Upcycled Bike Trailer

The Coffin

Ben Adams
Michael DeMaranville
Cory Hustead
Lukas Kennedy

Table of Contents

1 Problem Formulation 1
1.1 Introduction 1
1.2 Objective Statement 1
1.3 Black Box Model 1

2 Problem Analysis 2
2.1 Introduction 2
2.2 Specifications and Considerations 2
2.3 Criteria 2

3 Literature Review 3
3.1 Frame Material 3
3.2 Trailer Frame Design 5
3.3 Hitch Design 8
3.4 Brakes 11
3.5 Suspension 12
3.6 Bike Electrical 14
3.7 Wheels 15
3.8 Cover From Elements 17
3.9 Reflectors 18

4 Alternative Solutions 19
4.1 Introduction 19
4.2 Brainstorming 20
4.3 Alternative Solutions 20

5 Decision Making Process 27
5.1 Introduction 27
5.2 Solutions 28
5.3 Decision Process 29
5.4 Delphi Matrix 29
5.5 Final Decision 29
5.6 Specifications of Solution 29

6 References 36

Table of Figures

Figure 1-1 Black Box Model 1
Figure 3-1 A Bamboo Trailer (Huffington Post 2012) 4
Figure 3-2 A PVC Trailer (Instructables 2008). 5
Figure 3-3 Single wheel style bike trailer (B.O.B. Gear 2013). 6
Figure 3-4 A Platform style bike trailer made from bamboo (Carry Freedom 2013). 6
Figure 3-5 A Platform style trailer that has a deck that is below the axle centerline for lower center of gravity and increased stability (Cycle Tote 2013). 7
Figure 3-6 An angle style frame trailer (Burley). 8
Figure 3-7 A one wheel style hitch (B.O.B Gear 2013). 9
Figure 3-8 Handmade pinned hitch (Gene and Sue2013). 10

Figure 3-9 Ball and socket elastomer style hitch (Etrailer 2013)..... 10
Figure 3-10 An elastomer style hitch that clamps to the rear triangle of the towing bike (Kellogg 2006)..... 11
Figure 3-11 A cantilevered rim brake (Bike Rumor 2012)..... 12
Figure 3-12 A cantilevered rim brake (Park Tool 2013)..... 12
Figure 3-13 A coil suspension in a drag link system (JP Magazine 2013)..... 13
Figure 3-14 A leaf spring suspension (Etrailer 2013)..... 14
Figure 3-15 A bottle or side wall dynamo (Chester Cycling 2013)..... 15
Figure 3-16 A hub dynamo(Think Biologic 2012)..... 15
Figure 3-17 A pneumatic tire cutaway (Bicycle Touring 2011)..... 16
Figure 3-18 A solid tire in an industrial application (CE Attachments 2011).....16
Figure 4-1: Plastic storage tote used for cargo management (I Bike Daily 2012)..... 20
Figure 4-2: A box made from formed metal, pop riveted together(Frontier Nerds). 21
Figure 4-3: Removable bicycle style wheels on a bike trailer (Speed Pedal 2010)..... 22
Figure 4-4: An automobile utility trailer stored on hind end casters (Red Trailers 2013)..... 23
Figure 4-5 A bamboo trailer (Used HQ 2008)..... 24
Figure 4-7: Trailer with pneumatic bicycle wheels (Jose Crappus 2012)..... 25
Figure 4-8: A Conduit frame with wheel chair wheels (Bike Shop Hub 2010)..... 26
Figure 4-9: Figure of integrated cover, covering a load of goods (DeMaranville 2013) 26
Figure 5-1: The Up-Cycled Coffin, transporting donated goods to an afterlife since 2013 (Kennedy 2013)..... 30
Figure 5-2: Our wheelchair wheels and stub axles (DeMaranville 2013)..... 30
Figure 5-3: ¾" Electrical conduit frame (Adams 2013)..... 31
Figure 5-4: Tub-o-Metal formed from a highway sign (Adams 2013)..... 31
Figure 5-5:
A picture of our low hitch design (Kennedy 2013)..... 32
Figure 5-6: Design process, totaling 387 hours, expressed as hours invested by group members and divided into phases..... 33
Figure 5-7: Downhill braking test with 155 lb cargo (Kennedy 2013)..... 34
Figure 5-8: Uphill towing test with 155 lb cargo (Kennedy 2013)..... 34
Figure 5-9: View of the trailer from a driver's vantage point, approaching the trailer from behind (Kennedy 2013)..... 35
Figure 5-10: View of the trailer from a driver's vantage point, approaching the trailer from the side (Kennedy 2013)..... 35

Table of Tables

Table 2-1Criteria..... 2
Table 5-1 Delphi Matrix..... 29
Table 5-2: Capital costs associated with the final design solution..... 33
Table 5-3: Recurring costs associated with the final design solution..... 33

1 PROBLEM FORMULATION

1.1 INTRODUCTION

An objective statement and a black box describe the goal of our project as depicted in Figure 1.1. The black box model describes the state of the world given the current problem, and the target state with the implementation of our solution.
The client for this project is the Scrounger's Center for Reusable Art Parts, known as SCRAP.

1.2 OBJECTIVE STATEMENT

The object of this project is to construct a bicycle trailer utilizing recovered materials to demonstrate the creative reuse of materials deemed as waste, recyclable or otherwise.

1.3 BLACK BOX MODEL

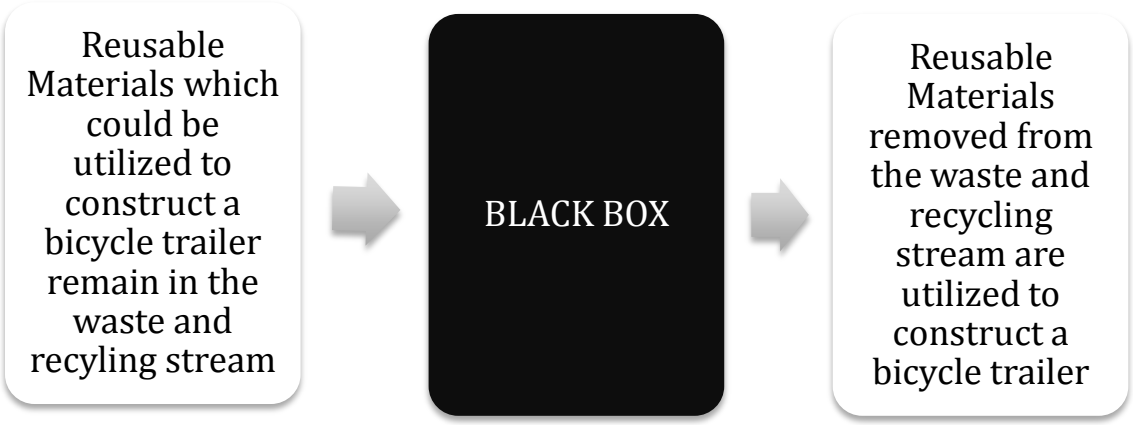

Figure 1-1 Black Box Model

2 PROBLEM ANALYSIS

2.1 INTRODUCTION

The problem analysis reviews our projects' objectives in greater detail. This section will highlight the general specifications and considerations that our client Humboldt SCRAP has set out for us. The criteria with its coinciding constraints will display additional details. Production volume for the bike trailer is one unit.

2.2 SPECIFICATIONS AND CONSIDERATIONS

The Specifications and considerations are requirements that the client has envisioned for the project to be successful. The specifications and considerations are as followed below.

2.2.1 SPECIFICATIONS

The specifications that the bike trailer must meet are:

- Must be able to fit through a California standard sized door
- Multiple types of bikes must have the ability to tow the trailer
- The SCRAP logo must be visible
- The trailer needs to safely tow up to 100-pounds of cargo

2.2.2 CONSIDERATIONS

The considerations we have made for the trailer are:

- The wet weather conditions in Arcata
- Should be easily visible on the road
- Cleaning the trailer shouldn't be a difficult task.
- Minimal preventative maintenance
- Design the trailer for longevity
- Simple and functional ergonomics

2.3 CRITERIA

The criteria and constraints that were set out by the client and Team Trailer Park Boys, are shown below

Table 2-1Criteria

Criteria	Constraints
Aesthetics	More than 4 colors
Cost	Less than or equal to $300
Usability	Compatible with 3 or more bike types
Durability	Minimum life span of 3 years with maintenance
Maintenance	Less than 1hr/15days of use
Safety	Must be visible at night, no sharp edges

Weight	No more than 75lbs
Size	Must fit through an ADA compliant doorway
Environmental Justice	Greater than 35% recovered materials by weight

3 LITERATURE REVIEW

3.1 FRAME MATERIAL

Determining the materials to be used for the construction of a frame is an important decision making process. Towing capacity, weather proofing, and durability all need to be accounted for in order to have a reliable frame that is capable of hauling cargo in a safe and efficient manner. In this section properties of various materials will be discussed

3.1.1 REDWOOD

Redwood can be used to make fences, decks, exterior sidings, interior panels, furniture or other projects that requires a wood that is resistant to rotting and dimensional change. Compared to other lumber, redwood has the lowest volumetric shrinkage, which means it can be exposed to more moisture than other woods before it reaches the same dimensional change. Due to this unique property, low volumetric shrinkage, cupping, warping, splitting and open joints are less likely to occur keeping the wood flat and straight. (Redwood 2012). The price of the lumber varies depending on where it is bought and also on what kind of cut the lumber comes from.

3.1.2 BAMBOO

Bamboo is a useful resource that has many applications such as textile production, construction projects, and other projects that requires a profoundly strong material. The environment in which bamboo is grown will affect its strength. Unlike hardwoods that have inconsistencies such as knots and rays, bamboo has far fewer inconsistencies and can therefore handle more stress. Bamboo also has a high silica content that acts as a natural pesticide and prevents insect infestation. Bamboo has a very fast growing cycle; some species can grow four feet in twenty-four hours and can restore its entire mass in six months. Bamboo is a self-sustainable species, they can be incessantly re harvested for three years without causing damage to the surrounding environment (Cali Bamboo 2011). There are numerous ways to incorporate bamboo into a design because of the material properties. Figure 3-1 displays a homemade bamboo trailer constructed by Gabor Lukacs, he claims that it can haul cargo around four hundred pounds (Leader 2012). The trailer was constructed without welding and few tools, making it a project anyone can be a part of.

Figure 3-1 A Bamboo Trailer (Huffington Post 2012).

3.1.3 ALUMINUM

Most bike trailers available currently are made from aluminum alloys. There are numerous products that use aluminum such as bicycles, car parts, screen doors, cans, amongst many others. Aluminum's light weight properties make it manageable material to work with. Aluminum's density is one third that of steel making it a more popular material to use for light weight applications. Aluminum is also susceptible to oxidation, which is comparable to rust on steel. When the surface of aluminum is exposed to oxygen, a thin film of aluminum oxide is formed, sealing the rest of the material from further oxidation (Hydro 2012). Aluminum is an ideal material to use in an environment with high levels of moisture. The strength of aluminum alloys vary depending on the types and quantities of other materials in the alloy. Aluminum bike trailers on the market typically are for towing children and the capacity to about ninety pounds. Whereas compared to trailers that come from Black Oak Fabrications, a company based out of Portland, Oregon, they use 6061* structural grade aluminum. They have different models that can haul loads up to two-hundred pounds (Black Oak Fabrications 2013). Aluminum alloys can be more expensive but in the long run can be a more stable option.

3.1.4 STEEL

Steel is widely used in the world because of the stability it brings for any function it is used for. It is an alloyed metal that has a broad spectrum of different metal combinations that can be utilized in an even broader realm of construction. "There are over 3,500 different grades of steel with many different physical, chemical, and environmental properties (World 2013)." Steel's heavy duty characteristics are quite useful for macro and micro designs that require stability for the base. Some are more appropriate for certain environments but overall is a consistent material.

3.1.5 PVC PIPE

Polyvinyl chloride (PVC) is a widely used plastic, capable of numerous applications. PVC pipe, generally used for water conveyance, will be specifically discussed. PVC is resistant to oxidation at the atomic level due to the arrangement of the chlorine and carbon atoms (PVC 2013). PVC pipes are usually buried, which eliminates direct exposure to ultraviolet radiation, the molecular bonds of the plastic begins an excitation state causing the pipe to lose elasticity and impact strength (American Water Works Association 2002). If the pipe is exposed to UV rays, paint or tape on the pipe would help prolong the lifespan of the pipe. Precautions should be made when high impacts are involved. Figure 3-2 shows that it is possible to build a bicycle trailer from PVC pipe. The load capacity will determine the size of the piping to use.

Figure 3-2 A PVC Trailer (Instructables 2008).

3.2 TRAILER FRAME DESIGN

The frame is the load bearing and transferring structure of the trailer. Frame design depends on the amount of weight that is to be carried with the trailer, the type of cargo to be carried, the hitch to be used and the number of wheels to be used. A trailer intended for moving heavy loads, will be most effective with the load placed as low as possible to allow for maximum stability. Bicycle trailers can have one, two or more wheels; one and two wheeled designs will be discussed below.

3.2.1 ONE WHEEL TRAILERS

One wheeled trailers are great for small stable loads, typically of approximately 100 pounds or less and are built with an enveloping style frame (Ayre 1986). A typical one wheel trailer is depicted in Figure 3-3. One wheeled trailers do require a specific hitch that does not allow the trailer to tip from side to side.

Figure 3-3 Single wheel style bike trailer (B.O.B. Gear 2013).

3.2.2 TWO WHEEL TRAILERS

Two wheeled trailers are most common, and when loaded properly, are most stable. Under proper loading conditions, two wheel trailers are capable of handling up to 300 pounds (Ayre, 1986). This is quite possibly more than anyone would enjoy towing with a bicycle. A two-wheel trailer does not require a restrictive hitch because the wheels positioned opposite each other, provide stability.

3.2.3 PLATFORM FRAME

A platform frame trailer is a design that places the carried load above the axle. The design can range from simple to complex and can be made of various materials. An advantage to a platform frame design is that large or bulky items can be carried such as barrels, lumber, Christmas trees or pallets; Figure 3-4 shows a typical platform trailer design. Disadvantages to the platform design include the raised center of gravity, which can lead to unstable towing conditions especially on rough terrain, at higher speeds, or while maneuvering around sharp corners.

Figure 3-4 A Platform style bike trailer made from bamboo (Carry Freedom 2013).

One way of avoiding the instability problem is to lower the center of gravity by lowering the load within the frame and between the wheels; this however may limit some carrying capacity Figure 3-5 shows a depressed loading area in a platform trailer. Depending on the hitch design chosen, a platform frame trailer can also be used as a hand cart when not attached to a bicycle.

Figure 3-5 A Platform style trailer that has a deck that is below the axle centerline for lower center of gravity and increased stability (Cycle Tote 2013).

3.2.4 ENVELOPING FRAME

An enveloping frame bicycle trailer is similar to a platform trailer except it has framed walls surrounding the platform. This is a very sturdy design, however it uses more frame material than the typical platform design. This design is very adaptable and allows for both high and low, or some creative design between, hitching options to the bicycle. When coupled with a high mount hitch this design resembles many garden style carts, and is very useful as a hand cart when not attached to a bicycle. Figure 3-5 also shows an enveloping style bicycle trailer.

3.2.5 ANGLED FRAME

The angled frame design looks and functions very similarly to a hand truck. The frame is configured in an L shape and is very useful for transporting uniform stackable objects, such as banker's boxes or storage totes. This style of frame design requires a high hitch point, typically somewhere above the rear wheel of the towing bicycle. Figure 3-6 shows an angled frame bicycle trailer. Because of the higher hitch point, this style of trailer is very easy to use as a hand cart while not attached to a bicycle.

Figure 3-6 An angle style frame trailer (Burley 2013).

3.3 HITCH DESIGN

A hitch is the device used to couple the bicycle to the trailer it is towing. It is typically comprised of two parts. One part is permanently affixed to the towing bicycle, and the other to the trailer. The hitch is the most complicated part of the trailer design, subject to a number of variables. There are two dominant styles of hitching a trailer to a bicycle, the hitch can be high, typically above the rear wheel, or under the seat; or the hitch can be low, mounting somewhere in the vicinity of the towing bicycle's rear axle.

3.3.1 ONE WHEEL HITCH

One wheel hitches are very specific, they are must allow for the trailer to move left to right (while turning), and up and down (while encountering slope changes), but not tilt from side to side. This is necessary because with only one point of contact with the ground, the trailer would tip over. High or low mount hitches can be used with one wheel trailers. Figure 3-7 shows a one wheel hitch.

Figure 3-7 A one wheel style hitch (B.O.B Gear2013).

3.3.2 TWO WHEEL HITCH

Hitches for two wheeled trailers must allow for articulation in multiple directions because both wheels must remain on ground at all times. Swaying left and right due to turning, up and down movements from slope changes and tilting left and right from bike leaning must all be allowed for by the hitch. High or low mount hitches can be used with two wheel trailers. Figure 3-5 best represents this.

3.3.3 HIGH MOUNT

A high mount hitch typically mounts somewhere above the rear wheel and below the seat. A disadvantage of this style of hitch is that the towing bicycle must remain upright while not in use, such as with a kickstand. If the towing bicycle tips over, the loaded trailer will most likely tip over as well. Figure 3-6 shows a high mount hitch.

3.3.4 LOW MOUNT

Low mount hitches typically mount around the rear axle or rear most portion of the rear triangle and provide hitch articulation within close proximity to the mounting point. An arm extending to the trailer projects sideways from the bicycle before turning aft toward the trailer to avoid interfering with the rear tire. An example this type of arm is shown in Figure 3-4. Rear most hitches mount to the bicycle frame in similar locations, but provide hitch articulation behind the rear tire. This design is to be utilized for trailering low tongue weight loads only for the following reason. The distance of the articulation point from the rear axle produces a moment about the rear axle of the bicycle. This moment can reduce or eliminate weight distribution on the front tire of the bicycle which can possibly inhibit the steering capabilities of the bicycle placing the user in great harm.

3.3.5 PINNED

A pinned hitch is affixed firmly to the frame of the towing bicycle. There is little play or “slop” in this design and it allows for smooth range of motion in all three axes while maintaining the ability to pull the load of the trailer. To eliminate the play, there are pivot pins oriented in three axes that only allow for movement concentric with that particular pin. The pins are long enough to resist moments orthogonal to

their orientation as well. A universal joint is an example of this style of hitch, and can be seen in Figure 3-8. A hitch that will accomplish the same task with only one moving part is one that functions very similarly to an automobile trailer hitch connection, it is known as a ball and socket type joint, and is pictured in Figure 3-9.

Figure 3-8 Handmade pinned hitch (Gene and Sue 2013).

Figure 3-9 Ball and socket elastomer style hitch (Etrailer 2013).

3.3.6 SPRING OR ELASTOMER

A spring or elastomer hitch is similar to the pinned hitch in respect to the axes of movement; however one or more of the axes of movement rely on the elastic properties of the material. For example the hitch may pivot about a pin left and right while turning, but bend up and down to account for slope changes, and twist for off camber situations. An example of this hitch is depicted in Figure 3-10.

Figure 3-10 An elastomer style hitch that clamps to the rear triangle of the towing bike (Kellogg 2006).

3.4 BRAKES

Bicycle brakes have a large variety of designs which can be narrowed down to the two primary groups of rim brakes and disk brakes. Rim brakes are a more traditional technology, and disk brakes are a more recent innovation.

3.4.1 RIM BRAKES

Rim brakes are the most common style of brakes found on bicycles. The components include a caliper, a wheel rim and brake pads. There are various designs ranging from single to dual pivot point calipers, cantilevered brakes, cam brakes, and even hydraulically actuated. Their basic function remains the same, which is applying force to a set of brake pads which are compressed against the wheel rim to provide resistance to motion, eventually stopping the bike. Rim brakes have the advantages of being inexpensive, requiring minimal maintenance and possessing relatively good power to weight performance. Due to the fact that bicycle rims are commonly very close to the ground, they are particularly susceptible to contamination and debris. This material can accumulate on the brake pad assembly, seriously degrading the performance and the stopping surfaces. Rim brakes are also not intended for heavy braking applications, as the heat generated through friction braking can heat the inner tube significantly enough to the a point of a possible blow out.

Figure 3-11 A cantilevered rim brake (Bike Rumor 2012).

3.4.2 DISC BRAKES

Disc brakes are similar in concept to rim brakes; the primary difference being, disc brakes utilize a dedicated disc for braking as opposed to the rim used by rim brakes. This dedicated disc is commonly mounted to the wheel hub which is farther from the ground and sources of contamination; this, coupled with the benefit of higher tolerances between the pads and disc result in an assembly less susceptible to debris. The disc is dedicated to braking which permits the use of harder, stronger steel, which in turn permits higher loads without the adverse effects of heating the rim. The complex components of disc brakes, particularly when the caliper is hydraulic, increase the cost, weight and maintenance of the system.

Figure 3-12 A cantilevered rim brake (Park Tool 2013).

3.5 SUSPENSION

Suspension, for the purpose of a bike trailer, provides a means to support a frame in such a manner as to facilitate vertical movement.

3.5.1 DRAG LINK

Drag link suspension is comprised of two control arms (links), which are situated parallel with the longitudinal axis of the vehicle. One end of the link is attached to the frame via a pin joint, and the other affixed to the axle. The purpose of the drag link is to facilitate suspension travel in the vertical direction. The resistance to movement is provided through a variety of means including but not limited to coil springs, torsion bars, and pneumatic bags.

3.5.2 LEAF SPRING

Leaf spring suspension is extremely common in automotive applications due to their simplicity and strength. One or more "leafs", are situated atop one another and held in place via retainers. One end of the assembly is fixed via a pin joint, permitting vertical travel, and other through a shackle kit. Leaf springs are similar in nature to drag links.

3.5.3 COIL

Coil suspension utilizes a coil spring to support the weight of the vehicle and absorb impact. The manner in which coil springs are applied varies with the arrangement of the controls arms. Coil springs can commonly be seen in A-arm suspensions. Figure 3-13 shows a coil spring in a drag link suspension.

Figure 3-13 A coil suspension in a drag link system (JP Magazine 2013).

3.5.4 PNEUMATIC

Pneumatic suspension makes use of airbags to resist compression via internal pressure. The net result is identical to coil springs, and pneumatic bladders are often used to replace coils with the added benefit of adjustability.

Figure 3-14 A leaf spring suspension (Etrailer 2013).

3.6 BIKE ELECTRICAL

For purpose of this discussion, bike electrical will describe potential means of generating and translating electrical current to light.

3.6.1 LIGHTING

3.6.1.1 LIGHT EMITTING DIODES

Light emitting diodes (LEDs) are currently leading in light technology due to their high efficiency and high output. Being significantly brighter and smaller than incandescent light bulbs, their application has an exceptionally large scope. LEDs can function over a wide range of voltages. The cost of LEDs is still higher than comparable incandescent bulbs, but the LED's life span is generally longer, and is considered more durable. (Cangeloso, 2012)

3.6.1.2 INCANDESCENT BULBS

Incandescent light bulbs are a traditional technology. Simple and inexpensive they provide a source of light by heating a tungsten filament to temperatures near 4000˚F(How Stuff Works). These high temperatures give off a significant amount of heat, which seriously degrades the efficiency of an incandescent bulb. A vacuum, to inhibit combustion, must also surround the filament; the glass "bulb" supplies this.

3.6.1.3 *ELECTRICAL GENERATION*

Electrical generation on a bicycle is commonly accomplished through the use of a DC generator known as a "dynamo", spun via the wheel by a two general methods.

3.6.1.4 BOTTLE DYNAMO

Bottle Dynamos are generators that engage with the bicycle wheel. They have a small contact roller which is driven by friction against the rubber tire. The ratio in size between the roller and tire translate the tire RPM to a significantly higher armature RPM, which is needed for this generator to function. Common dynamo outputs are three watts at six volts. Bottle dynamos have the option of being disengaged when not in use, thus eliminating unnecessary drag. Simplistic in nature, bottle dynamos are an inexpensive alternative to hub dynamos.

Figure 3-15 A bottle or side wall dynamo (Chester Cycling 2013).

3.6.2 ELECTRICAL GENERATION

3.6.2.1 *HUB DYNAMO*

A hub dynamo is a generator that is integrated into a bicycle hub. The result is a generator that spins at the same rpm as the wheel, and can never be disengaged. Due to this lower RPM, hub dynamos typically operate at a higher efficiency than bottle dynamos but are far more expensive. Common outputs are three watts at six volts.

Figure 3-16 A hub dynamo (Think Biologic 2012).

3.7 WHEELS

Pneumatic and solid wheels will be the subject of this section.

3.7.1 PNEUMATIC

Pneumatic wheels consist of a rim, tire, and commonly an inner tube. Their application scope is broad, with a plethora of variations, each with their own advantages. The inner tube, or just the tire in tubeless tires, is pressurized with air, giving the tire a semi-rigid form. Depending on tire type and pressure, the semi-rigid form has dampening qualities that can absorb energy in the form of impacts. Pneumatic wheels are very common, can be quite inexpensive, lightweight, and adjustable for different applications.

Figure 3-17 A pneumatic tire cutaway (Bicycle Touring 2011).

3.7.1.1 *ROAD TIRES*

Road tires in bicycle applications are generally narrower, semi smooth or smooth, and operated with high pressures. They're purpose is to maximize efficiency by reducing energy lost through drag and tire deformation. This reduces their ability to absorb impact, and results in impact energy being transferred to the bicycle frame.

3.7.1.2 *OFF ROAD TIRES*

Off road tires are wider than road tires, commonly have a more aggressive tread, and have a greater surface area in contact with the ground at any given time. This allows the tire to run at lower pressures, while still supporting the same weight. The increased surface area increases traction, while the decreased pressure better absorbs impacts. The load capacity of off-road tires is potentially higher than road tires due to larger weight distribution.

3.7.2 SOLID WHEELS

Solid wheels share similar components to pneumatic wheels, such as, a tire and rim. The primary difference lies in the tire, which is comprised of a solid material as opposed to hollow structure of a pneumatic tire. Commonly seen in industrial applications, solid wheels have a high weight capacity, and often the rims themselves are solid. The rigid material used for the tire is meant to resist deformation, and in turn transfers energy more so than absorbing it. Thus their application is traditionally limited to slow moving vehicles.

Figure 3-18 A solid tire in an industrial application (CE Attachments 2011).

3.8 COVER FROM ELEMENTS

Designing a cover for a trailer can be a challenging and crucial element to the construction of a useable trailer. Factors such as weight, ability to withstand elements of nature, and function must all be considered.

3.8.1 FRAME

Designing the frame of the cover is the first step and it may have many different shapes and functions. It can be a flat cover that lies on materials in the trailer or it can be raised like a shell; the cover may also be removable or fixed. Each type of frame has benefits and limitations.

3.8.1.1 FLAT

A flat cover is light, simple, and ergonomic. These qualities make it very useful in everyday use. It is comprised of a simple cover material that is placed on top of cargo needing protection against the elements. Unfortunately the simple nature of this style of cover also limits its ability to withstand significant stresses in the form of wind and heavy rainfall. Its application would be restricted to moderate weather.

3.8.1.2 HARD SHELL

A hard shell type cover provides excellent protection against heavier weather but increases complexity and restricts the accessibility. Building this style of a cover in a manner that allows accessibility from multiple sides could be a complicated process. The complex design would add additional weight to the trailer.

3.8.1.3 SKELETON

A skeleton shell would use a semi-rigid cover which would provide a large reduction in weight. The skeleton structure would use braces that run on tracks allowing the entire assembly to collapse neatly at one end of the trailer resulting in a very accessible cargo tub.

3.8.1.4 ROLL-UP

A roll up cover would be very simplistic in nature and could make a very accessible trailer from all sides Building a bay to hold the rolled up tarp could potentially add excess weight as well as reduce potential cargo volume.

3.8.2 COVER MATERIALS

A cover is defined as a thing that lies on, over, or around something in order to protect or conceal. The cover may be made out of many different reusable materials including those discarded in everyday households. A cover can protect goods from the elements, however whenever adding material to a trailer it could add weight which can be an important factor in your criteria.

3.8.3 PLASTIC

3.8.3.1 AMINO

Amino plastics are strong but still breakable. This type of plastic can resist stains and scratches, and will not burn or soften when exposed to fire. This plastic is thermally resistant which could be a criterion if you're making a trailer for goods that are temperature dependent.

3.8.3.2 POLYETHYLENE

The common plastic grocery bag is comprised of polyethylene plastic which can be made into a utilitarian cover. Multiple polyethylene bags can be ironed on top of each other to gain a thicker and sturdier material to better resist the elements. However this material can rip and tear easily.

3.8.3.3 POLYESTERS

Polyester is a strong form of plastic and are resistant to weather. They also can be ridged or flexible.

3.8.3.4 VINYL'S

Vinyl has an excellent ability to resist water and chemical exposure. However, vinyl is vulnerable to extended amounts of UV radiation and will deteriorate over time.

3.8.3.5 TARP

Another useful cover that can be used is a blue tarp. Tarps that have flown out of vehicles can be found on the side of freeways or in common home improvement stores. A tarp can withstand elements from nature but can tear from human faults and with age tarps tend to weaken and fray.

3.8.3.6 CANVAS

Canvas is a very sturdy material that can last a very long time, although canvas is not a waterproof material by itself. The canvas cover can be treated with a water resistant coating. Canvas is a relatively light material that can be taken off and put back on easily.

3.9 REFLECTORS

Visibility is very crucial to any vehicle on a roadway. Cycling on the road is a very dangerous way to get around; the key is to be seen. There are many different types of reflecting objects that are discarded from industrial complexes and average households. The idea of a reflector is something that can reciprocate light without absorbing it.

3.9.1 STREET SIGNS

Street signs are very a reflective material, a discarded street sign can be cut into a reflector to be placed on a trailer. This material is unique but can be heavy and if not properly acquired legal repercussions can ensue if the sign was stolen.

3.9.2 CD/DVD

A very common discarded item that reflects light well is the CD or DVD. These could be placed in such a fashion that it could be art.

3.9.3 GLASS

Along the same line, a broken mirror, glass, and broken Christmas bulbs would be a wonderful reflector. The down side of that is that glass products can and will cut you. As well as if pieces started to fall of glass would litter the streets and work area. However, little pieces could be arranged in a beautiful mosaic around the trailer.

3.9.4 GLITTER

A unique reflecting material would be glitter. Glitter isn't discarded in bulk often and what is discarded would be really hard to gather due to that fact that glitter is so small.

3.9.5 PLACEMENT

Placing the reflectors on the bike trailer is very important to the safety of the people operating the trailer.

3.9.5.1 HIGH

Placing the reflector high on the trailer can be very a beneficial placement. The reflectors will be easy to see and increase safety for the operator.

3.9.5.2 LOW

Alternatively, placing the reflector on the bottom of the trailer can help bring the center of gravity down. If the reflector was large and heavy this will be crucial, and the trailer will not tip when turning quickly and at a fast speed.

3.9.5.3 EVERYWHERE

Having reflector placed all around the trailer would be the most effective for safety. Putting all reflective materials high and low on the trailer would insure the most protection and safety. In California the law requires one to have bright reflectors on the front and back that is visible from a distance of 500 feet on any vehicle (Safety).

4 ALTERNATIVE SOLUTIONS

4.1 INTRODUCTION

This section will touch on some of the design alternatives that were conceived in the brainstorming session. There is never one solution to a problem and many other possibilities will be considered that will not be listed here.

4.2 BRAINSTORMING

The purpose of brainstorming is to come up with as many independent variations of the design solution as possible and still meet the design requirements and project objectives. During a brainstorming session there is no such thing as a bad idea, and there is also no criticism. The lack of criticism leads to a positive environment that contributes to active thinking and creative solutions that may not have normally been thought of. We used different methods that were online from BUBBL.US and on a blank piece of paper.

4.3 ALTERNATIVE SOLUTIONS

The following alternative solutions were born in the brainstorming session. Some of the solutions are full trailer designs, and some are only portions of the design that can be altered. The Delphi Matrix method will be used to determine which alternative is best suited for the final design.

4.3.1 BINFORD 6100 TUB-O-PLASTIC

Tub-o-Plastic is a very simple and easy alternative solution. The Tub-o-Plastic is a large plastic storage tote that would have previously been used for storing household items in a garage or similar storage area. The largest complication to arise from implementation of this design alternative is, being unable to locate a suitable tub in the waste stream. The tub is an integral part of the design of this trailer. The tub will contain loose items in the event that the donor does not have a proper storage container to accompany the donations to SCRAP Humboldt.

Figure 4-1: Plastic storage tote used for cargo management (I Bike Daily 2012).

4.3.2 BINFORD 6100 TUB-O-METAL

Tub-o-Metal is a slightly more complicated alternative solution. The Tub-o-Metal is in principle the same design as the Tub-o-Plastic, but instead has been formed from

a scrapped highway sign, used to alert drivers of conditions ahead. The largest complication to arise from implementation of the Tub-o-Metal design alternative is, being unable to locate a road sign that is large enough to form into the tub size required. The Tub-o-Metal is an integral part of the design of this trailer and will contain loose items in transit to SCRAP Humboldt. The design of the Tub-o-Metal incorporates drain holes at the four bottom corners to drain the ever present gift from the skies in Humboldt county, rain, that is.

Figure 4-2: A box made from formed metal, pop riveted together (Frontier Nerds).

4.3.3 BINFORD 6100 QUICK DRAW RICKSHAW

The Quick Draw Rickshaw is a bicycle trailer design that takes full advantage of the constrained dimensions. The trailer, less wheels, is 32" wide, and therefore requires the wheels to be removed in order for the trailer to fit through an ADA compliant doorway. The wheels are attached to the frame with a standard quick release axle and hub assembly.

Figure 4-3: Removable bicycle style wheels on a bike trailer (Speed Pedal 2010).

4.3.4 BINFORD 6100 VERTICALLY UNCHALLENGED BICYCLE TRAILER

The Vertically Unchallenged Bicycle Trailer incorporates a design that has been used in the automobile trailer community for years. This specific trailer design allows for essentially unlimited trailer width, and a maximum single length of 8'6". The trailer has four swivel casters and a pivot bar mounted on the rear face of the trailer, where a tailgate might go. When the trailer is to be stored, it shall be unhitched from the bicycle, and tipped up on its end. The pivot bar will first come into contact with the ground and provide a fixed pivot point to keep the trailer from sliding away on the swivel casters. In the final angles of tipping the trailer to the full upright position the casters will support the entire weight of the trailer. The trailer can then be wheeled through a doorway and into final storage position. Final cargo space pending the hitch may need to be folded down in order to fit through a conventional 6'8" doorway.

Figure 4-4: An automobile utility trailer stored on hind end casters (Red Trailers 2013).

4.3.5 BAMBOOZLED BIKE TRAILER

Bamboo can be utilized for a bike trailer in many different ways; It is properly used when it is allowed to age for more than three years, shrinking the diameter of the bamboo making it more durable. You can join bamboo in many different ways, it can be and cut into a fixed shape and joined to another piece, tie together with nylon or other non shredding string, or bolted. The condition that the bamboo is in determines the joining process. Bamboo that is in poor condition or that is still young in the aging process can crack when drilled into. Humboldt county weather is not an ideal for fresh cut bamboo because of the potential problems that can occur during the curing process but bamboo that is already cured shows potential for a long lasting material. Here in Figure 4-5 is an example of a bamboo trailer.

Figure 4-5 A bamboo trailer (Used HQ 2008).

4.3.6 CAN DO IT ALL

Electrical Metallic Tubing, or E.M.T., is readily available because of its numerous applications. Bike trailers can be designed in many different ways and conduit gives access to that option. Joining conduit to other metal materials can be done in a many different ways whether it is drilling pieces together, welding, or a combination of the two. In Figure 4-6 is an example of a bike trailer made from E.M.T . Conduit. This alternative is a pleasing solution for the availability if E.M.T.

Figure 4-6 An E.M.T. Conduit Bike Trailer (Drum Bent 2000).

4.3.7 PUMP IT UP

Pneumatic wheels are readily available due to their common application in bicycles. Inherent to this application is the attribute of versatile design(s). Variations ranging from road tires with high pressure, narrow, and minimal drag profiles, to off-road tires with lower pressure, tall sidewalls, increased traction, and excellent dampening qualities, give the client a plethora of options. When compared to solid tires, pneumatic tire possess an intrinsic complexity. They are comprised of multiple independent components, which coincide to create the end result. The rims themselves include spokes which must be independently adjusted to maintain a straight (true) wheel, a valve stem confining the air within the inner tube, the inner tube itself which is a fragile bladder susceptible to any and foreign object which penetrates or significantly compresses the tire against the rim, and the tire itself

with its limited lifespan. The common hub used in bicycle applications is designed to be supported on each end of its axle, and thus any frame design utilizing such a hub would require dual supports for each tire, thus increasing frame complexity. The primary structure is also commonly a steel alloy susceptible to corrosion. That being said, with proper maintenance and conscientious application, the pneumatic bicycle wheel can be a reliable and inexpensive option.

Figure 4-7: Trailer with pneumatic bicycle wheels (Jose Crappus 2012).

4.3.8 IT'S A HARD KNOCK LIFE

Wheel Chair wheels are nowhere near as available as pneumatic bicycle tires; this is primarily due to their volume of production. The intended purpose of this style of wheel is not synonymous with a bicycle trailer, but is still adaptable. A cantilever hub greatly increases the simplicity of the required frame design, the polymer construction prevents corrosion, and the simple tire and rim construction increases reliability and simplicity by reducing components. Yet the solid nature of the tire transfers impacts directly to the frame through the rim with minimal dampening. This decrease in dampening may not be of concern when dealing with light loads, but heavy loads coupled with the magnitudes of accelerations associated with impulse shocks can result in either the failure of the frame or rim. Such an application may warrant the use of a secondary dampening structure to minimize such stresses upon the frame and rim. This would in turn increase the complexity of the frame structure.

Replacement tires for a solid wheel chair rim are uncommon, and are generally are limited to purchase. Though the polymer construction of the rim prevents corrosion, it is still susceptible to UV radiation an Ozone resulting in a brittle degradation. This may be hard to recognize and can result in a catastrophic failure. Conclusively, the applications of such wheels are less predictable when compared to the "trailed and tested" experience of bicycle wheels, yet they remain a viable option.

Figure 4-8: A Conduit frame with wheel chair wheels (Bike Shop Hub **2010).**

4.3.9 WRAP IT UP NICE

Using an integrated cover on the trailer will insure the materials inside the trailer are at all times dry. There will be no need to carry a cover while on a trip. A complication of having an integrated cover is if the cover were to tear or no longer able to protect from the elements. Replacing the cover could be costly and time consuming. The cover would need to be a durable material that could withstand punishment from the elements nature. With having straps that are fastened to the cover tightening down the cover would be a simple task. Example in Figure 4-9.

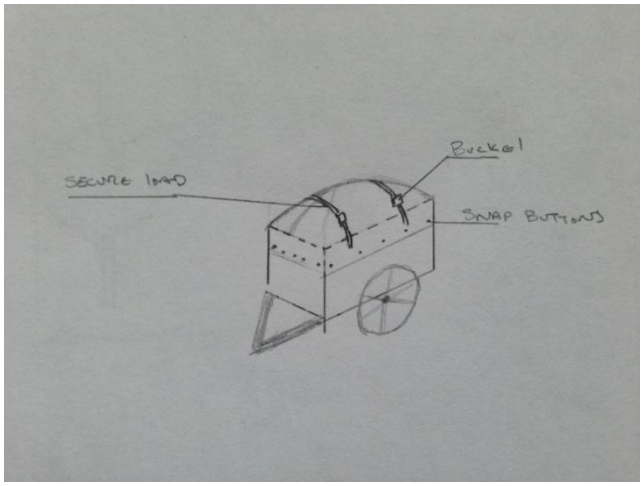

Figure 4-9: Figure of integrated cover, covering a load of goods (DeMaranville 2013).

4.3.10 DON'T LOSE IT NOW

A non-integrated cover has its place for covering materials in a trailer that does not experience a lot of rain. A removable cover can be a hassle when the cover has been lost or not properly secured. The availability of a removable cover is desirable; however it comes with a cost.

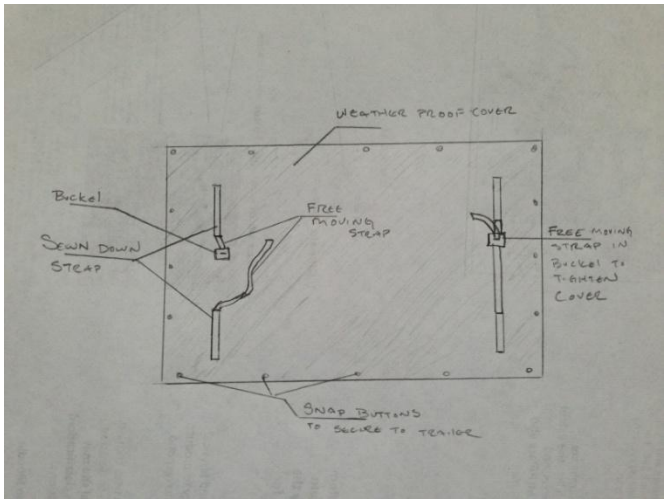

Figure 4-10: Sketch of cover (flat) with straps attached for securing goods inside the trailer (DeMaranville 2013).

4.3.11 COMBINATIONS

In this document there are 10 separate design alternatives with a possible combination of over 32 million. The document is laid out to show the pros and cons of each different alternative. This paper is a brainstorm of new ideas to show the client new ideas that could possibly better for production, weight, or durability.

5 DECISION MAKING PROCESS

5.1 INTRODUCTION

The decision making process is comprised primarily of a weighted criteria, alternative solutions, and a cumulative analysis to determine the final decision.

5.1.1 CRITERIA

5.1.1.1 *AESTHETICS*

Aesthetics are defined as the physical beauty or the appreciation thereof. With respect to our design, this translates to a trailer that demonstrates a respectable representation of functional design and the client SCRAP Humboldt.

5.1.1.2 *COST*

The gross expense is not to exceed three hundred dollars.

5.1.1.3 *USABILITY*

For the purposes of this project usability is synonymous with functionality and generally ergonomics. The trailer needs to be compatible with a least three bicycle types, easily maneuverable on and off the bike, and as light as feasible.

5.1.1.4 *DURABILITY*

Durability is a combination of structural integrity and longevity. With appropriate maintenance the life span should not be less than 3 years, and shall withstand the general stresses and abuses inherent to its operation.

5.1.1.5 *MAINTENANCE*

The target maintenance regime is one hour per 15 days of use (day is approximately 8 hours). Simplicity of design is a key contributor to this criterion.

5.1.1.6 *SAFETY*

General Safety is factored by structural integrity, night visibility, and general project finish (i.e. no sharp edges).

5.1.1.7 *WEIGHT*

The empty weight of the trailer shall not exceed fifty pounds, and the useful load is minimally seventy-five pounds for a gross weight of one hundred twenty five pounds.

5.1.1.8 *SIZE*

Our trailer must be able to fit through a standard sized door with relative ease. The width must not surpass 32-inches and the length cannot be longer than six feet.

5.1.1.9 *ENVIRONMENTAL JUSTICE*

The trailer must be comprised of more 35% by weight repurposed material.

5.2 SOLUTIONS

The following solutions are the top three combinations of the design alternatives as determined by group consensus.

5.2.1.1 *SOLUTION 1*

Tub-O-Metal, Vertically Unchallenged, Can do it All, Hard Knock Life, Wrap it up Nice

5.2.1.2 *SOLUTION 2*

Tub-O-Plastic, Binford 6100 Vertically Unchallenged Bicycle Trailer, bamboozled, pump it up, don't lose it now

5.2.1.3 *SOLUTION 3*

Tub-O-Plastic, Can do it All, Quick Draw Rickshaw, Wrap it up Nice

5.3 DECISION PROCESS

Using the Delphi Matrix allow for an unbiased qualitative assessment of each design solution. Each solution is weighted independently and compared against the weighted criteria for total point score. This will be the primary method of our decision process.

5.4 DELPHI MATRIX

Table 5-1 Delphi Matrix

		Alternative Solutions (0-50)		
Criteria	**Weight (0-10)**	**Solution 1**	**Solution 2**	**Solution 3**
Aesthetics	7	40 / 280	40 / 280	30 / 210
Cost	7	40 / 280	30 / 210	30 / 210
Usability	10	40 / 400	30 / 300	50 / 500
Durability	10	50 / 500	35 / 350	40 / 400
Maintenance	7	45 / 315	35 / 245	30 / 210
Safety	10	40 / 400	25 / 250	30 / 300
Weight	6	30 / 180	40 / 240	35 / 210
Cargo Capacity	7	50 / 350	37 / 259	40 / 280
Environmental Justice	7	45 / 315	50 / 350	45 / 315
	Total	**3020**	**2484**	**2635**

5.5 FINAL DECISION

The final decision is a combined effort from both our group and the client's criteria. A wheel chair has be retrieved from Humboldt Scrap and Salvage which will be integrated into and metal conduit frame. Highway signs are also readily available, the largest of which is 4ft by 5ft and will be formed into the Tub-O-Metal. The conduit for the frame will also be obtained the scrap yard.

5.6 SPECIFICATIONS OF SOLUTION

5.6.1 SOLUTION DESCRIPTION

The Up-Cycled Coffin, Figure 5-1, is an all-encompassing solution that combines various alternatives to serve SCRAP Humboldt's wants, needs, and desires of transporting materials from donors to SCRAP Humboldt's storefront in southern Arcata. The Up-Cycled Coffin solution consists of wheelchair wheels and tires,

weather resistant frame, a reflective cargo tub, articulating hitch, and water proof cargo cover.

Figure 5-1: The Up-Cycled Coffin, transporting donated goods to an afterlife since 2013 (Kennedy 2013).

5.6.1.1 *WHEEL CHAIR WHEELS*

Wheelchair wheels and axles were utilized due to their single sided axle/hub configuration shown in Figure 5-2. This allows for the cargo tub to be situated between the wheels and lower without an axle imposing on the cargo space. The Wheelchair was originally rated for 350lbs which far exceeds our expected 150lbs gross trailer weight.

Figure 5-2: Our wheelchair wheels and stub axles (DeMaranville 2013).

5.6.1.2 *E.M.T. CONDUIT FRAME*

Three quarter inch electrical conduit was used to construct the frame and was chosen because of its availability, weather resistant galvanized coating, and relatively high strength to weight ratio.

Figure 5-3: ¾" Electrical conduit frame (Adams 2013).

5.6.1.3 *TUB-O-METAL*

The cargo tub was formed from an aluminum highway sign with the reflective surface on the outside, thus greatly increasing the visibility of the trailer at night. The aluminum sign also has weather resistant properties which make it an ideal choice of material for the trailer.

Figure 5-4: Tub-o-Metal formed from a highway sign (Adams 2013).

5.6.1.4 *LOW HITCH MOUNT ASSEMBLY*

A low style hitch displayed in Figure 5-5 was utilized to minimize the feedback transferred from the trailer to the bike and rider. The forces exerted on the bicycle by the loaded trailer create a smaller moment about the point of tangency between the rear bicycle wheel and the ground, when using a low style hitch as compared to a high style hitch, i.e. the trailers effect on the bicycles stability is minimized.

Figure 5-5: A picture of our low hitch design (Kennedy 2013).

5.6.2 COST ANALYSIS

The capital costs associated with our design are listed in Table 5-2 and the recurring costs are listed in Table 5-3. The most expensive line item is the millwright work provided by our department shop tech. Turning the aluminum slug for the heim joint at the hitch and the frame inserts used to adapt the wheelchair frame to the conduit frame on the lathe, could have been replicated with a drill motor, hand file, and lots of time. The conduit frame was welded together, but also could have been replicated by brazing or silver soldering or even mechanical fasteners to achieve the same result.

The amount of time consumed by the project is illustrated by Figure 5-6, the values are in hours and the phases are representative of the design process.

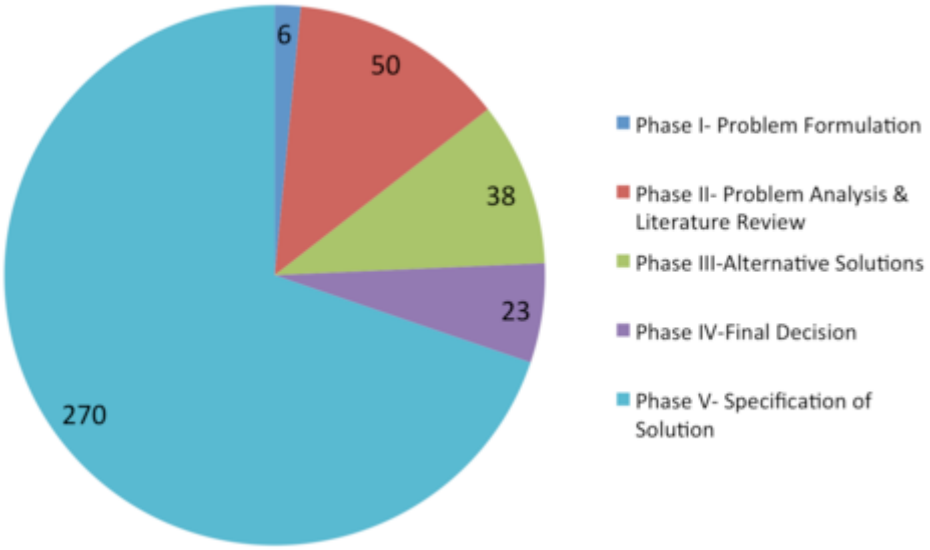

Figure 5-6: Design process, totaling 387 hours, expressed as hours invested by group members and divided into phases.

Table 5-2: Capital costs associated with the final design solution.

		Retail		Team	
Item Description	**Quantity**	**$/Item**	**Total**	**$/Item**	**Total**
Marty's Labor	8	$ 70.00	$ 560.00	$ -	$ -
Kokatat Material	1	$ 300.00	$ 300.00	$ -	$ -
Wheelchair	1	$ 120.00	$ 120.00	$ 30.00	$ 30.00
10' x 3/4" EMT Conduit	10	$ 11.00	$ 110.00	$ -	$ -
Road Sign	2	$ 28.50	$ 57.00	$ 19.00	$ 38.00
Helm Joint	1	$ 15.00	$ 15.00	$ 10.00	$ 10.00
5' x 1/2" Galvanized Steel Pipe	1	$ 10.00	$ 10.00	$ -	$ -
1/4" x 20 Fasteners	8	$ 1.00	$ 8.00	$ 1.00	$ 8.00
Pop Rivets	50	$ 0.13	$ 6.50	$ -	$ -
3/4" Wood Dowel	1	$ 4.00	$ 4.00	$ 4.00	$ 4.00
		Total	**$ 1,190.50**		**$ 90.00**

Table 5-3: Recurring costs associated with the final design solution.

Operation & Maintenance	**Material Cost ($)**	**Frequency/Yr**	**Hrs**
Cleaning / Wiping Dirt	0	4	0.25
Inspect and/or Replace Bearings	12 / bearing	2	0.5
Inspect and/or Replace Tires	40 / tire	1	0.5
Repair Cover	36 / repair kit	1	0.5
		Total	**3**

5.6.3 INSTRUCTIONS

For the intent of replication, instructions with pictures detailing the trailer construction can be found at our Appropedia website: <http://www.appropedia.org/SCRAP_Humboldt_upcycled_bicycle_trailer>

5.6.4 RESULTS

The trailer performed flawlessly with the exception of some noise caused by vibration rattling the cargo tub against the frame. This was easily rectified by riveting the tub to the frame, eliminating the excess movement and therefore noise. The trailer successfully transported 155 lbs uphill, Figure 5-8; and downhill, Figure 5-7. The brake test was a success and the trailer did not need brakes to bring the bicycle to a complete stop. The trailer is also plenty visible at night Figure 5-9 and 10.

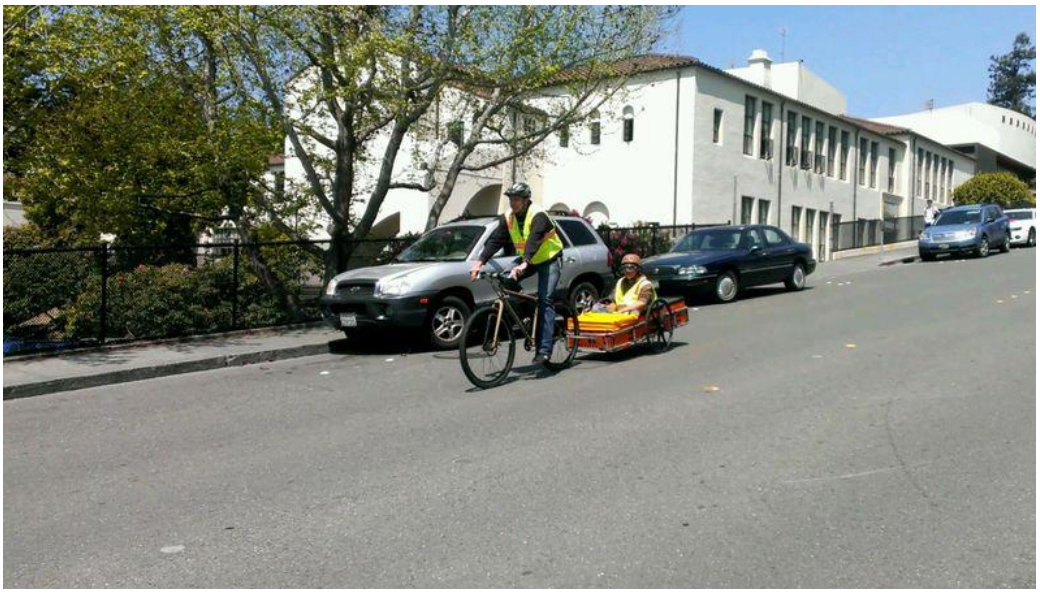

Figure 5-7: Downhill braking test with 155 lb cargo (Kennedy 2013).

Figure 5-8: Uphill towing test with 155 lb cargo (Kennedy 2013).

Figure 5-9: View of the trailer from a driver's vantage point, approaching the trailer from behind (Kennedy 2013).

Figure 5-10: View of the trailer from a driver's vantage point, approaching the trailer from the side (Kennedy 2013).

6 REFERENCES

Ayre, Michael (1986). *The Design of Bicycle Trailers,* Intermediate Technology Publications Ltd, London, UK

Bicycle Touring 101 <http://www.bicycletouring101.com/InterviewSchwalbeCeleste.htm>(2011)

Bike Rumor <http://www.bikerumor.com/2012/05/20/paul-components-mini-moto-v-brakes-now-available/> (2012)

Bike Shop Hub <http://www.bikeshophub.com/johns-wheelchair-revisioned-as-bike-trailer/> (2010)

Black Oak Fabrications., (2012). "Bike Trailers." http://www.blackoakfab.com/bike-trailers/ (Feb. 23, 2013).

B.O.B. Gear <http://www.bobgear.com/bike-trailers/yak> (2013)

Burley Design <http://burley.com/> (2013)

Cali Bamboo (2011). "Why Bamboo?", http://www.calibamboo.com/whybamboo.html (Feb. 21, 2013).

California Redwood Association. (2012). "Dimension Stability of California Redwood" < http://www.big-creek.com/files/9213/3831/1253/dimensional-stability-of-california-redwood.pdf> (Feb. 22, 2013).

California Redwood Association. (2012). "Lumber Grades and Uses." <http://www.calredwood.org/pdf/Grades+Uses.pdf> (Feb. 22, 2013).

Cangeloso, Sal. *LED Lighting*. N.p.: O'Reilly Media, 2012. Web.

Carry Freedom <http://carryfreedom.com/bamboo.html> (2013)

CE Attachments <http://www.ceattachments.com/news/currentnews/05-06-01/No_Flat_Tires_with_Solid_Flex_Tires_from_CEAttachments.aspx?> (2011)

Chester Cycling <http://chestercycling.wordpress.com/category/bottle-dynamo/>(2013)

Cycle Tote <https://cycletote.com/touring_cargo.html> (2013)

DeMaranville, Michael "Group Member"

Drum Bent < http://drumbent.com/photos/bikes/trailer/trailerframe.jpg>(2000)

Etrailer <http://www.etrailer.com/Sport-Carriers/Chariot/CH10100231.html> (2013)

Etrailer <http://www.etrailer.com/TrailerSuspension/Timbren/A35RD545E.html> (2013)

Kellogg <http://www.flickr.com/photos/larsks/93569964/> (2006)

Frontier Nerds <http://frontiernerds.com/metal-box >

Gene and Sue <http://www.geneandsue.com/bike_trailer/bike_trailer.htm> (2013)

"How Light Bulbs Work." *HowStuffWorks*. N.p., n.d. Web. 27 Feb. 2013.

Huffington Post< http://www.huffingtonpost.com/2012/08/14/bamboo-bike-trailer-how-to_n_1775233.html>(2012)

Hydro (2011). "Properties Of Aluminum." http://www.hydro.com/en/Subsites/NorthAmerica/Aluminum/Properties-of-Aluminum/ (Feb. 22, 2013).

I Bike Daily < http://ibikedaily.com/category/storage/>(2012)

Instructables <http://www.instructables.com/id/PVC-Bike-trailer_1/>(2008)

Jose Crappus <http://www.josecrappus.com/home/cycletotechild-dog-cargobiketrailerforsale> (2012)

JPMagazine<http://www.jpmagazine.com/techarticles/suspension/154_9903_black_diamonds_new_coil_suspension_for_jeep_yj_and_cj/photo_07.html>(2013)

Kennedy, Lukas "Group Member"

Leader, J., (2012). "Bamboo Bike Trailer: How To Build Your Own." http://www.huffingtonpost.com/2012/08/14/bamboo-bike-trailer-how-to_n_1775233.html (Feb. 23, 2013).

Park Tool <http://www.parktool.com/blog/repair-help/avid-reg-mechanical-disc-adjustment> (2013)

PVC Pipe—Design and Installation, 2nd addition(2002), Chapt. 1, Pg. 7, American Water Works-Association, Denver.

Red Trailers < http://www.redtrailers.com/ShowTrailer.asp?id=6>(2013)

Speed Pedal <http://speedpedal.files.wordpress.com/2010/07/pushbutton-detachable-wheels.jpg>(2010)

Think Biologic <http://www.thinkbiologic.com/products/joule-ii-dynamo-hub-20-wheel-set>(2012)

Used HQ < http://www.used-hq.de/used-website/assets/images-2008/bamboo-trailer.jpg> (2008)

World Steel Association. (2013) "about Steel. " http://www.worldsteel.org/faq/about-steel.html (Feb. 22, 2013).