, Jeff Foster claims that the BarFlys weigh more than the Diva 400s, which are made of metal parts that make them more durable than Diva 400s (pg.161). Nevertheless, Diva lights still have the advantage of being used for small shoots and interviews due to their lightweight design.

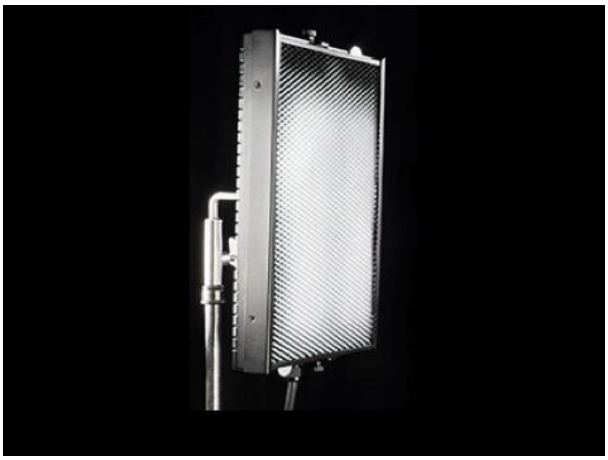

Figure 2-10: Kino Flos: BarFlys, http://www.kinoflo.com/Archives/BarFly200/BarFly200.html

Figure 2-11: Diva 400s, http://www.kinoflo.com/Archives/BarFly200/BarFly200.html

2.5.4.3 Lightpanels

Light panels are another type of LED light often used in the film industry (Figure 2-12). A light panel is unique because of the low amount of energy it uses. Light panels are suitable for travelling film crews, because a battery can be used as a plug-in instead of a power source. Furthermore, in his book "Film Lighting," Kris Malkiewicz claims that light panels have been widely used by filmmakers due to their size and their charging versatility, especially when recording from the inside of a car. Light panels can receive power from a car or a battery. According to MicroPro, a manufacturer of light panels, their systems can produce 1.5 hours of light using half a dozen AA batteries, or 5-6 hours when using Energizer e2 Lithium cells (http://files.tse.si/litepanels-br-allproducts2009.pdf pg.5). Considering their small size, light panels can produce a very bright, yet soft light that can be adjusted easily. Nevertheless, what makes light panels preferred by many is that they can be used on a tripod or placed on top of the camera depending on the size and model.

Figure 2-12: Light panels, http://files.tse.si/litepanels-br-allproducts2009.pdf

2.5.5 Applying Lighting On Set

2.5.5.1 Indoor vs. Outdoor

When considering lighting on set, it is important to differentiate between artificial and natural light. Natural light comes from the sun and works best in non-reflective environments. Artificial light is used for indoor applications.

2.5.5.1.1 Outdoors

One of the most important details of natural lighting is finding a location that provides enough sunlight. The time of day comes into play when considering location. Noon is the brightest time of day. Too much light causes filming conditions to be harsh and reflective for a green screen, which causes contrast with shadows. The most appropriate way to set up a green screen outdoors has the sun bouncing off the screen as shown in figure (2-13). The most appropriate way to set up a green screen outdoors has the sun bouncing off the screen as shown in figure 2-13 (below).

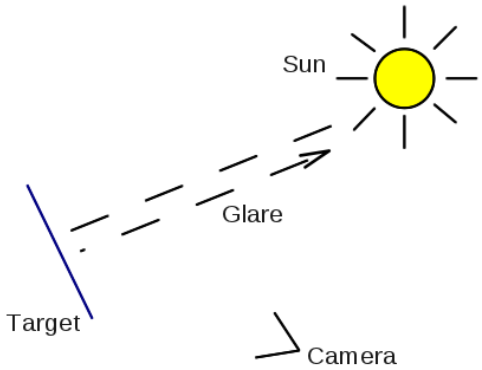

Figure 2-13: The target being the green screen in this case is best supplied with outdoor light when fully light up by sun beams at an acute angle with the ground, https://stephenstuff.wordpress.com/2012/01/07/an-introduction-to-digital-camera-profiling/

This setup allows the camera to capture film with the best conditions concerning natural light. At night when light variations can be controlled, the most desirable location is a wide open area with no surrounding shadows. This eliminates the chance of surrounding objects being able to interfere with the film. A good example is demonstrated in figure 2-14 (below).

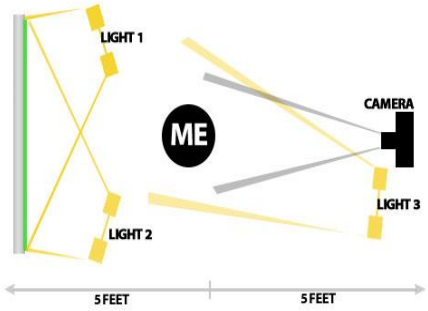

Figure 2-14: For nighttime outdoor use primarily, creates a shadowless environment when the correct lighting is applied, http://www.biblemoneymatters.com/how-to-create-a-diy-green-screen-setup/

LED bulbs have the tendency to work well in dark conditions due to their brightness. This makes LED bulbs perfect for outdoor green screen shooting at night because the cross lighting that could be created during the film is reduced. Adding additional lights on either side of the camera is an option that will bring extra light to the entire set. If added, those lights should be Kino Flo lights that will adjust light output for the film. (Ferncase, Richard Basic Lighting Worktext for Film and Video).

2.5.5.1.2 Indoors

Production values can be increased significantly by shooting indoors. Lighting can be

controlled and perfected in an indoor scenario. When considering a lighting setup for the green screen indoors, a large room is recommended to allow for equipment flexibility. When lighting a set, the main objective is to eliminate all shadows that may cause issues with the film. Another objective is to make sure the green screen is fully illuminated. If the screen is not well lit, problems may arise in the editing process. A diagram is displayed in figure (2-15) and shows desired lighting positions.

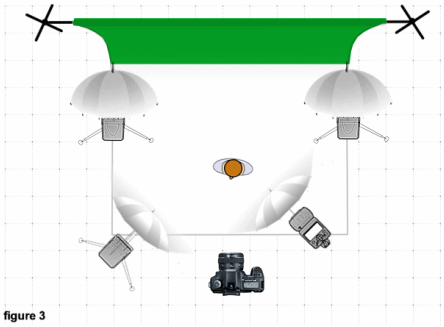

Figure 2-15: Four lights are used across from each other to light up all angles of the set. Reflectors may be put on top of the lights to allow the camera to capture any surrounding light.)
http://www.louish.com/2010/09/Easy_and_Perfect_Green_Screen_removal_for_sti

Setting up the lights against each other with reflectors ensures that most of the artificial light produced will be contained on set. Kino Flo lights should be used in all four lights in figure 2-15 (above) because they have the ability to create soft indoor light. If additional lighting is needed, surrounding the green screen with LED strips directed towards the screen is a very helpful solution. LED rings can also be fitted around the lens of the camera to place greater emphasis on the film subject. Placing the lights in different locations on the set can help create shadows for mood lighting such as a early morning in a room or a dimly lit dinner table (seen in figure 2-16). Getting the right shadow effect can be difficult and should be experimented with in order to get the desired result. This can include changing the number of light fixtures and locations of the lights.

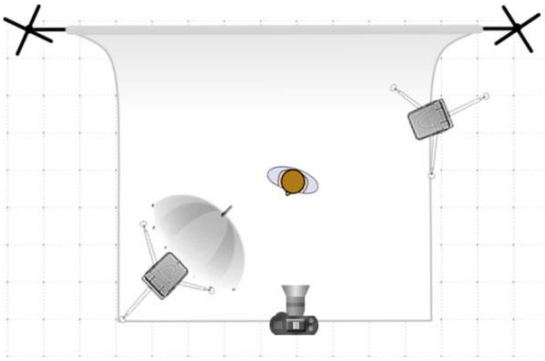

Figure 2-16: Two lights are aimed towards the object being filmed with one light fixed with a reflector to create shadows by the object being filmed, https://photography.tutsplus.com/articles/5-tools-to-create-and-share-studio-lighting-diagrams--cms-23285

2.5.6 On Set Lighting Conveniences

2.5.7.1 Maneuverability

Lighting on a green screen set must be versatile. Placing wheels on the bottom of light fixtures allows them to be placed in various locations on the set. Lights can also be built on gyro style fixtures with bendable arms so that a variety of lighting angles can be achieved.

2.5.6.1 Proper Care for Lighting

Lights and fixtures tend to be delicate by nature and proper care should be given to extend product life. It is very important to turn lights off after filming is completed. Any non LED form of light used on a studio set should not be turned on and off frequently. LED bulbs and products tend to be very sturdy and only malfunction if tampered with directly. Different kinds of lighting such as Kino Flos have bulbs that lock into place in fixtures and must be wheeled around slowly to avoid any hard bumps the light cart may come across on set. It is always good to have extra light sources on set such as spare bulbs or lights that may need to be replaced.

3 Search for Alternative Solutions

3.1 Introduction

Section 3 contains a variety of alternative solutions created by Team Visual Effects. Brainstorming different concepts and ideas led to the designs shown in the subsections below.

3.2 Brainstorming

Brainstorming was a process of feedback being given on the pros and cons of each one. As a list of possible green screen designs were created, actual pictures were quickly represented on a white board by each team member to clarify specific functions. This led to easy selection of what kind of material would be implemented with our design because it was concluded that it has to be durable and user friendly. Following the initial brainstorming phase, each group member tried to find flaws in the respective designs. Criteria such as frame material and portability were considered. Brainstorming is an important factor to any project because considering every possibility when it comes to using and maintaining the green screen is important.

3.3 Alternative Solutions:

3.3.1 The Ghost Wheels.

The Ghost Wheels design features special controllable wheels (Figure 3-1) that are attached to the bottom of the green screen. The advanced technology of remote control wheels will improve the productivity of filmmaking. The wheels are controlled by a remote control that sends a signal to the Receiving and Transmitting (RI) part on the wheels. This technique is valuable because when the subject being filmed is moving, the screen will be moving along with them. Using the remote control to move the screen, there will be no need for a human interaction to move the screen.

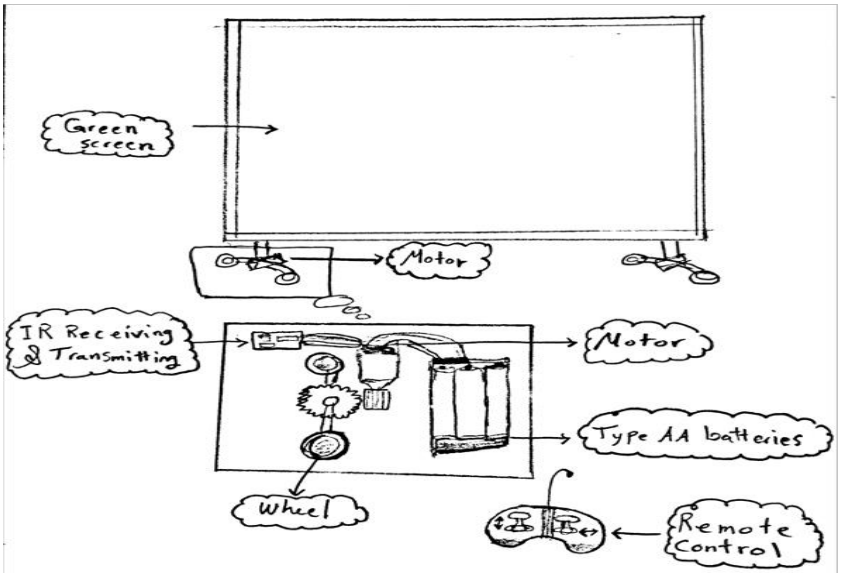

Figure 3-1: A Drawing of The Ghost Wheels.

The sketch shown above is to illustrate how the wheels will be ran and controlled by a remote control which would make portability not a problem at all. Remote control wheels would allow this to be moved around easily without interaction with the screen. When installed properly, the technology will give a smooth and constant movement of the screen. Drawing by Abdullah Alyami.

3.3.2 The Collapsible Frame.

The Collapsible Frame is a frame that is designed to be adjustable to different sizes Figure (3-2). Sometimes film producers like to change the environment in which they shoot a film. Thus, it would be very convenient to have a Collapsible frame that can easily be adjusted to fit through doors. Also, The Collapsible Frame is designed to be easier to carry by one person and easy to fit in an SUV.

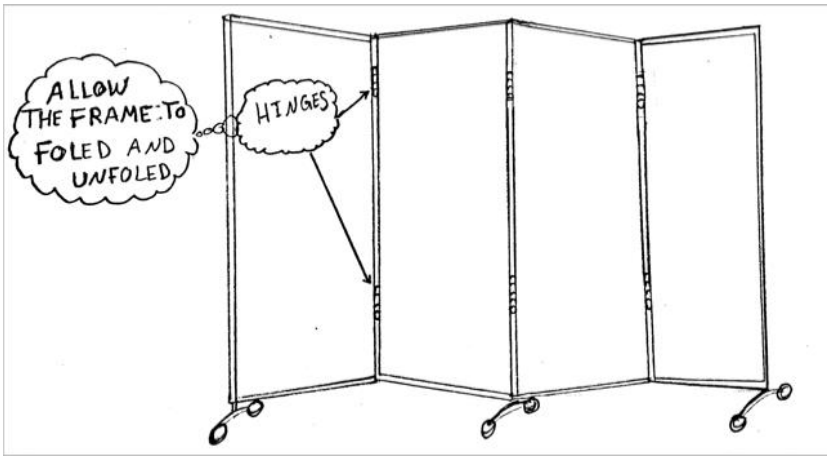

Figure 3-2: A Drawing of The Collapsible Frame.

showing above The Collapsible Frame. The drawing shows how the frame would be folded and unfolded. Drawing by Abdullah Alyami.

3.3.3 The Double Sided Screen.

The Double Sided Screen is a composed of a blue side and a green side attached to one frame Figure (3-3). Two different screens advance the film production by allowing the user to select the appropriate screen for the environment, subject, and lighting. The two screens have a metal bar attached at the top ends of the frame, which will allow the screens to be folded and unfolded separately.

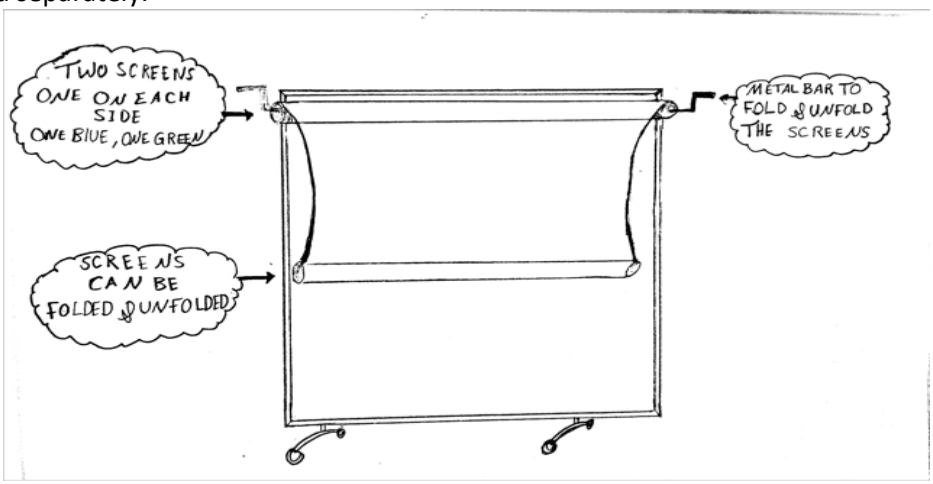

Figure 3-3: A Drawing of The Double Sided Screen.

The sketch above illustrates The Double Sided Screen. The visual shows how beneficial and convenient it is to have two screens in one frame. Drawing by Abdullah Alyami.

3.3.4 The Stand Still

The Stand Still is a basic design that focuses on portability and function. This design is very simple to build and easy to use for middle school students. This design allows the kids to set up easily and move the project to any desired filming location. If all else fails, this design will be very simple and easy to iterate. The screen can be pulled tight over a PVC pipe frame which can be attached to a rolling base or rolling cart.

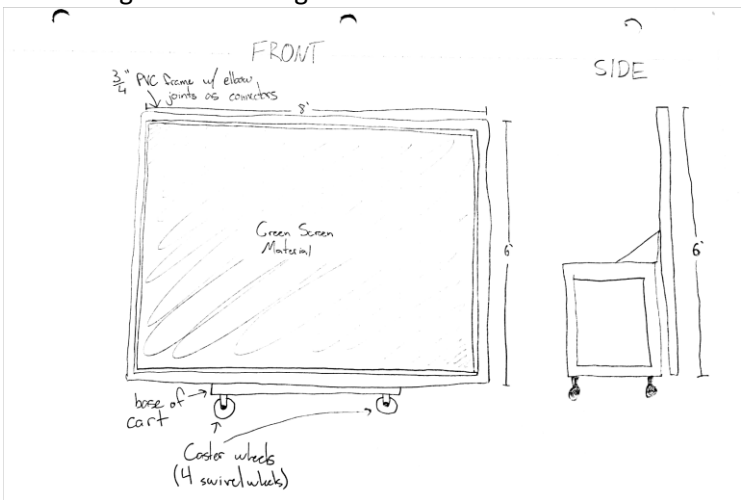

Figure 3-4: Drawing of The Stand Still. (Drawing by Liam Dooley).

3.3.5 The Amphitheatre.

The Amphitheatre (see figure 3-5 below) is a simple, elegant solution for any chroma keying

scenario. It is composed of a light, sturdy roll-up background, an arched stand that provides stability, and an arched structural support above the screen that provides a platform for lighting and helps to maintain the half-cylinder shape. The background is made of a flexible, light, cardboard-like material that rolls up and stores easily. The structural support is made of steel or aluminum tubing, similar to what is found in tent poles. The stand is made of molded plastic that is easily stored and lightweight.

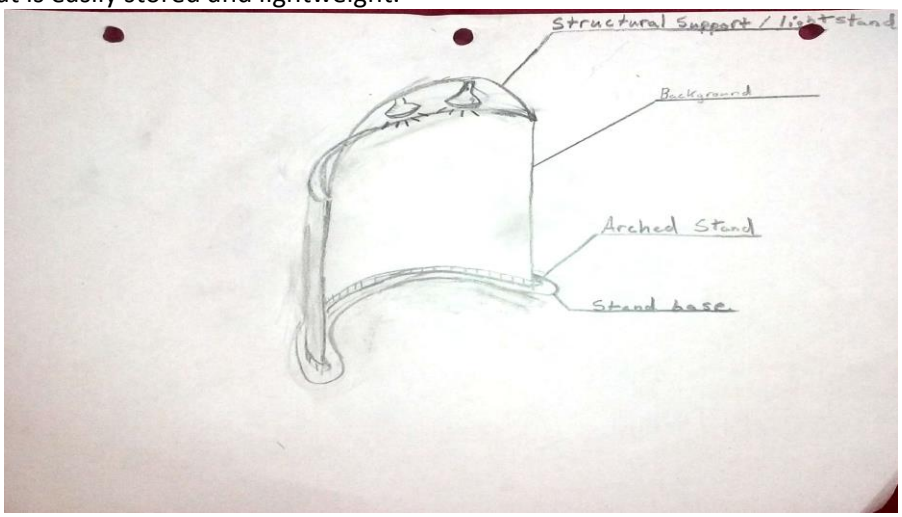

Figure 3-5: Sketch of The Amphitheatre. Drawing by Karl Oman.

3.3.6 The Icarus

The Icarus (figure 3-6 below) is a bold and innovative two-piece system that features a quick assembly, a winged background, and a lightweight wooden stand. The winged background uses hinges that allow many different background options, depending on the type of shot desired. The hinges also allow the background to be folded up and easily packed away for storage. The background is made of lightweight foam-board that provides an even Chroma keying surface and easy transportation. The wooden stand is also hinged, and folds up easily for packing. It is placed behind the screen, and is not visible from a front view.

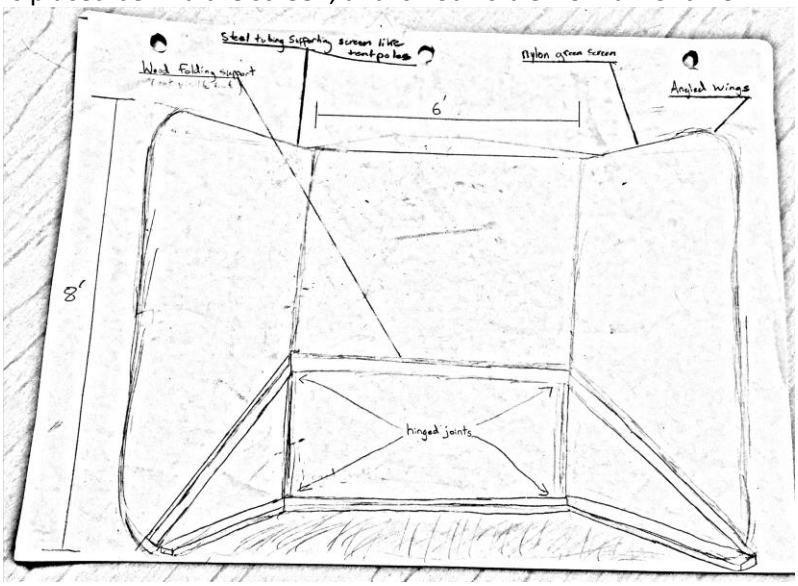

Figure 3-6: Drawing of The Icarus. Drawing by Karl Oman.

4 Decision Phase

4.1 Introduction

Section 4 describes the selection process that resulted in the final green screen design. The section defines the criteria, shows how criteria were used to assign a quantitative score to the alternative solutions in a Delphi matrix, and describes the qualitative factors that contributed to the final design choice.

4.2 Criteria Definitions

The design criteria are evaluated and assessed according to the following definitions:

- **Cost**: The cost of all materials and labor provided in exchange for currency.
- **Aesthetics**: The pleasure felt when looking at the product.
- **Portability**: The ease of transport of the product.
- **Durability**: The ability of the product to withstand the tests of time and wear.
- **Functionality**: The customer's ease of product use.
- **Degree of Difficulty**: The number of hours spent designing, constructing, and acquiring skills necessary for the fabrication of the product.
- **Performance**: The product's achievement of its primary intended purpose.

4.3 Decision Process

Our decision process utilized the Delphi chart (see figure 4-1 below) to rank alternative solutions based on criteria fulfillment. Portability was assigned the highest weight of all criteria (10), because the client considered it the most essential quality of the final green screen design. Cost, durability, and performance additionally received high rankings (9), due to their importance in the context of the project (i.e. built for a middle school classroom, to be used by middle school students). Aesthetics and functionality received fairly low scores because it was decided in the client interview that a product meeting average levels of those criteria could still satisfy the needs of the client. The final results of the Delphi method were considered in the decision process, in addition to input from group members and the client interview.

Criteria		Alternative Solutions (0-50 high)					
List	Weight (0-10 high)	The Ghost Wheels	The Collapsible Frame	The Double Sided Screen	The Stand Still	The Amphitheater	The Icarus
Cost	9	10 / 90	47 / 423	48 / 432	50 / 450	25 / 225	47 / 423
Aesthetics	7	25 / 175	40 / 280	42 / 294	24 / 168	40 / 280	40 / 280
Portability	10	35 / 350	40 / 400	32 / 320	30 / 300	35 / 350	37 / 370
Durability	9	22 / 198	37 / 333	28 / 252	25 / 225	27 / 243	30 / 270
Functionality	7	47 / 329	45 / 315	40 / 280	35 / 245	25 / 175	42 / 294
Degree of Difficulty (construction)	8	4 / 32	25 / 200	40 / 320	30 / 240	39 / 312	40 / 320
Performance	9	25 / 225	25 / 225	45 / 405	30 / 270	43 / 387	34 / 306
Total		1399	2176	2303	1898	1972	2263

Figure 4-1: Delphi Chart by Abdullah Alyami.

4.4 Final Decision Justification

The final design draws inspiration from a variety of the alternative solutions, but is unique and does not replicate any of our previous designs. It includes a three-piece frame, a clamp system, a green muslin fabric backdrop and a system of rotating legs. It scores well in all design criteria, especially in portability, functionality, cost and performance.

5 Specification of Solution

5.1 Introduction

The solution specification section of the document contains specifications for the portable green screen, including costs, work-hours, a scaled drawing of the design, use instructions, and product testing results.

5.2 Solution Description

The final design solution incorporates a three-piece PVC frame figure (5-1), a PVC connection system figure (5-2), a green muslin cloth and clamps figure (5-3), and detachable legs figure (5-4). It is designed for indoor/outdoor use, although it is not recommended to set up the system outdoors when wind speeds are above 8 mph.

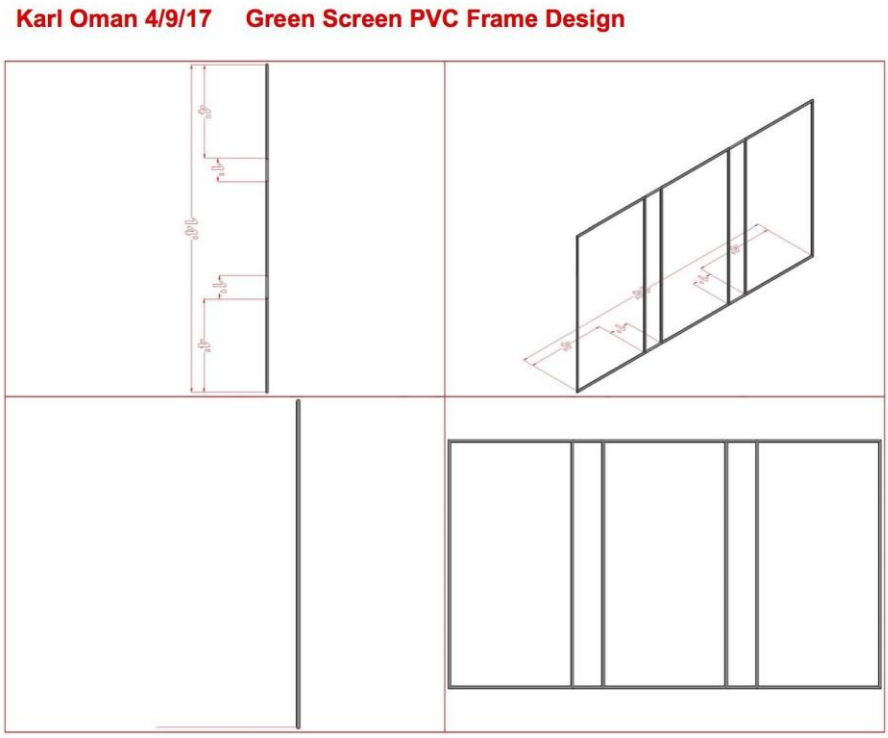

Figure 5-1: Three-piece frame. Drawing by Karl Oman

5.2.1 Frame

The rectangular frame of the structure is composed of 1” PVC pipe and stands 6’ tall by 14’ wide, as seen in the figure above. The frame breaks down into three 4’ by 6’ rectangular frames. Double vertical crossbars seen on the right half of figure (5-1) were introduced to improve frame rigidity and allow for a three-piece design.

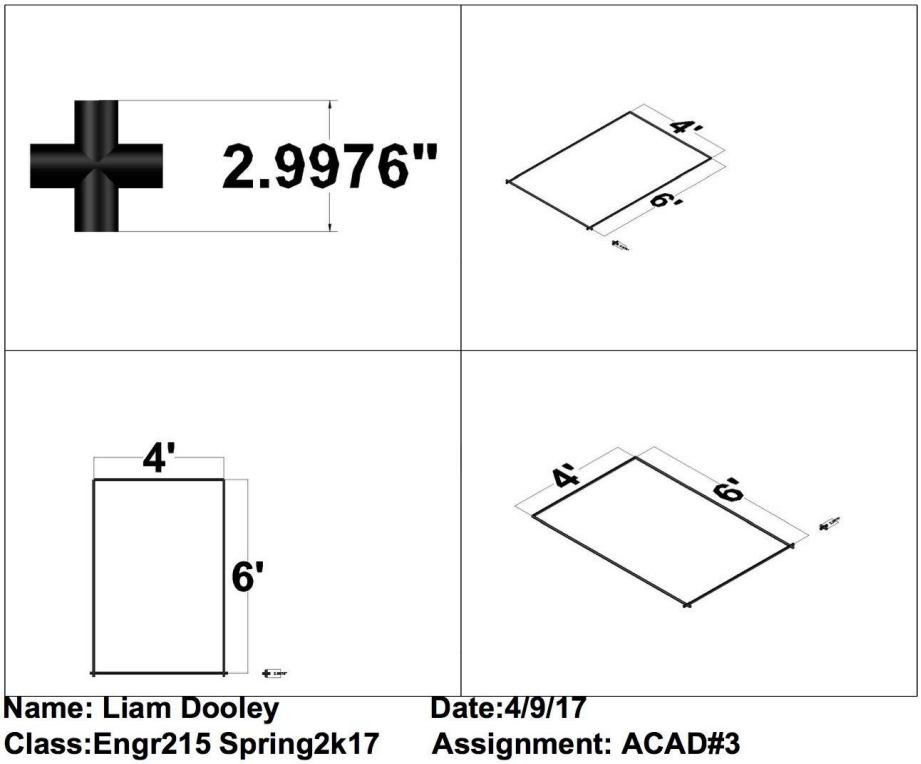

Figure 5-2: Drawing of frame and PVC union. Drawing by Liam Dooley

5.2.2 Connections

The bottom of the three-piece frame is connected by four-way PVC unions seen in the upper left of figure (5-2) that link two horizontal members of the frame, one vertical member, and the stand. Along the top of the frame are T- shaped unions that connect a vertical member and two horizontal members. At each connection, one side is glued and the opposite side is free so that the frame can be disassembled.

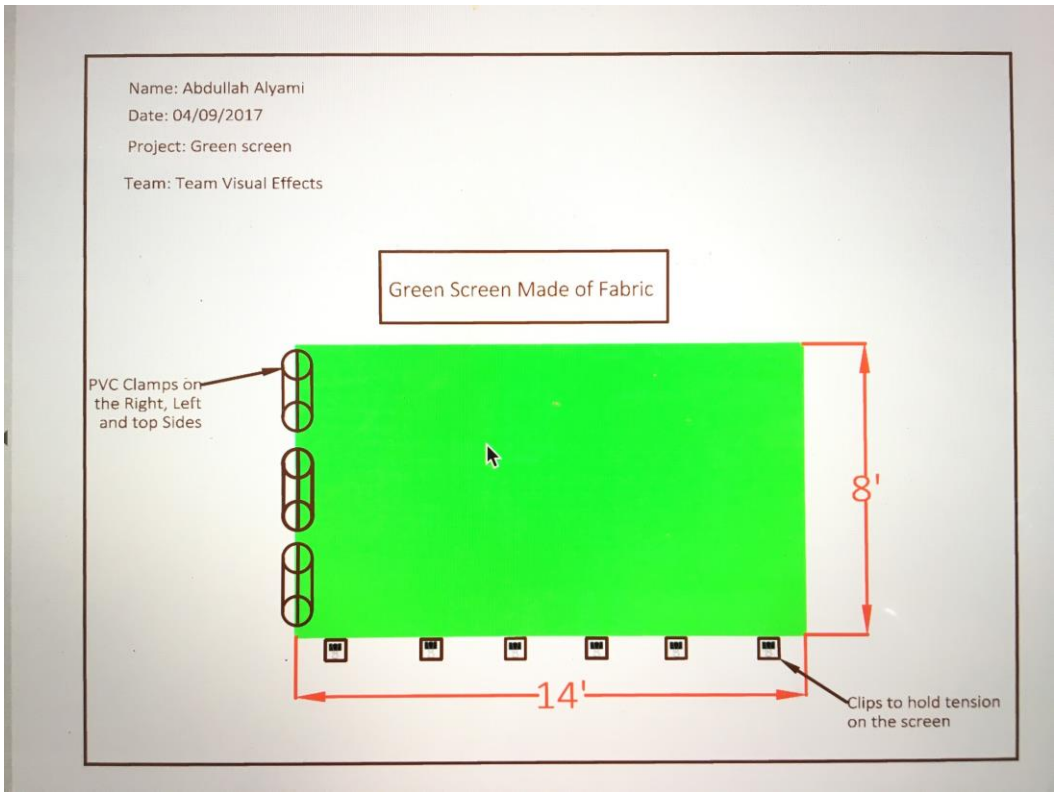

Figure 5-3: Drawing of fabric and clamp system. Drawing by Abdullah Alyami

5.2.3 Clamp System

The screen fabric is made to extend slightly longer than the frame seen in figure (5-3) above so that clamps can be applied and tension adjusted. The PVC clamps can be slid outward to increase screen tension, and inward to decrease tension. The screen is designed to easily detach from the frame for simple and efficient storage.

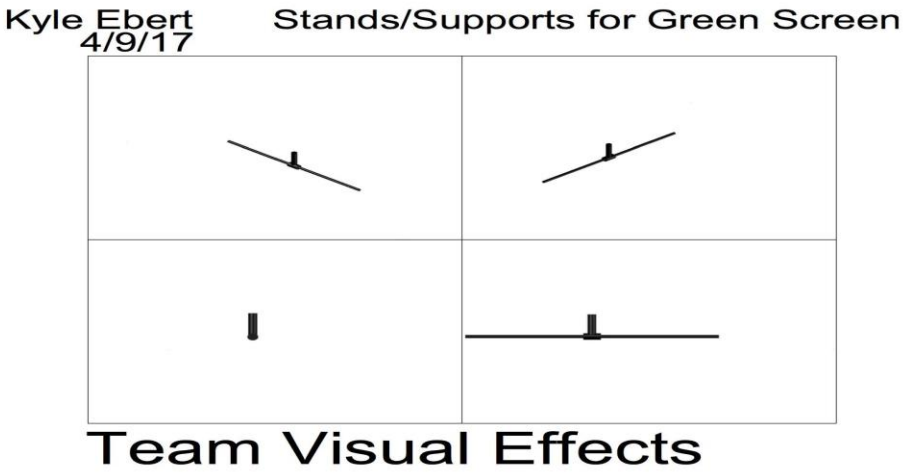

Figure 5-4: Drawing of screen stand. Drawing by Kyle Ebert.

5.2.4 Stands/Supports

The supports for the structure as seen in figure (5-4) above are designed to maximize efficiency while maintaining simplicity. Connections along the bottom of the frame reach 6”

down to T- joints extending 2’ out on either side giving the structure a steady platform to rest on. When determining the length of the supports, the height was taken into account because the taller the screen stands, the longer the legs on the bottom need to be to prevent it from toppling over. The legs were also designed to rotate 360 degrees on the bottom to allow the students or user to fold up the frame using feet and hands.

5.3 Cost

5.3.1 Design Cost

The design cost indicates the amount of time (hours) that Team Visual Effects have put into building the Green-Screen. Overall, 69.5 total hours were spent designing the project. The team spent most of the design hours on the literature review section (see figure (5-5) below).

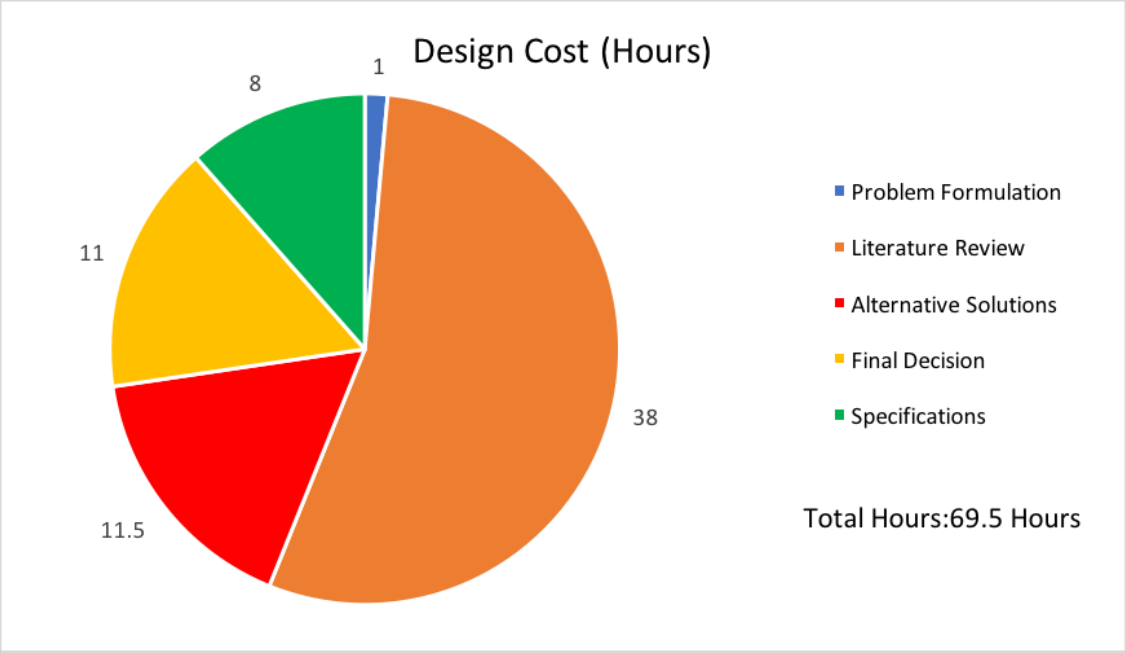

Figure 5-5: Design Hours. Chart by Abdullah Alyami

5.3.2 Material Cost

Table (5-1) below shows the cost of all the materials that were used to build the green screen. $164.34 was spent in total. PVC pipes represent the biggest cost of the project.

Table 5-1: Material Costs (In dollar)

Items	Cost ($)
Green Fabric	36.96
Clips	9.99
Clamps	11.02
PVC Pipes	85.15
Steel Bar	2.17
PVC Connectors	19.05
Total	164.34

5.3.3 Maintenance Costs

The green screen is built from low-cost materials, resulting in low anticipated maintenance costs. The screen will be used by middle schoolers and damage to some parts of the screen may frequently occur due to heavy use. The parts most at-risk for damage include the fabric and clamps, due to their fragility. Table (5-2) below shows all anticipated maintenance costs.

Table 5-2: Maintenance Costs (In dollar)

Maintenance	Tasks Frequency	Projected Cost/5 Yr ($)
Fabric	5 Years	36.96
Clamps/Clips	5 Years	20.01
	Total	57.97

5.4 Usage and Instructions

The system is intended for indoor/outdoor use. It should not be used outdoors in wind speeds above 8 mph. It is recommended that a lighting system be used with the green screen, so that the surface is shadow-less and evenly lit.

Assembly of the PVC pipe frame is fairly simple. All components of the system can be easily transported and stored by three people The three-piece frame fits together as one large PVC pipe rectangle that the fabric can easily be draped over. Once the three large pieces are attached together, legs can be inserted into the frame. The screen can be easily laid out over the entire frame. The clamps are then snapped into the PVC pipes with the screen being held between the clamps and the PVC pipe. With the frame completely assembled, fabric tension can be adjusted to the user specifications. Then the frame can be lifted from the ground into a vertical standing position. It is recommended for the frame to be lifted by at least two people. The green screen system is now ready for use.

5.5 Results

Product testing yielded fair results. Satisfactory screen tension was achieved through the use of a system of pipe clamps. It was discovered that the clamps have a tendency to rip the screen fabric upon removal. This problem was fixed by replacing the metal clamps with PVC substitutes. Product testing showed that the screen has a strong base and is easily assembled and disassembled. An area of concern revealed by testing is the product's instability in light to moderate wind conditions. The screen acts like a sail and has a tendency to blow down. To resolve this issue, it is instructed to use the screen only in situations where very little wind is present.

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