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1 Problem Formulation

1.1 Introduction

In section 1 of the process, The Train Conductors formed an objective statement which serves to provide a clear and concise goal for the design process. The Train Conductors also created a Black Box Diagram, which will serve to demonstrate a simplified version of the design process.

1.2 Background

Zane Middle School is a medium sized junior high located in Eureka California. The school is a STEAM school, which stands for "Science, Technology, Engineering, Arts, and Math." The school puts focus on the sciences as well as the arts to give the students a more rounded education. Zane Middle School utilizes performance arts within the classrooms to create a more entertaining and productive learning style.

1.3 Objective Statement

The goal of this design project is to create a lightweight, stable, and portable stage that Zane Middle School can use for assemblies and performances. The implementation of the stage at Zane Middle School will allow students to have more opportunity and experience in performance art activities. The criteria for the design will be provided by the project's client, Zane Middle School.

1.4 Black Box Model

The Black Box Model is a simplified representation of the design process. The first box (reading left to right) shows the state of the situation before the design is implemented, and the last box shows the desired state of the situation after the implementation of the design. The middle box is considered the design (or solution) and is represented as a black box because the design has not yet been determined.

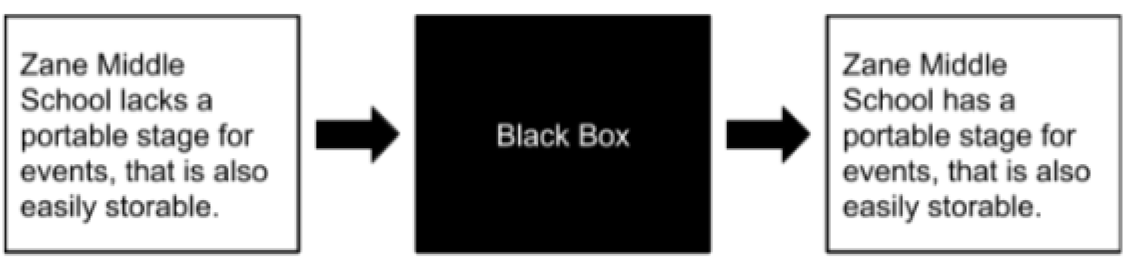

Figure 1-1 The Black Box Diagram created by the Train Conductors

2 Problem Analysis and Literature Review

2.1 Introduction

The problem analysis and literature review section will contain the in-depth analysis of the design problem as well as a large grouping of researched topics that may hold some form of importance to the design process.

2.2 Problem Analysis

The problem analysis will discuss the client's criteria for the project and analyze any issues serving as a constraint to the overall objective. This section also covers the parameters of the project, explaining the considerations and specifications, usage, and production volume.

2.2.1 Specification

The specifications of this project are factors that must be implemented in the design process. The following three specifications will be considered during the design process.

- The stage must have a skirt on it, or full sides, so that the audience cannot see below the stage.
- The stage must be a neutral coloring, so that the audience is not distracted from the performers.
- The stage must not be too loud when walked on, meaning a sound dampener must be used. (Be it paint or carpet or another.)
- The stage must be structurally sound from abrupt movement on stage.
- Must be easily moveable for junior high students.

2.2.2 Considerations

When designing the stage, one must consider the average weight on the stage when being used (approximately 500-1000 pounds), the size that the stage will be when stored, the typical weather pattern in the local area for outdoor use, and the safety precautions necessary for use.

2.2.3 Criteria

The criteria are a necessary element to consider because it is the qualities that must be met by the project for it to be considered successful by the client.

Criteria	Constraints
Total Cost	Maximum budget of $225
Portability	Must be light enough to be moved by students and simple to store
Weight Capacity	Must hold the weight of 5 to 10 students (500-1000 lbs.)
Durability and Longevity	Must be long lasting and require little to no maintenance.
Safety	Must not pose a safety hazard to students.

Table 2-1: Criteria and coinciding constraints giving by the client representative.

2.3 Literature Review

2.3.1 Introduction

The literature review section contains a variety of researched topics. This provides valuable information that will be used in designing the product. It will also provide background information and research on topics related to the project. Some of the topics covered include, materials, hardware and safety.

2.3.1.1 Materials

2.3.1.1.1 Wood

Wood is a strong and lightweight material, which comes in a numerous variety of forms, from plywood sheeting to solid or pressure treated form boards. The most common for load bearing building is 2”x (pronounced “two by”) Doug Fir. (The 2”x refers to the boards measurements, 2”x _”. The most common are 2”x4”, 2”x8”, and 2”x12” boards. The average density of Douglas Fir (a standard type of wood for construction) is 33 pounds per cubic foot (lbs./ft^3). (engineering toolbox, 2018) Wood is a relatively low-cost material, making it easier to access. Tooling of the material is easy and does not require specialty equipment. Wood is relatively soft however and is more susceptible to damage than other materials may be. A wood stage would be relatively easy to move due to its lower density, and if properly cared for would last much longer than most light weight plastic-based materials.

2.3.1.1.2 Aluminum

Aluminum is significantly stronger than wood, but also much heavier. Due to its being a non-ferrous metal it requires specialty welding equipment as well as special milling. The average density of aluminum is 168 pounds per cubic foot (lbs./ft^3). (coyote steel, 2018) which is almost 5 times more than wood. It is significantly more expensive than the wood alternative as well. Aluminum is also harder to acquire than wood, as it must be purchased from a wholesale materials business, rather than a local hardware store. An aluminum stage would last much longer than wood but would also be much harder to move and much harder to build.

2.3.1.1.3 Steel

Steel is by far the strongest of the materials but is also the heaviest. The average density of steel is 490 pounds per cubic foot (lbs./ft^3). (coyote steel, 2018) Steel is also prone to oxidizing (rusting) if not properly treated, which could cause aesthetics issues. A steel framed stage would not be moveable but would last the longest if properly cared for. Steel is much harder than aluminum and wood and would therefore have the highest level of resistance to any kind of damage that the students may be able to do.

2.3.1.1.4 Milk Crates

Milk crates are durable plastic crates that are often used as stepstools and chairs because of their strength. They are most commonly found in 13” x 13” x 11” (Lexington Container Company). The milk crates are light weight and strong but are made of a plastic material. Prolonged exposure to sun and the elements may result in cracking and therefore damage to the crates. Students may also accidentally kick and the plastic gridded sides, which could damage them significantly. Milk crates are available from wholesale or retail sites but would have to be shipped in from out of the area. Milk crates are relatively inexpensive, costing around $10-$15 on average (Lexington Container Company).

2.3.1.1.5 Paint

A simple layer of exterior or floor grade paint would serve to protect the wood from weathering, as well as providing a more uniform surface for the stage, which wouldn’t draw the audiences’ attention from the performers. The paint would be a relatively cheap option and would be readily available at most hardware stores and paint shops.

2.3.1.1.6 Carpeting

Carpeting is an expensive addition to the stage, but when laid over the top of the stage would effectively reduce the noise of students’ footsteps on stage, as well as make it softer for comfort if performing in socks or barefoot. The carpeting would be heavy and would not be able to be used outside in the weather but would perform fine indoors.

2.3.1.1.7 Nylon Cover

A nylon cover is a sheet of plasticized material that would be glued down on the stage. The purpose of this would be to provide a uniform and non-distracting top to the stage, as well as provide a bit of extra traction and to protect the stage from abrasions and stains.

2.3.1.2 Hardware

There are a multitude of possible types of hardware that could be used to construct the stage. To make it easier to take the stage down and move it, it is likely that the hardware would need to be quick release capable, and not require any special tools to take apart.

2.3.1.2.1 Hard Fastened

The traditional method of building a frame requires the pieces to be hard fastened together, meaning that they remain in the frame shape and do not come apart without completely destructing the stage. This can be done with nails or screws and would be the cheapest option. It is also the strongest option, especially when paired with L-brackets or other such hardware. However, this would mean that the frame of the stage would not come apart, and it may make storage and movement harder.

2.3.1.2.2 Drop Pin

Using a drop pin system would allow the stage to be quickly assembled and disassembled, just by dropping a pin into a hole. This is a more expensive option, as it requires the stage to have metal brackets for the pins, as well as grade 5 zinc alloy drop pins (or equivalent of or better). The drop pin components would cost somewhere between $2 and $10 per unit. This would be a strong alternative but may compromise the stability of the stage to a certain degree, as it may have some room to move around. Room to move around is subject to change given different pairings of pins and brackets and would likely be a few millimeters or less. This would not be a safety hazard, but it may lead to an irritating squeaking or clicking when students move across the stage. The drop pin may be paired with an extended wing nut to lessen this issue. The drop pin may also be paired with a quick detach ringlet for easy removal. This system would allow the individual lengths of the frame to be recombined in different patterns, allowing for different uses. This would make the stage more versatile, as it would be able to be combined in a few different ways, thereby changing its size and shape.

2.3.1.3 Safety

2.3.1.3.1 Elevation of the Stage

The elevation of the stage is restricted by the California code of regulations. The rule concerning decks, patios, and stages is that anything in excess of 8” in height requires a step, and anything in excess of 24” requires a handrail. The stage will also need to be slid and skid resistant, to ensure the students don’t fall and get injured.

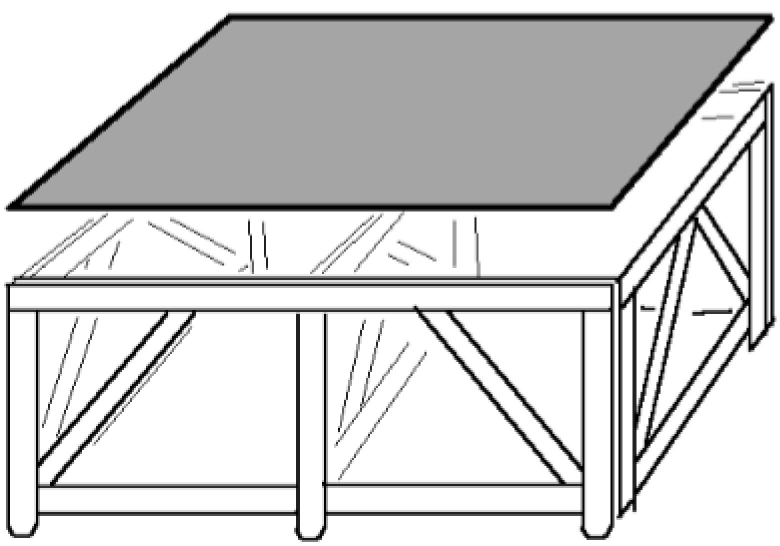

Figure 2- 1 Auto CAD drawing of the stage frame and top, displaying the general height of the frame

2.3.1.3.2 Corners of the Stage

The corners of the stage will need to be sufficiently smoothed and/or rounded, to prevent students from being injured by sharp edges, or getting splinters.

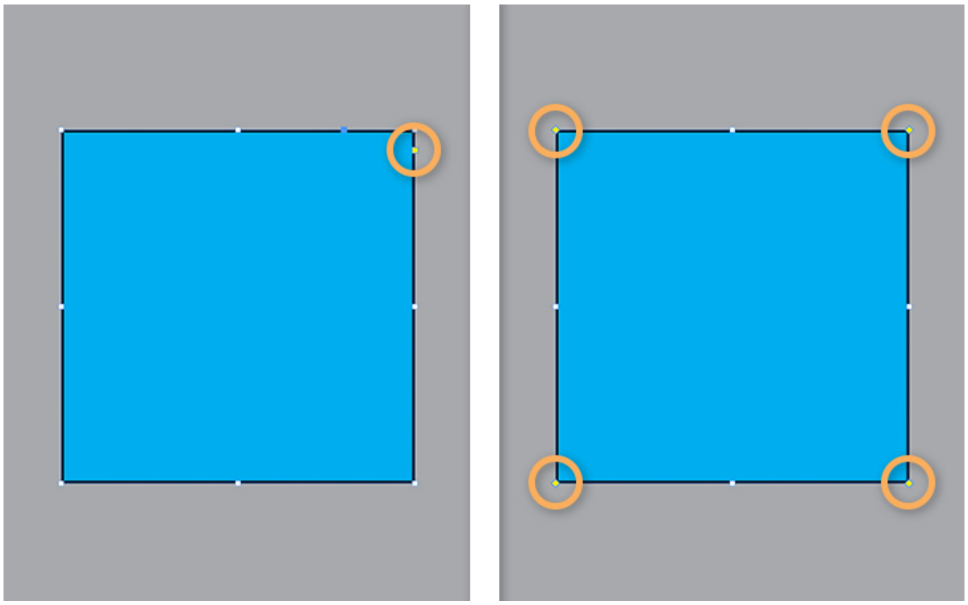

Figure 2- 2 Image Auto CAD drawing of placer where rounding could be to increase safety

2.3.1.3.3 Paints/Covers

The paints or covers that go on the stage will need to be slip and skid resistant. If paint is used, it must be lead and VOC free paint.

2.3.1.4 Other Considered Topics

2.3.1.4.1 STEAM

STEAM is an educational method which incorporates the subjects of science, technology, engineering, art, and mathematics. STEAM programs are recognized as a vital aspect in the development of youth education, better preparing them for college and workforce. Zane Middle School implements this learning process throughout their curriculum, making the stage an important factor for progression in art skills for students. STEAM allows students to develop the important aspects needed to succeed in science and math fields, but also encourages more critical thinking, imagination, design, and innovation through art.

2.3.1.4.2 Local Weather and Geography

Knowing the weather patterns is important because it can determine what materials a project can or cannot use. For example, Since the stage will be used outdoors, knowing the usual conditions and weather patterns will be essential for building a high quality, long lasting project. Zane Middle School is located on the coast in Eureka, California. This area receives an average of forty-five inches of rain annually, approximately double the amount that the rest California averages. Due to these conditions, the stage must be designed and constructed properly to ensure longevity and safety.

3 Alternative Solutions

3.1 Introduction

Section 3: Search for Alternative Solutions provides examples of alternative solutions for the portable stage design generated through brainstorming and collaborative work based on the parameters of the client's criteria and constraints. By designing alternative solutions for the stage, the outcome of the stage will be of much higher quality and there will be a much better chance that the client's criteria will be met. Included in this section are tables, diagrams, comparisons and examples of our alternative solutions.

3.2 Criteria

In order to examine all the alternative options in an equal capacity, a set of standardized criteria will be put forth for use in judgement. The criteria will follow the **CRUDE** method. The purpose of creating a standardized set of criteria with which to judge the alternative solutions is to give each solution an equal opportunity, and to create a more objective list of factors that will influence the final decision later.

Cost of material.
Resistance (to weathering and damage).
Usability (how easy to tool or work with).
Density/**D**urability (weight, and the ratio of how strong it is to how much it weighs).
Ease of Access (how easy it is to obtain the material).

Criteria	Constraints	Weighted Ranking
Total Cost	Budget of $225	**8**
Portability	Must be light enough to be moved by staff and students	**5**
Weight Capacity	Must hold the weight of 5 to 10 students (500-1000 lbs.)	**7**
Durability and Longevity	Must be long lasting and require little to no maintenance.	**8**
Safety	Must not pose a safety hazard to students.	**10**

Table 3-1: Criteria and constraints weighted by significance.

3.3 Brainstorming

The Process of brainstorming Formulates different ideas for a topic our brainstorming sessions led to many alternative types of materials and design to increase factors like stability and durability or decrease factors like cost and maintenance over time on the stage.

3.4 Alternative Solutions

The search for alternative solutions includes examining each of the potential solutions through a set of given criteria. Due to the nature of the project *The Train Conductors* have worked on, the alternative solutions are all based on differences of materials. The criteria used for examining each material follows the **CRUDE** method that has previously been outlined.

3.4.1 Top

Plywood Sheeting	OSB Sheeting	Plastic Sheeting

3.4.1.1 Plywood Sheeting

The top made of plywood sheets would be very easy. The plywood comes precut in 4'x8' sections. The plywood would be laid over the top of the frame and would be somehow fastened to the frame to prevent shifting during use.

Cost Plywood sheeting is inexpensive, between $35.00 and $70.00 per sheet.
Resistance Plywood is more susceptible to damages from sharp objects being dropped on it but is still more durable than a lightweight plastic sheeting would be.
Usability Plywood does not require any special tools.
Density/Durability Plywood has an excellent durability to weight rating, which is why it is commonly used for walls, ceilings, and floors in construction.
Ease of access Plywood is readily available at most hardware stores and is therefore very easy to obtain.

3.4.1.2 OSB Sheeting

OSB sheeting is similar to plywood. It is made by pressing and gluing wood chips together into boards. OSB is also known as particle board and is commonly found in construction. It is much lighter than plywood but is also less durable. The OSB sheeting would be assembled the same as the plywood, as it comes in 4'x8' sheets. It would be implemented the same way as the plywood sheets.

Cost OSB is significantly cheaper than plywood sheeting.
Resistance OSB is significantly softer than plywood sheeting and plastic sheeting and would therefore be much more susceptible to damage. OSB also becomes waterlogged and rots if it gets wet.
Usability OSB sheeting does not require any special tools.
Density/Durability OSB has a poor durability to weight ratio.
Ease of access OSB is readily available at hardware stores, so it would be easy to obtain.

3.4.1.3 Plastic Sheeting

Plastic sheeting would be available in 4’ x 8’ sections comprised of a particle board layer with a plasticized face. It would be implemented the same way as the plywood sheets.

Cost Plastic sheeting is much more expensive than plywood.
Resistance The plasticized face on the particle board would be prone to scuffing and cracking.
Usability The plastic would need a specialized small tooth saw blade to cut.
Density/Durability The plastic has a poor weight to durability ratio.
Ease of access The plastic would need to be special ordered through a wholesaler.

3.4.2 Frame

Wooden Fixed Frame	Aluminum Fixed Frame
Wooden Folding Frame	Aluminum Folding Frame
Rack Steel Frame	Steel Pipe Fixed Frame
Milk Crate Frame	Steel Pipe Folding Frame

3.4.2.1 Wooden Fixed Frame

The wooden fixed frame is one of the most mechanically simple options and would likely be the easiest to produce in any larger volume than we are. The fixed wooden option would be comprised of four boards around the perimeter, fastened together with screws, with the top fastened to the frame by screws as well.

Cost The wooden fixed frame would likely be one of the cheapest options.
Resistance The wooden frame would be fairly impact and abrasion resistant but could be damaged by sharper objects.
Usability The wood is easy to work with and requires little to no special tools.
Density/Durability The wood has most likely the highest durability to weight ratio, making it an excellent choice for construction purposes.
Ease of access Wood is easy to obtain at nearly any hardware store.

A simplified rendering of the stage is shown below.

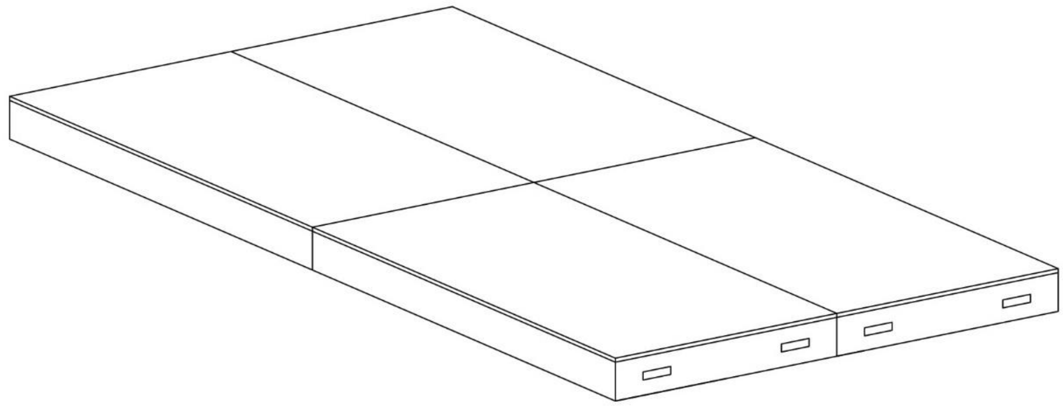

Figure 3-1: An AutoCAD rendering of the stage's design

3.4.2.2 Wooden Folding Frame

A wooden folding frame is another cheap option and presents many of the strengths of having a fixed wooden frame. The folding frame would consist of hinged corners, and a removable top, making it so that the frame folds down flat for easier storage and movement.

Cost The cost would be similar to that of the fixed wooden frame, but slightly higher due to the price of hardware such as hinges.
Resistance The wooden frame would be impact and abrasion resistant, but the hinges may become bent or damaged and rendered unusable.
Usability The wood would be easy to work with and would require little to no special tools.
Density/Durability The wood has a good weight to durability ratio.
Ease of access Wood is available at most hardware stores and would therefore be easy to obtain.

3.4.2.3 Rack Steel Frame

A rack steel frame would be a frame welded together made of rack steel. Rack steel is commonly used in industrial shelving. The steel would make a solid but extremely heavy frame and could be topped with any of the topping options. Rack steel has a unique “L” shape to its profile.

Cost The rack metal is very high priced when compared to the wood alternative.
Resistance The rack metal is very strong but will rust if not properly coated with paint.
Usability Rack metal requires special saws and welding equipment to build with.
Density/Durability Rack metal is very strong but has a poor weight to durability ration due to its weight.
Ease of access It is hard to get rack metal, as it needs to be special ordered from a steelwork.

3.4.2.4 Milk Crate Frame

The milk crate frame is a cheap and easy alternative solution, with low maintenance costs. The milk crate frame would be a large amount of milk crates strapped together with military grade zip-ties. This would make it multi-functional, as it could be the stage frame or could be stood on end to make a set of cubbies. However, it may be hard to move around due to its weight and how the milk creates might slightly move when attempted to be picked up. The movement could be minimized by adding more zip-ties, but there would still be some shifting when moving the frame. There would still be the four separate sections to the stage each of which being made up of their own individual crates. The milk crates are 13" long x 13" wide x 11" tall, meaning it would take four panels that are each 7 crates x 4 crates in size. This would make each section 4 ⅓' x 7 ½' in size. This is an odd size and would make the final stage size 15' x 8 ⅔' in size. The height of the stage would be 11 ¾", which is tall enough that OSHA mandates there be a step. (California Code of Regulations, Title 8, Section 3231. Stairways.)

Cost The average cost for a milk crate is about $10.00, however approximately 112 crates would be needed to support 500-1000 pounds as well as be the size needed for the stage, making it quite pricey.
Resistance The milk crate has a high resistance to weathering and will not deteriorate quickly.
Usability This material is very easy to work with.
Density/Durability It is quite durable for weight support, however eventual cracking is possible.
Ease of access The accessibility is high due to there being many places where they can be obtained.

3.4.2.5 Aluminum Fixed Frame

An aluminum fixed frame would consist of a skeletonized frame made of aluminum bars bolted together. The frame would need to have siding or skirt around it to prevent the audience from seeing beneath it. The aluminum fixed frame would allow for a more durable stage, also a long-lasting material that won't rust or corrode. Also, aluminum is less likely to bend, dent and scratch while moving making it a durable option. However, given the size of the stage an aluminum frame would be very heavy.

Cost- The average cost of a linear foot of aluminum varies by the shape but would be in a range from $9-$35 per foot of aluminum.
Resistance-Aluminum has a high resistance to weathering and would not rust or corrode easily
Usability-Because of the type of material aluminum is very hard to work with.
Density/Durability-Aluminum is a very durable material that will not rust or corrode over time. Also, because it is alloyed with other metals it is a very durable metal.
Ease of access-Construction aluminum is not very easy to come unless obtained by a manufacturer.

3.4.2.6 Aluminum Folding Frame

The aluminum folding frame would be a frame made of aluminum bars jointed together to fold in an easy manner. The foldable pieces will allow the stage to be easily store in almost any area. However, the foldable frame would make it harder than a fixed frame to make portable because of all the moving pieces. It may be heavier once folded and harder to move unless carried by more students and staff.

Cost- The average cost of a linear foot of aluminum varies by the shape but would be in a range from $9-$35 per foot of aluminum.

Resistance - Aluminum has a high resistance to weathering and would not rust or corrode easily.
Usability - Because of the type of material aluminum is very hard to work with.
Density/Durability- Aluminum is a very durable material that will not rust or corrode over time. Also, because it is alloyed with other metals it is a very durable metal.
Ease of access - Construction aluminum is not very easy to come unless obtained by a manufacturer.

3.4.2.7 Steel Pipe Fixed Frame

The steel pipe fixed frame will offer significant durability and weight capacity; however, the cost and weight of a fixed steel pipe frame outweigh the positives. The frame of the stage would be very stable and last a long time in terms of durability, however welding would need to be done to the joints and connections for the sections at the stage. The weight of each section for the stage would be quite significant, making portability for the middle school students quite tough. Overall, the cost and lack of portability make the fixed steel pipe stage alternative efficient.

Cost The cost of steel pipe is $7.50-$10.00 per linear foot, making the construction of the stage quite expensive compared to other materials
Resistance The steel pipe would be strong against most weather, however it may be vulnerable to rusting without a cover
Usability Steel pipe would require one to use metal saws and welding equipment to construct a frame
Density/Durability The strength of a steel pipe frame would allow for the stage to last a sufficient amount of time with proper welding
Ease of access The steel piping can be purchased from most hardware stores, but may need to find to large manufacturer for a quality product

3.4.2.8 Steel Pipe Folding Frame

The folding steel pipe frame alternative would allow for simple storage and significant weight capacity. The stage design would be very similar to that of the fixed steel pipe frame, however hinges would be incorporated near joints and connections that would allow the stage to break down into sections for simple storage. The hinges would pose a pinching hazard to students as well.

Cost The cost of steel pipe is much higher than the cost of wood per foot.
Resistance The steel pipe would be strong against most weather, however it may be vulnerable to rusting without a cover
Usability Steel pipe would require one to use metal saws and welding equipment to construct a frame
Density/Durability The strength of a steel pipe frame would allow for the stage to last a sufficient amount of time with proper welding
Ease of access The steel piping can be purchased from most hardware stores, but may need to find to large manufacturer for a quality product

4 Decision Process

4.1 Introduction

The following section is dedicated to the decision-making process for choosing a portable stage design. This section will be assessing the usefulness and effectiveness of each of the alternative solutions from section 3. The decision-making process will be conducted using the Delphi process, which entails ranking the alternative solutions in categories that are based upon the client's criteria introduced in section 2. This method will provide a more definite, objectified decision with less personal bias.

4.2 Criteria

Criteria	Constraints	Weighted Ranking
Total Cost	Budget of $225	**8**
Portability	Must be light enough to be moved by staff and students	**5**
Weight Capacity	Must hold the weight of 5 to 10 students (500-1000 lbs.)	**7**
Durability and Longevity	Must be long lasting and require little to no maintenance.	**8**
Safety	Must not pose a safety hazard to students.	**10**

4.3 Alternative Solutions

The alternative solutions for design options from Section 3 are listed below. These alternative solutions will be judged through using the Delphi system, justifying an objectified ranking to each of the design options.

4.3.1 Tops

- Plywood Sheeting
- OSB Sheeting
- Plastic Sheeting

4.3.2 Frames

- Wood fixed frame
- Wood folding frame
- Aluminum fixed frame
- Aluminum folding frame
- Milk crates frame
- Fixed rack steel frame
- Steel pipe fixed frame
- Steel pipe folding frame

4.4 Decision Making Process

The decision process for the portable stage is going to be made utilizing a Delphi Matrix model. The Delphi model works by choosing a design that best fits the client's criterion that is defined in section 2. Within the Delphi chart, each of the client's criterion is rated on a scale of 1-10, with the higher number being more significant. Each alternative solution is then assigned a score on the scale of 1-50, representing how well each solution meets the client's criteria. For example, a cost rating of 50 means best cost, which would be the lowest cost, whereas a weight capacity rating of 50 would mean it could hold the most weight. All the numbers for each alternative solution is then summed together to produce a total score for each of the design solutions, the highest score representing the best design option.

		ALTERNATIVE SOLUTIONS					
	WEIGHT	Plywood		OSB Sheeting		Plastic Sheeting	
CRITERIA	0-10	TOP		TOP		TOP	
COST	8	35	280	45	360	10	80
PORTABILITY	5	25	125	30	150	40	200
WEIGHT CAPACITY	7	45	315	25	175	30	210
DURABILITY	8	40	320	15	120	25	200
SAFETY	10	45	450	25	250	30	300
		1490		1055		990	

Figure 4-1: Delphi Chart for the decision of TOP, higher score being the better alternative solution.

CRITERIA	WEIGHT 0-10	ALTERNATIVE SOLUTIONS							
		WOOD FIXED FRAME	WOOD FOLDING FRAME	ALUMINUM FIXED FRAME	ALUMINUM FOLDING FRAME	MILK CRATE FRAME	RACK STEEL FRAME	STEEL PIPE FIXED FRAME	STEEL PIPE FOLDING FRAME
COST	8	40 / 320	25 / 200	10 / 80	5 / 40	40 / 320	7 / 56	6 / 48	5 / 40
PORTABILITY	5	30 / 150	35 / 175	40 / 200	42 / 210	45 / 225	12 / 60	10 / 50	12 / 60
WEIGHT CAPACITY	7	35 / 245	25 / 175	40 / 280	35 / 245	25 / 175	40 / 280	45 / 315	43 / 301
DURABILITY	8	35 / 280	30 / 240	45 / 360	40 / 320	15 / 120	40 / 320	45 / 360	43 / 344
SAFETY	10	45 / 450	25 / 250	40 / 400	25 / 250	25 / 250	20 / 200	22 / 220	20 / 200
		1445	1040	1320	1065	1090	916	993	945

Figure 2-2: Delphi Chart for the decision of FRAME, higher score being better.

4.5 Final Decision

The final decision was decided using the Delphi Matrix chart, concluding that a fixed wooden frame with a plywood top would be the best option when constructing the portable stage according to the Delphi matrix chart in table 4. A fixed wooden frame proves to be the most cost effective and is also much lighter, safer, and more durable than the other alternative solutions in terms of design options. The plywood is proved to have the best ratios of durability, weight, and price. Using the Delphi Matrix made it much simpler to make the decision for construction because it clearly showed the best design option and definite winner when comparing the alternative solutions.

5 Design Specification

5.1 Introduction

Section 5 of the document provides a thorough description of the final solution for the design of the stage. This section of the document also includes an account of the costs for the stage, comprising of the team design hours, implementation costs for construction, and maintenance costs. Lastly, this section will cover the instructions for implementation and use of the stage along with final results for the stage.

5.2 Description of Solution

The stage that we decided to produce was constructed out of Douglas Fir 2”x 8” boards, and ¾” construction grade subfloor plywood sheeting. The frame of the stage was made of the 2”x 8” boards held together with Torx type screws. The frame was built in four sections that each measure 4’x8’. The sections will each be topped with a sheet of plywood that measures 4’x8’. The plywood will be fastened to the frame with Torx type screws. The stage is made of four of these units, making it a total of 8’x16’ and 8” tall. The purpose of having built the stage in four standalone sections is that it makes the stage much easier to move as well as allowing the users to reorganize the stage into different configurations. The stage is covered in high grade exterior paint, to make it more uniform and so that it will not distract from the performers.

Figure 5- 1: Labeled photo of the portable stage final design.

Figure 5- 2: Final photo of the stage within a classroom at Zane

5.3 Costs

This section lays out the total costs of the projects. It will cover the design costs as well as the time spent to formulate the design and construct this project.

5.3.1 Design Costs

The design costs represent the amount of time The Train Conductors spent (in hours) within each section of the design document and project.

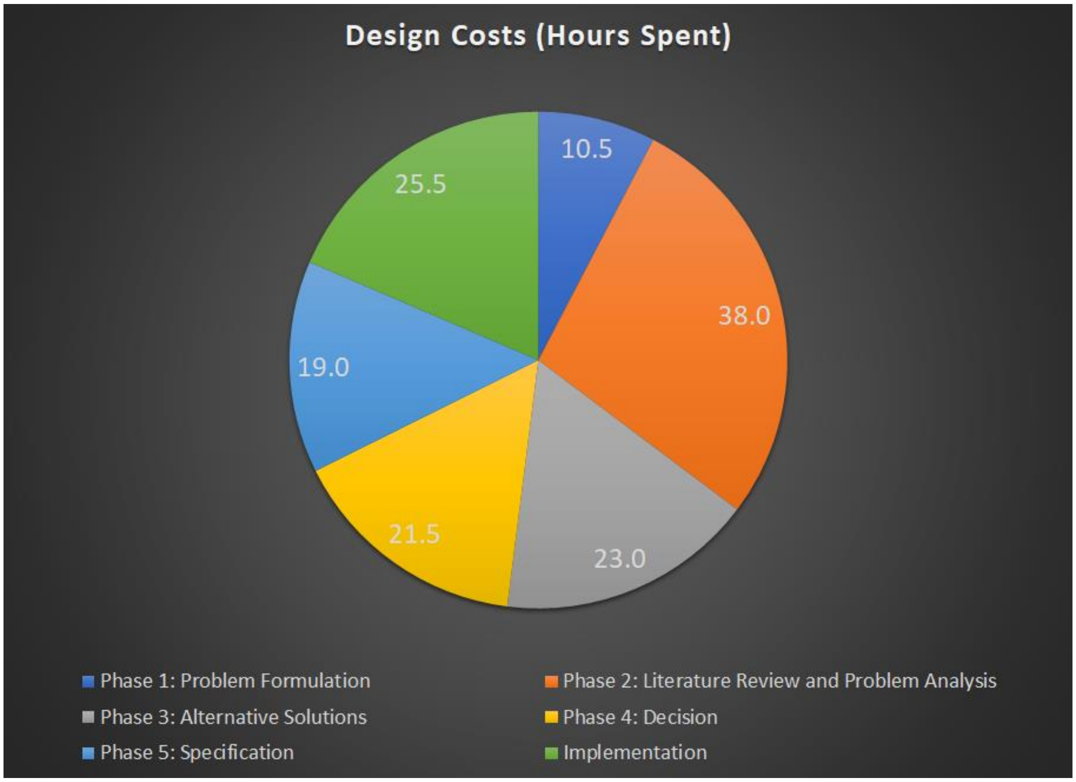

Table 5-15.3.1: Design cost in hours representing the total time spent on the project.

5.3.2 Implementation Costs

The costs of materials are shown in the table below:

*Donation from Pierson Building Company
**Donation from Jim Mclaughlin Landscaping

Material	Quantity	Retail Cost ($)	Cost w/ Donations ($)
2"x8" Douglas Fir Boards	12	123.84	110.94 (1 donated*)
3/4" Plywood sheets (4'x8')	4	167.96	41.99 (3 donated*)
Furniture Dollies	2	23.84	23.84
Torx Screws	1	16.90	donated**
Fortified Latex floor paint (1 gallon)	1	31.99	31.99
Paint Tray	1	2.59	2.59
CA Assessment Fees	1	2.79	2.79
Taxes	1	27.84	15.68
TOTAL COST		$397.75	$229.82

Table 5-2: Implementation and construction total cost to build portable stage.

5.3.3 Maintenance Costs

The cost to maintain the stage is very minimal, as it only requires the user to touch up the paint if it should get chipped or scratched aesthetically. Many issues that could occur with the stage would most likely be simply fixable with sanding, new screws, or wood glue. Maintenance costs should be below 10$ a year.

5.4 Instructions for Implementation and Use of Model

Before using the stage, the user must first set the stage up. To set the stage up, the four pieces must first be unstacked from the corner of the room and put together on the floor. The easiest way to do this is to use the hand-holds that are at either end of the stage pieces on the 4' sides. The stage when put together should resemble the diagram below.

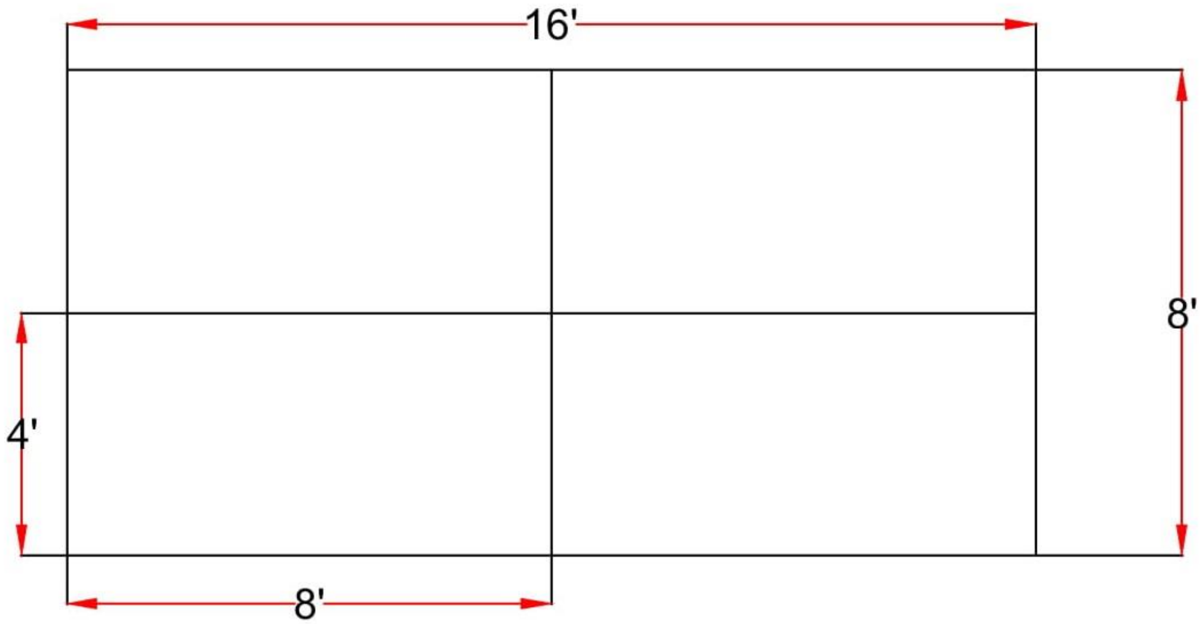

Figure 5-3: AutoCAD drawing showing the dimensions and how the stage should be put together.

There are no locking mechanisms on the stage pieces to hold the separate pieces together, so there is no need to be very specific where each piece goes if they are all placed snug to each other. In the case where the user must move the stage over a larger distance they will use the furniture dollies. To use the furniture dollies a user must put it as close to the center as possible under one of the 8’ sides of a stage section. Then they flip the stage with this 8’ section face down on the dolly. If they need to move more than one section they can repeat this with the rest of the sections.

5.5 Results

The implementation of the stage at Zane Middle School allows students to become more engaged in performance art activities.

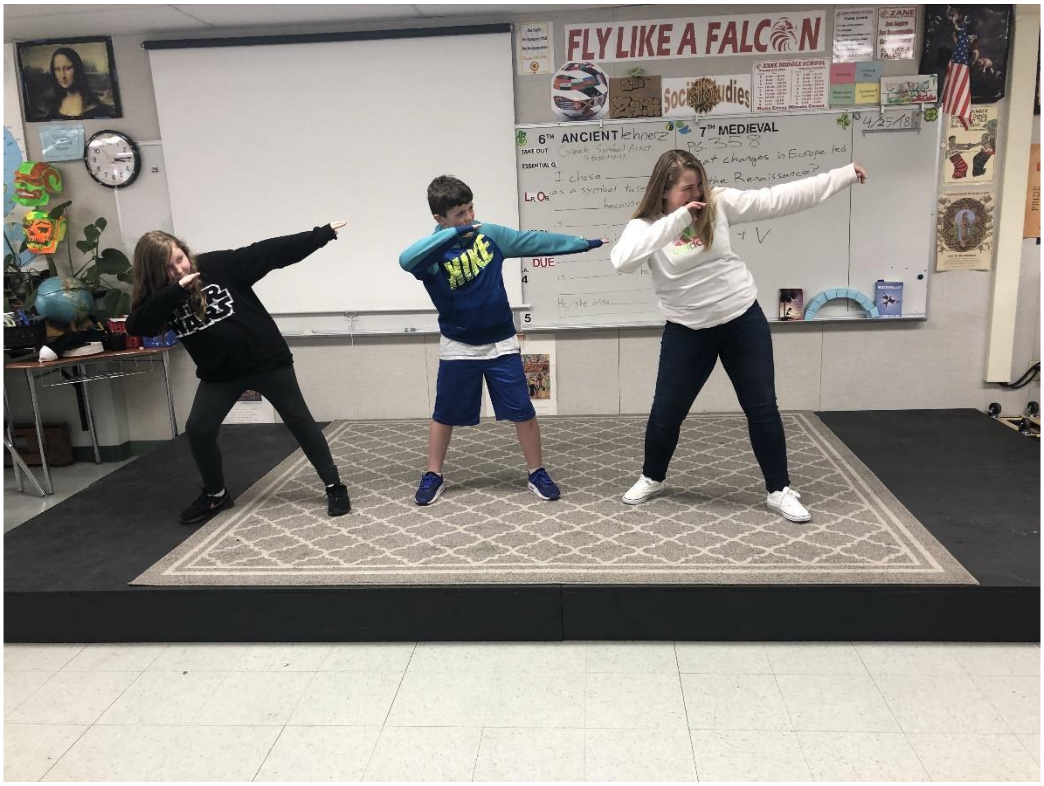

Figure 5-4: Students at Zane Middle School acting during class on new stage.

Figure 5-5: Client representative, Zach Lehner, testing out the new portable stage.

6 Appendices

6.1 References

- California Code of Regulations, Title 8, Section 3231. Stairways. (https://www.dir.ca.gov/title8/3231.html)
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6.2 Brainstorming Ideas

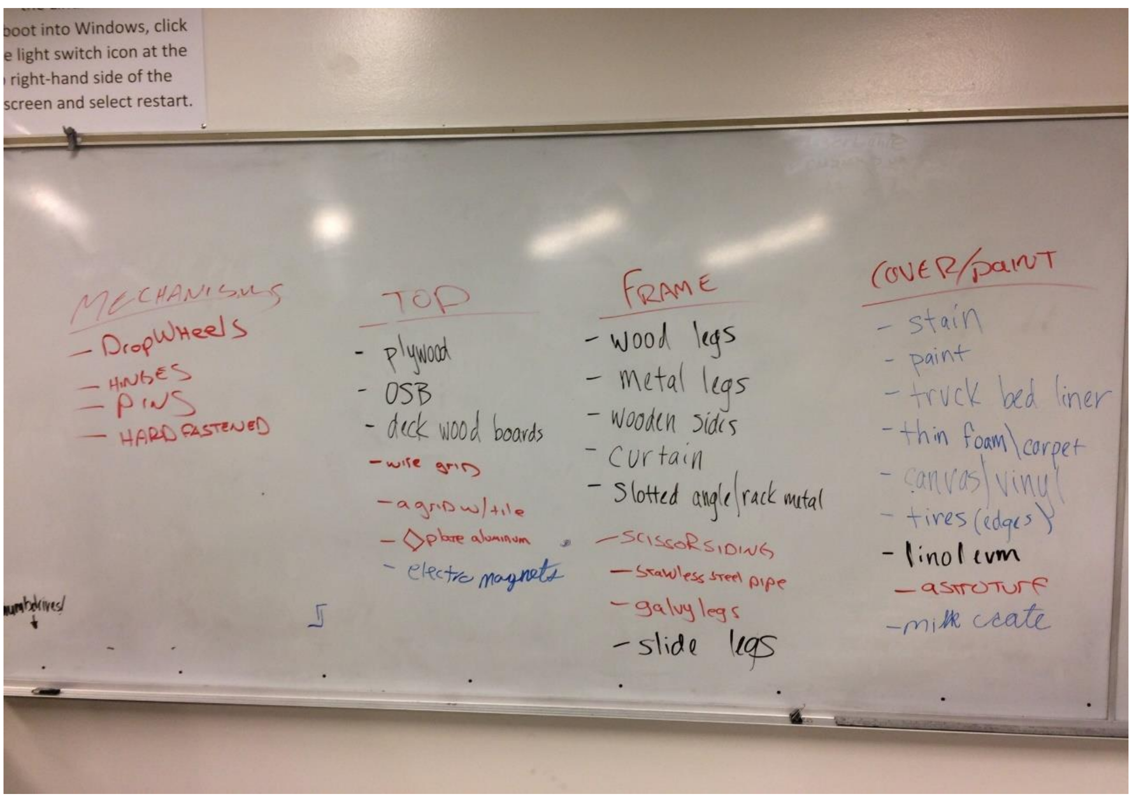

Figure 6-1: The brainstorming done prior to designing the portable stage