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1 Problem Formulation

1.1 Introduction

Section 1 consists of the introduction, the mission statement, and the black box model. Our Spring 2014 Engineering 215 semester design project will be building disc golf stations for the client, Zane Middle School. The school has grades six through eight, and is located in Eureka, Ca. Zane implements a program known as S.T.E.A.M. which stands for science, technology, engineering, art, and math. Much of the faculty wishes to improve the campus while further enriching the students' education about sustainable practices.

1.2 Mission Statement

The objective of this project is to design and build a collapsible and portable disc golf station from upcycled materials. The design of the station will be based upon criteria given by the client, Zane Middle School.

1.3 Objective

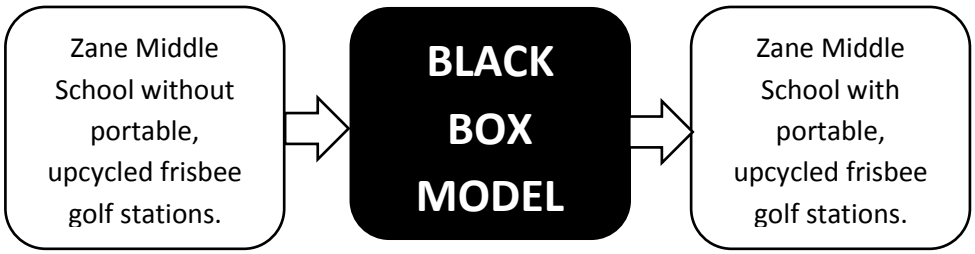

Figure 1-1: The Black Box Model shows the initial state of ZMS, the solution, and the resulting state.

2 Problem Analysis

2.1 Introduction to Problem Analysis

The Problem Analysis section provides an analysis of the problem specified in section 1.2. This section discusses the specifications and considerations of the disc golf basket. Also, the client's criteria will be analyzed and constrained. In addition, usage and production volume are also discussed.

2.1.1 Specifications and Considerations

The specifications and considerations are the guidelines that must be followed to meet the client's needs and the needs of the project. The specifications for the project are:

- Collapsible
- Made from Upcycled Materials
- Portable
- School colors
- Durable

Some of the major considerations for our project are:

- Safety: Children will be using the baskets so they must be safe
- The baskets will spend much time outside
- Official disk golf regulations

2.1.2 Criteria

The criteria and constraints developed with Zane Middle School are shown below in **Table** 2-1. The criteria and constraints subsection provides measureable goals which will be used to determine the quality of the project.

Table 2-1: Criteria and Constraints

Criteria	Constraints
Cost	≤ $75*3 team members= $225
Aesthetics	School colors, as appealing as the average disk target
Safety	Stable (won't topple over if a kid quickly pulls on the edge), no sharp edges
Design Specs	≥ 80% Up-cycled materials, regulation size, reproducible, ≤ 50 lbs
Durability	Withstand Eureka weather and kids ≥ 3 years old
Reproducibility	Able to be constructed by a teacher and students

2.1.3 Usage

The disk golf baskets will be used frequently by students from 6th-8th grade (approximately twelve to fourteen year olds). The baskets will be used for a disk golf unit taught in Zane Elementary P.E. classes, and for intramural disk golf play.

2.1.4 Production volume

We will construct one disk golf station as well as provide instructions for building more.

2.2 Literature Review

2.2.1 Introduction to Literature Review

The purpose of the literature review is to provide appropriate background information which will provide and give a foundation for the design process. A range of topics will be covered starting with client criteria and followed by upcycled materials, up-cycled target designs, rules of recreational disk golf, Eureka weather, and Safety.

2.2.2 Client Criteria

The client would like for a disc golf station to be created out of upcycled materials. The client did not say much about what they want the project to be. The guidelines that were given were to make a disc golf target out of upcycled materials that can be replicated for the other eight targets of the course. The main goal that the client wants is to have something that the kids can play with and enjoy. There should be an educational aspect to the project, such as what up-cycling is. Other than that, the client did not want too much out of the project.

2.2.3 Up-Cycled Materials

The majority of examples of homemade disk golf targets are built from metal, plastic, or a combination of the two. The next section will cover possible usable upcycled materials and the physical properties of each material.

2.2.3.1 Metals

After the research of many different materials, only a few materials remain plausible for this project. The metals that are most suitable for the project are: aluminum, iron, and steel. Most other metals were ruled out because they were either too expensive to use, or were not easy to be found for up-cycling. Copper for example, has a really high cost in today's market. Tin and bronze, are usually just the plating for other metals, so therefore would not be appropriate for this project. Of the metals list, there are only a few that remain that will be reasonable to use for our project, as previously stated.

2.2.3.1.1 Iron

Iron is a very strong metal. But, iron metal will rust, and therefore the structural integrity of the target would be compromised. Considering the weather in Eureka, CA, and the iron will rust even quicker than it would otherwise. But, since iron is so strong, it could be used for different components of the project.

2.2.3.1.2 Aluminum

Aluminum is a great metal. It is strong, yet light. For example, there are many bike frames that are made from aluminum, and seeing bikes frequently in Humboldt County, this metal would be a good choice for the project. Aluminum also does not rust. Aluminum still corrodes, but when it corrodes it produces aluminum oxide which makes the metal even stronger.

2.2.3.1.3 Steel

According to the Professional Disc Golf Association, steel is the most commonly used material for disc golf targets. Steel, and galvanized steel are frequently used. This metal is strong and resists corrosion well. Steel is another metal that is used in in construction and as frames for structures. Steel would be another good choice for Humboldt County because of its strength and resistance to corrosion.

2.2.3.2 Bike Tire

Modern bicycle wheels are made out of aluminum and butyl rubber. These materials are lightweight, relatively durable, and resistant to the weather. (Exploratorium 2009). They come in various sizes, ranging from 8 to 29 inches in diameter.

2.2.3.2.1 Butyl Rubber

Butyl rubber, a copolymer of isobutylene, is a common rubber used to make bike and car tires. Physical properties of butyl rubber include low permeability to air, gases, and moisture; vibration damping; and resistance to aging and to weathering from atmospheric exposure. (Exxon Mobil 2014) Figure 2-2 is a picture of butyl rubber being used on a bike tire.

Figure 2-2: Close up profile shot of a bike tire.
http://www.gizmag.com/pumptire-self-inflating-bike-tire/19613/

2.2.3.3 55 Gallon Drum

The plastic used in fifty five gallon drums is High Molecular Weight High Density Polyethylene (HDPE). These drums are strong yet tensile, and are ideal for withstanding deterioration from weather and the elements. The dimensions of a typical 55 gallon drum are as follows: total weight of one drum is 21.9 pounds; maximum diameter is 23.5 inches; assembled height of 36.3 inches; and a minimum wall thickness of 2.2 millimeters. (Plastic Drum Standards 2012)

2.2.3.3.1 High Density Polyethylene

High Density Polyethylene's high strength and light weight is why it is a very frequently used plastic in the industrial world. **Table 2-2** lays out the general physical properties of high density polyethylene. (Typical Engineering Properties 2009)

Table 2-2: Properties of HDPE in terms of English and SI units

General Properties	English Units	SI Units
Molecular Weight	0.062 lbs	28.0 g
Density	58.1 - 60.2 lbs/ft3	0.930-0.965 g/cm3
Melt Density	47.7 lbs/ft3	0.764 g/cm3
Bulk Density:		
Pellets	36 – 40 lbs/ft3	577 - 640 kg/m3
Flake	31 – 35 lbs/ft3	497 – 561 kg/m3
Permeability Coefficients:		
Water (@ 25°C)	1.7x10-12in2/sec2-atm	1.3x10-10cm2/(sec-cm Hg)
Oxygen (@ 30°C)	1.4x10-12in2/sec2-atm	1.06x10-10cm2/(sec-cm Hg)
Carbon Dioxide (@ 30°C)	4.6x10-12in2/sec2-atm	3.5x10-10cm2/(sec-cm Hg)
Nitrogen (@ 30°C)	0.35x10-12in2/sec2-atm	0.27x10-10cm2/(sec-cm Hg)
Water Absorption @ 24 h Immersion	0.03%	0.03%

2.2.3.4 Polyvinyl chlorine

Polyvinyl chlorine, commonly known as PVC, is a very durable plastic that is able to withstand a number of chemical and physical abrasions. PVC's high durability is due to polar chlorine atoms that don't allow it to oxidize with atmospheric oxygen thus allowing its strength to last a long time. It is also able to withstand most inorganic chemicals. (PVC.org)

2.2.4 Upcycled Target Case Studies

When it comes to constructing targets there are many options of upcycled materials that can be used. Some of the more commonly used upcycled designs involve barrel designs, bike tire designs, and barbeque designs. Each design has a disk catchment system (usually made out of chains or ropes), a base that won't let the target topple over, and a disk basket to hold the disks after being stopped by the chains. (PDGA 2013) The following section covers case studies of previously up-cycled designed disc golf catchers.

2.2.4.1 Plastic Drum Design

The plastic drum target design uses a fifty five gallon plastic drum, cut on the top and the bottom, to provide the disk target basket and the disk target top. The HDPE plastic used in fifty-five gallon drums is light weight, durable, and weather resistant. (Disk Dog 2014)

2.2.4.2 Barbeque Design

The barbeque target design uses a grill grate as the top of the target and a barrel liner as the disk basket. This design is sturdy because it uses metal materials that can withstand the elements. (Orange Guy 2014)

2.3 Rules of Recreational Disc Golf

2.3.1 Objective

The objective of disc golf is much like that of traditional golf, meaning the goal is to reach the target with the least amount of throws possible. Each player starts at the "tee" and throws the disc from there. Each throw will count as a stroke. Wherever the disc lands after the first throw is called the lie. The players' next throw must be thrown from just behind the lie.

2.3.2 Fairway Throws

Fairway throws must be made from directly behind the lie. A run-up and normal follow-through, after release, is allowed, unless the lie is within 10 meters of the target. Any shot within 10 meters of the target requires that the player not move past the lie until the disc is at rest.

2.3.3 Dogleg (or Mandatory)

A dogleg is one or more designated trees or poles in the fairway that must be passed as indicated by arrows. Until the dogleg is passed the closest foot to the dogleg must be on the lie when the disc is released.

2.3.4 Out of Bounds

If any area of O.B. is visible between the disc and O.B. line, then the disc is considered O.B. A throw that lands out of bounds, must be played from a point 3 feet in bounds from where the disc went out of bounds. Permanent water hazards and public roads are always out of bounds.

2.3.5 Completion

The hole is completed when the disc lands in the target. There are unplayable lies. The unplayable lie is when the disc lands in vegetation or a tree. The player must move the disc directly under the unplayable lie.

2.4 Weather

Eureka, California has an average annual rainfall of around 39 inches. The mean temperature of Eureka is 54 degree. The hottest months are June, July, and August, which have an average temperature of 61.5 degrees. The coldest are December and January, which have an average of 41.75 degrees. On average, Eureka receives 78 clear days per year, and 288 cloudy or partly cloudy days. The mean yearly wind speed is 10.9 mph, and the average annual humidity is 86% (ClimateZone 2003).

2.5 Safety

School playground equipment must be safe. There can be no dangerous, sharp, unstable, or ensnaring components. Also, there can be no dangerous materials used. Many common building materials, glues, and paints are toxic to children (Spodek 1993). Lead-based paints provide a severe health risk for children (Markowitz and Rosner 2000). Equipment designed for children should be completely free of toxins.

3 Alternative Solutions

3.1 Introduction

Section three describes alternative designs for the disc golf station/target. This section also describes the brainstorming sessions that took place over the time for this section to be completed. The alternative designs meet the client criteria, from section 2, in different ways, such as portability and collapsibility.

3.2 Brainstorming

Our team had two brainstorming sessions. One of the brainstorming sessions was structured, with a computer in front of us to look at and decide on the designs that we produced during the unstructured session at HSU. The unstructured session provided us with a setting that helped us creatively come up with ideas and designs for more disc golf stations. The structured session was in the library where we sat down, as mentioned above, and looked at our designs. Refer to Appendix B for an example of one of the brainstorming sessions.

3.3 Alternative Solutions

The alternative solutions are solutions based on the research of the literature review and based on the brainstorming activities. The following sections describe the solutions that our group has come up with alternative designs for a disc golf station. Each solution has a basket for catching the discs, a top that holds the chains for the basket, and a base. The solutions are: Hangin' Out, Armstrong Disk Stopper, 55 Gallon Frisbee, Fris-B-Que, Santa's Chains, and Blow Your Disc Away.

3.3.1 55 Gallon Frisbee

Fifty five gallon Frisbee target design uses a fifty five gallon plastic drum, cut on the top and the bottom, to provide the disk target basket and the disk target top respectively. The target basket is cut eight inches from the top of the drum, and the target chain holder is cut four inches from the bottom of the drum. The top and bottom of the drum is then assembled in a manner similar Figure 3-1. With a transportable base, the 55 Gallon Frisbee target design is light weight and portable.

Figure 3-1: 55 Gallon Frisbee design http://www.instructabls.com/

3.3.2 Armstrong Disk Stopper

The Armstrong Disk Stopper design uses a bicycle tire as the chain holder for the target. The spokes on the bike tire provide for variable “droopiness” in the chains. The basket is made of angle brackets attached in the middle to a round cut out of wood. Figure 3-2 shows a schematic of the Armstrong Disk Stopper and each of its labeled components.

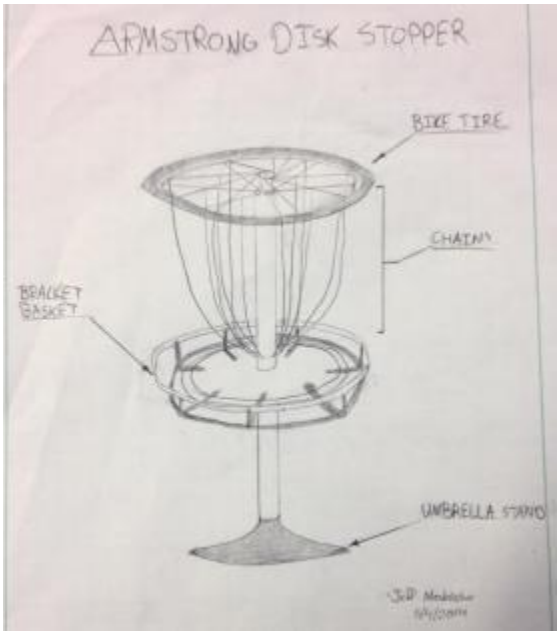

Figure 3-2: Armstrong Disk Stopper drawing

3.3.3 Totally Tubular

This design is made almost entirely of PVC pipes. The design meets the client criteria for portability and for collapsibility. The design can be take apart and put back together easily, since it is made of fitted pipes. The product can be put into the ground, or a base can be made for portability. The PVC is very durable and safe and light, so the students will be able to safely and easily use the target. Both top and bottom of the basket is PVC pipe. The bottom part of the basket has plastic safety fencing zip tied to the pipe to provide a more stable and usable basket to catch discs. Half of the chains are plastic chains and the other half are metal chains. Overall, the PVC material provides a light and safe alternative design. The design can easily be reproduced and put back together by anyone. The design will also meet the cost criteria because PVC pipe is relatively inexpensive.

Figure 3-3: PVC Pipe Design http://i683.photobucket.com/albums/vv195/PitScorpion/DiscBasket.jpg

3.3.4 Hangin' Out

This design is different than most of the other designs. This design features a permanent base cemented into the ground. The design uses a hanging basket instead of one attached to a pole base. The design most incorporates wood, which would not be the best design for Zane Middle School, but, the design will also work with metal materials. The hanging target can be moved from base to base as needed for a round of disc golf. The basket is attached to a hook that then attaches to another hook on the base that is in the ground. This design is very portable because of the hooks. It is appropriate for what the client is asking for because it can be transferred to different bases around campus.

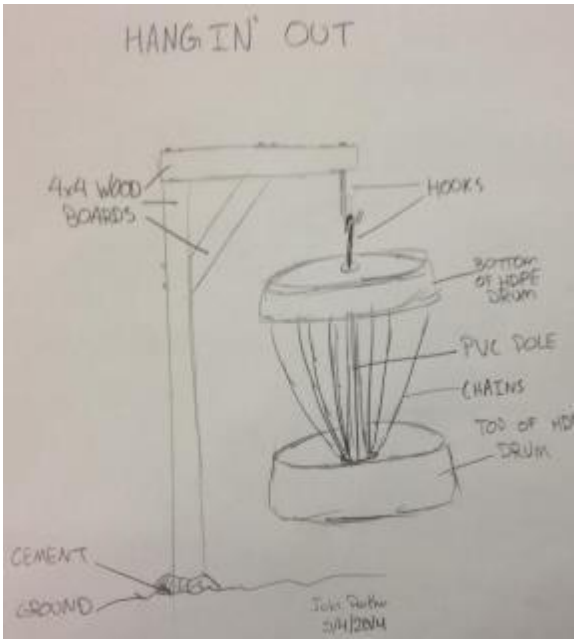

Figure 3-4: Hanging basket design

3.3.5 Blow You Disc Away

Blow Your Disc Away is a design that uses a household fan and PVC pipe for the disc golf target. This design meets the criteria for collapsibility. The design uses PVC pipe for the interior and the base. The pipe is put together to hold up the basket that includes the fan and some chains. The pipe is slid into each other to form a solid, yet removable base for the target. The design uses an old fan that is taken apart. The fan is split in half and then the chains will be attached to both halves, as observed in Figure 3-5. This design is simple, yet fits the criteria that the client proposed. It is collapsible, therefore becoming easy to store. The design is also light and portable and it can be reproduced easily.

Figure 3-5: Fan Disc Golf Target

3.3.6 Santa's Chains

Santa's Chains is a collapsible Disk golf basket that utilizes a Christmas tree stand as its base. The basket collapses via a telescoping pole. When collapsed, the chains rest in the bottom half of the basket.

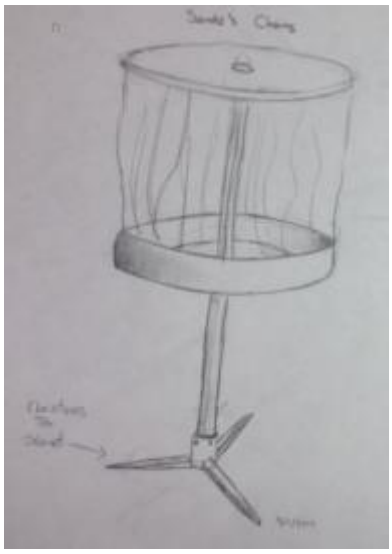

Figure 3-6: Santa's Chains Disk design drawing

3.3.7 Fris-B-Que

The Fris-B-Que is a Disk golf basket made from a barbeque. The top and bottom halves are separated by a telescoping pole, which allows it to collapse. The base can be detached and put inside the collapsed basket to save space. A latch secures the basket closed. Figure 3-7 shows the Fris-B-Que design drawn out.

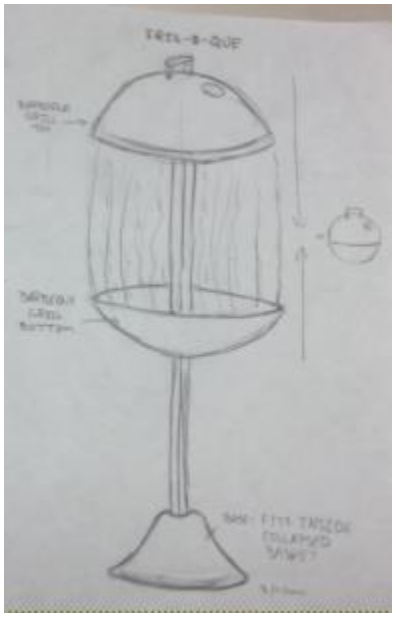

Figure 3-7: Fris-B-Que target design drawing

4 Decision

4.1 Introduction

Section 4 of the design document details the decision process. The alternative designs from Section 3 are given numerical weight based on how well they meet the criteria discussed in Section 2. The Delphi Method is used to analyze the values to determine which design best meets the client's criteria.

4.2 Criteria

The Criteria from Section 2:

Aesthetics: The visual appeal of the project. Should be Zane Middle School colors and easy on the eyes.

Cost: How much the project costs in total, which is less than a store bought disc catcher.

Safety: The safety of the project is that it is free of risk of danger or injury.

Design Specs: The project must be made from as much upcycled materials as possible and also must be portable and collapsible.

Durability: Able to work for a long period of time and resist wear and decay.

Reproducible: Able to me recreated by a class of middle school students.

4.3 Solutions

The solutions are narrowed down into these different options:

1. Gallon Frisbee

2. Armstrong Disc Stopper

3. Totally Tubular

4. Blow Your Disc Away

5. Fris-B-Que

4.4 Decision Process

The decision process included the team talking about each project. During the decision process, a Delphi Matrix was created to help make the decision based on individual rankings. It uses a rating of 0-50, 0 being the worst and 50 being the best, for each criteria, and is then multiplied by the score we gave the criteria of 0-10, also by level of importance. A ranking of 0 is the least important and 10 is the greatest importance. The matrix is each score for each criteria of each alternative design added up, thus giving a total ranking of the solution. A decision is made based on the best solution based on the scores and client criteria. The weighted criterion is in **Table 4-1** and the Delphi matrix is **Table 4-2**.

Table 4-1: Criteria Weights

	Criteria Weight			
Criteria List	Jake	Nick	Jeff	Group
Cost	7	7	10	8
Aesthetics	5	8	3	5
Safety	10	10	5	8
Design Specs	8	5	4	6
Durability	9	6	3	6
Reproducibility	6	9	4	6
Total	45	45	29	40

Table 4-2: The Delphi Matrix shows the scores of each alternative solution based on how the team ranked each criterion.

Criteria	Weight (0-10)	Alternative Solution (0-50 high)				
		Gallon Frisbee	Armstrong Disc Stopper	Totally Tubular	Blow Your Disc Away	Fris-B-Que
Cost	8	35 304	38 304	33 264	38 304	35 280
Aesthetics	5	30 150	33 165	38 190	28 140	20 100
Safety	8	43 344	43 344	49 392	40 320	33 264
Design Specs	6	43 258	39 234	33 198	30 180	28 168
Duability	6	41 246	38 228	28 168	28 168	40 240
Reproducibility	6	47 282	40 240	38 228	40 240	30 180
Totals		1584	1515	1440	1352	1232

4.5 Decision Justification

The decision was that the Gallon Frisbee would be the best option for the project. It has the highest score in the Delphi matrix. It was clear that this design would best suit the criteria for up cycling. It will also be the best design for portability and collapsibility. The gallon drum design will make the best design choice because it best meets the criteria that the client provided. The project is best using this design.

5 Design Specification

5.1 Introduction

Section 5 of the design document specifies the details of the final solution chosen in Section 4. Included in this section are: an in-depth solution description, multiple diagrams of the solution, a complete cost analysis, and instructions for construction, implementation, and maintenance. The cost analysis will include both material cost and hours of labor time. Instructions for construction, implementation, and maintenance include step by step instructions on how to build, use, and maintain the model.

5.2 Description of Solution

The Decked-Out Disc Catcher, fully diagrammed in Figure 5-1 is the final design for a disc golf basket. The main components of the basket are a 55 Gallon HDPE drum, 3 skateboard decks, chain, and PVC pipe. It is PDGA regulation size, collapsible, and upcycled.

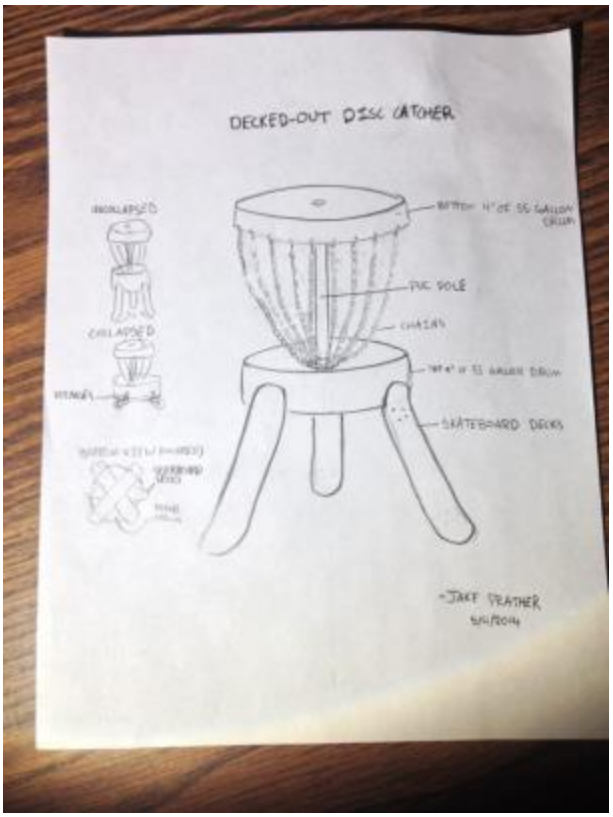

Figure 5-1: Decked-Out Disc Catcher Schematic

5.2.1 The Basket

The basket is designed to catch discs without damaging them. The top of the basket is made by cutting the bottom 4" off of a standard 55-Gallon HDPE drum. Every 6", there is a hole drilled ½" above the cut, numbering 12 in total. These serve as the attachments for the s-hooks, which hold up the chain. The top of the basket is attached to 3' of 2" schedule 40 PVC pipe via a 2" flange. The 12 chains are cut into 24" segments. The bottom of the chains connect to a 5" metal ring which hangs around the PVC pipe connecting the top to the bottom of the basket. The bottom of the basket is made from the top 8 inches of the HDPE drum. The bottom of the basket is attached to the PVC pipe with a 2" flange.

5.2.2 The Base

The base is designed to support the weight of the basket without falling or wobbling. Our base consists of 3 standard skateboard decks affixed to the bottom of the basket using hinges. The hinges are attached every 25½" of the circumference. This tripod design provides sturdy support, and also allows the skateboard decks to fold up against the bottom of the basket.

5.3 Cost Analysis

The cost analysis discusses the amount of time and money spent on the project, which includes design cost in hours, materials cost, and maintenance cost.

5.3.1 Design Cost (hours)

The design costs for hours is the amount of time spent working on the project thus far. The total is 82 hours spent on the project. The most time was spent in section 5, the testing and implementation section of the document. Figure 5-2 shows the hours that went into the project in the form of a pie chart.

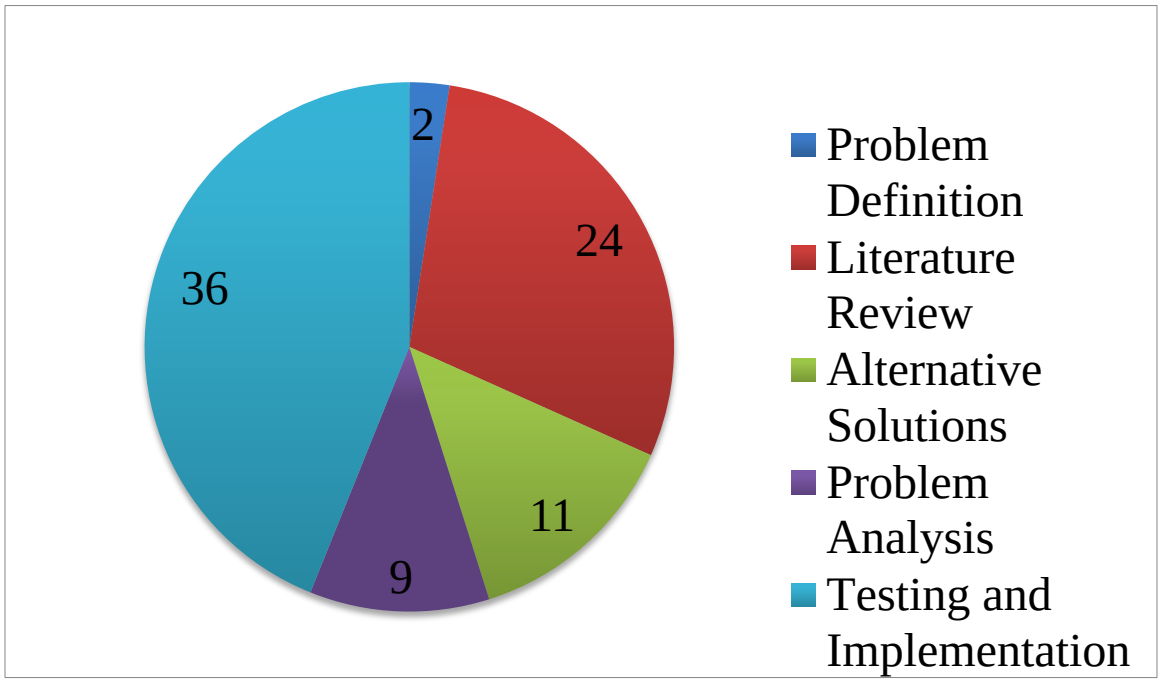

Figure 5-2 Design Hours Pie chart

5.3.2 Materials Cost

The materials added up to $36.14. A majority of our materials were donated. This is shown in **Table 5-1**. The retail cost of all of the items is $266.07.

Table 5-1: Cost of materials used to build.

Quantity	Material	Source	Our Cost	Retail
1	55 Gal. Drum	Arcata Scrap	0.00	67.00
2	Hinge (2)	Ace Hardware	10.76	10.76
2	S Hooks (6)	Ace Hardware	5.38	5.38
1	Sch.40 PVC 2”x5’	Ace Hardware	5.00	5.00
1	30 ft. chain	Home	0.00	13.00
8	Skateboard Deck	Ampt Skate	0.00	89.85
1	Sch.40 PVC1.5”x5’	Ace Hardware	5.00	5.00
2	Metal Pipe	Arcata Scrap	10.00	70.08
	Total		$36.14	$266.07

5.3.3 Maintenance Cost

The only maintenance is possible repair costs. These repair costs will depend on the part that is broken. The price can be found in the previous table. The nature of the project is using up-cycled materials, so there will not need to be maintenance cost for most of the parts.

5.4 Instructions for implementation and Use

To use the Decked out Disk Basket, simply unclasp the top and bottom part of the collapsed basket, screw in the center pole to the basket bottom and top, and lower the skateboard decks to the desired height.

5.4.1 Deconstruction

To deconstruct the basket, unscrew the center pole and lay it down in the basket section. Next, lower the chains into the basket and close the clasps around the perimeter of the barrel. Last, fold up the legs and use the handles to transport the collapsed barrel with all its contents to the proper storage facility. Figure’s 5-3 through 5-5 shows the steps for proper deconstruction:

Figure 5-3: Unscrewing the top

Figure 5-4: Bottom of the basket completely collapsed

Figure 5-5: Completely collapsed basket

5.5 Results

The results of the design process showed that the Decked-Out Disc Catcher was very effective at catching discs. Also, it was sufficiently sturdy and did not damage discs. The final design weighs less than 20 lbs. and collapses to half its original size.

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Appendix B: Brainstorming