The Eco-Cone

A Recyclable Drink Container for Marathons and Races

EDSGN 100-012, Team 1
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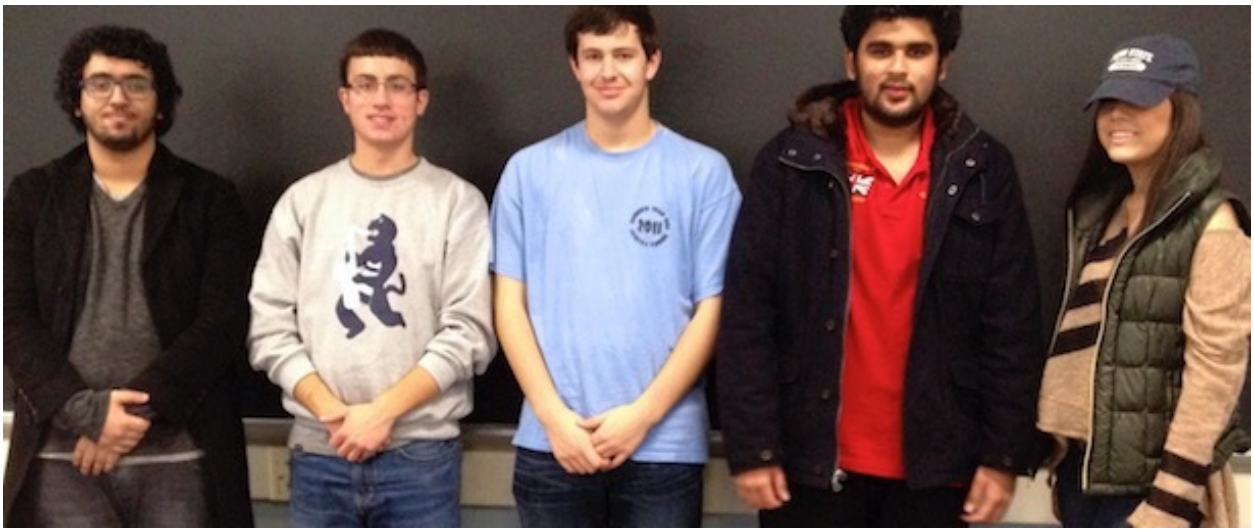
http://sedtapp.psu.edu/design/design_projects/edsgn100/fa13/



Left to right: Mohammed Alktebi, Nick Caggiano, Jared Anapolle, Adi Singh, Morgan Geraghty

Summary
Team One's goal was to make a 100% recyclable, one-time-use drink container specifically for use in marathons and other races across the country as well as in the Penn State and State College community. Each year millions of non-recyclable paper cups are used once in marathons and races and then tossed on the ground to be sent to a landfill. Team One has developed a solution that will increase the recycling process immensely by using aluminum cups as a more sustainable alternative to the currently used paper cups. The team chose a cone design with the goal of creating an easy to hold container while minimizing the amount of aluminum used. However, the Eco-Cones will not be able to stand on their own and therefore necessitated the development of a reusable aluminum stand. With a cost efficient manufacturing process, the Eco-Cone could present a viable alternative to paper cups used in marathons and races.

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Introduction

Today's engineer is very much concerned about the environment, resulting in the development of eco-friendly products and technologies. As engineers, it is the team's responsibility to develop objects that are made from sustainable materials. The team defined sustainability as imparting a positive impact on environment and economy by way of recycling and other environmentally responsible practices of product design and operation. The Alcoa Project has provided the team with the opportunity to contribute to the eco-friendly generation of engineering.

The major issue that concerned the team was the use of paper cups. Being in a college where plastic and paper cups are very common, the team decided to work on paper cups where they have a major impact. One such place where the paper cups have a major impact is in marathons and races, where drinks are often distributed to runners in paper cups. The team decided to continue with this idea of replacing paper cups used in marathons with materials that are more eco-friendly. The next step was to gather information about the cups used in marathons. At first a survey was carried out that gathered information about the kind, number of cups used in the marathon and the idea about using aluminum cups in marathons. The next step consisted of gathering information from couple of directors of the race clubs about the size and the number of cups used in the marathon. The race directors were also asked about their opinions about using alternate materials that is less harmful to the environment and can be reused.

Through the information that was gathered, it was found out that currently the paper cups used for the purpose of water consumption during races are made of paper. These cups are used and immediately disposed of. These cups are non-recyclable and non-composable because they are lined with plastic that makes it harmful for the environment. This makes it more important to use a different material that has less environmental impact than plastic lined paper cups. As an alternative, the team decided to develop an alternative made of aluminum.

Concept Development

After initial brainstorming, the team decided to consider three different concepts. One idea was an aluminum under-bed storage container to replace the ubiquitous storage containers made of plastic (Figure 1). A couple team members had experienced problems with plastic storage containers breaking; aluminum could be a more durable material for these storage containers, thus reducing the amount of waste generated by people disposing of broken storage containers. Moreover, when aluminum containers need to be disposed of, they could be recycled more more easily than their plastic counterparts. Although some types of plastic are recyclable, when plastic is recycled it typically degrades in quality. Therefore, a new plastic container cannot be manufactured from a recycled plastic container. Also, this degradation in quality also limits the number of times plastic can be recycled. Aluminum, however, does not suffer from these limitations; it can be recycled an almost infinite number of times with little to no reduction in quality.

Figure 1: A typical plastic under-bed storage container
Source: http://s3.amazonaws.com/spacesavers/14329-28-quart-clear-plastic-underbed-storage-tote-by-sterilite_1_375.jpg

Another idea presented by the team was for the development of aluminum bed risers. The motivation behind this idea was similar to that behind the idea of an aluminum under-bed storage containers. Bed risers are another dorm room accessory that many student own, but they are currently manufactured mainly of plastic (Figure 2) and they were thought by the team to be prone to breakage. Additionally, it was speculated that many student do not have any use for bed risers after moving into off-campus living arrangements. The disposal of plastic bed risers when they are no longer needed presents a similar problem to that of plastic under-bed storage containers when they break or reach the end of their useful life. Bed risers made from recyclable aluminum would also be expected to

Figure 2: A typical plastic bed riser
Source: http://images.containerstore.com/catalogimages/111518/BedRisers_l.jpg

be more durable than plastic bed risers, thus also reducing the waste generated by the disposal of broken bed risers.

The third idea was a one-time-use, recyclable aluminum cup for use during marathons and other races. Currently, paper cups are the most common container used to distribute drinks during races and marathons (Figure 3), but (as with most hot and cold paper drink cups) they are often not recyclable nor compostable due to the presence of a thin layer of wax or polymer inside that prevents liquid contents from seeping through the paper.

Figure 3: Paper cups at a typical hydration station at a race or marathon.

Source: http://commons.wikimedia.org/wiki/File:Gatorade_cups_at_marathon.jpg

An aluminum drink container would present a much more recyclable alternative. At marathons and races, the cups are usually used for a quick drink and then are immediately disposed of, resulting in piles of empty cups strewn across the race path and sidelines (see Figure 4).

Figure 4: Empty paper cups pile up at a marathon.

Source: http://2.bp.blogspot.com/-VuYri5Y2-nw/TjDBnBuCfoI/AAAAAAAACBo/PrMWYnAKNKw/s1600/piles_of_empty_cups_lg.jpg

In the New York City Marathon alone, 2.3 million paper cups are used[1]—a huge amount of waste destined for a landfill. Because the cups are usually used and then disposed of immediately (runners do not run with the cups in hand), collection bins designated for the aluminum cups could be placed near the water sources. Runners typically grab a cup of water, drink it, and dispose of it on the spot, and it is likely that a large percentage of the cups could be collected and then recycled—the goal would be close to a 100% collection rate. This is the reason the team chose to develop cups specifically for use in marathons and races.The near-100% recycling rate is a critical component of the design and application of the product; in settings other than marathons and races, the potential benefits of aluminum drink containers could be negated by people simply disposing of the containers in a landfill. If used in a normal drink setting, the recycling rate would likely decrease drastically. In the United States, for example, only 29% of PET bottles (typically used to hold soda and water) are recycled[2]. Moreover, selling the disposed-of aluminum to a recycler would help to offset the expected additional cost of aluminum container over the very inexpensive paper cups that are in use today.

In order to down-select from these three ideas to two ideas to research further, the team created a design selection matrix with different features thought to be important to the concepts,

as well as a weighting system that accounted for the relative importance of each feature. (This design selection matrix is included in full in Appendix A.) Features included in the matrix were the potential cost advantage of the new (aluminum) product as compared to the current product; the rate of recycling potential for the new product (how likely is the product to be recycled by the consumer?); the potential impact for the new product on society (how much of a benefit would the new product be for the environment and for society?); the overall advantage of the new product as compared to the current (an estimation of the potential benefits as compared to the drawbacks of producing the product out of aluminum instead of the current material); the relative durability of the new product as compared to the current product. The aluminum drink container for marathons and races received the highest score in the design selection matrix, while the aluminum under-bed storage container concept received the second highest score. As a result, those two ideas were chosen by the team for further research.

In order to conduct further research on both the marathon/race drink container and under-bed storage concepts, two surveys were created using www.surveymonkey.com and subsequently posted on social media sites such as Facebook in order to gather responses from a variety of people. However, it is acknowledged by the team that there is the possibility of some slight survey bias in the responses due to fact that the population using Facebook is skewed towards younger age groups. This bias is likely present in a higher degree in the marathon/race drink container survey, as race and marathon runners are not always in the younger age groups and thus may not have been adequately targeted by this survey (hence the additional direct contact with race directors). The survey bias is not likely as substantial for the under-bed storage survey, as its main audience was typical college students, a demographic to which the team believes the survey was adequately distributed to using social media.

The results from the marathon/race drink container survey, which can be viewed in full in Appendix A, indicated that the majority of containers used to distribute drinks during marathons and races are paper and plastic (Survey 1, Q4). Additionally, a large percentage of respondents (over 76%) said that drinking cups for water were provided during the last race they ran (Survey 1, Q3). This information, along with the responses to the other questions in the survey, indicated a large potential positive societal and environmental impact for a sustainable drink container.

The survey results from the under-bed storage container storage, which can also be viewed in full in Appendix A, did not indicate that there was as large of a potential for positive societal and environmental impact for an aluminum under-bed storage container. While 90.7% of respondents said that they used under-bed storage containers (Survey 2, Q4) and over 81% of respondents indicated that the under-bed storage solution they use is made of plastic (Survey 2, Q5), the main problem with the survey responses was that a relatively small proportion (18.6%) of respondents indicated that they had experienced problems with the durability of their under-bed storage containers (Survey 2, Q6).

The team's correspondence with two race directors further seemed to support the development of a sustainable drink container. Mr. David Eggler of the Nittany Valley Running Club stated, "I'd be open to using recyclable aluminum [for drink containers used during races]," but he also made a point to mention that he buys paper cups for roughly $0.03 per cup and that cost is a major consideration for race directors. Mr. Gary Lackey, a race director in western PA, stated that at the his last race plastic water bottles were handed out to runners at the finish line. While plastic bottles are more recyclable than paper cups, they are still not nearly as recyclable as aluminum. Also, another environmental concern for water bottles is the increased cost and environmental impact that occurs as a result of transporting bottles filled with water, which weight much more than empty paper cups or aluminum containers that would be filled with water on-site. Therefore, as a result of this survey, the team decided to develop a sustainable aluminum drink container for use at marathons and races.

Detailed Concept Development

The design for the marathon cup went through many stages of research and design, including much brainstorming (Figure 5). The first consideration was a design that would be the most efficient. These details include the volume, storage ability, ease of use, and reusability.

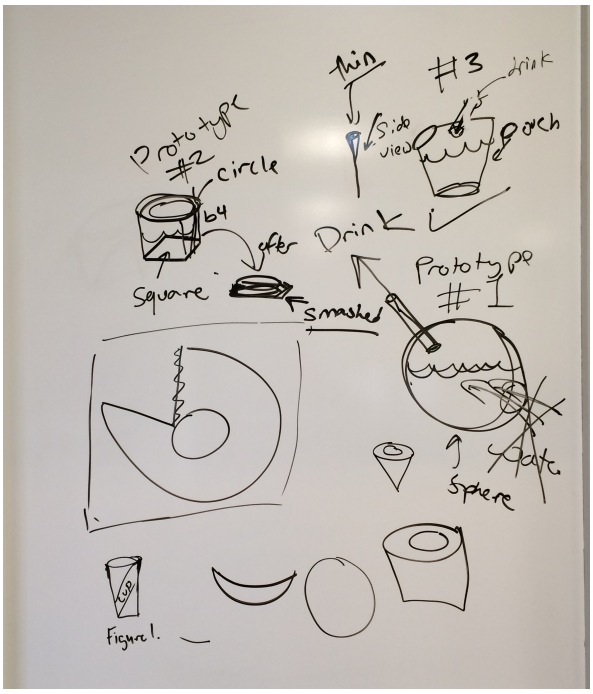


Figure 5: Initial Team Brainstorming on Whiteboard

For the material, an aluminum foil style was decided as best for the design. Compared to other materials such as paper or a soda can style aluminum, this a clear winner. It is very lightweight and is 100% recyclable. Also, this style of aluminum would be easy to manufacture the cup from.

The other design choice for the cup was shape. During research three designs were considered: tapered cylinder—the shape of a typical paper cup (Figure 6), sphere (Figure 7), and cone (Figure 8). While considering the three concepts we went through two types of tests to consider the designs. First we built each cup on the SolidWorks program to look at sizing, shape, and overall design. Next, we used aluminum foil to build a prototype of each of the cups. Prototyping was also done with aluminum foil

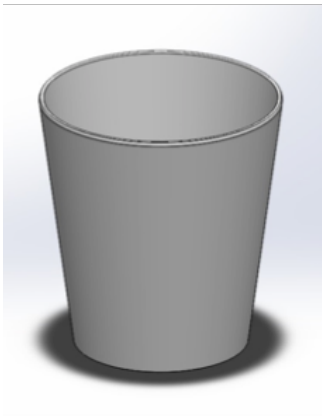


Figure 6: Cylindrical Cup Prototype

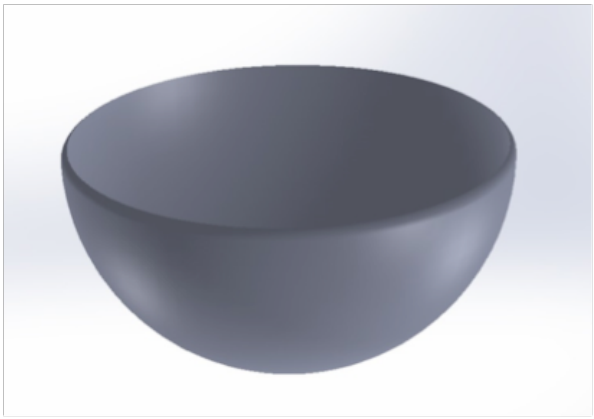


Figure 7: Spherical Cup Prototype

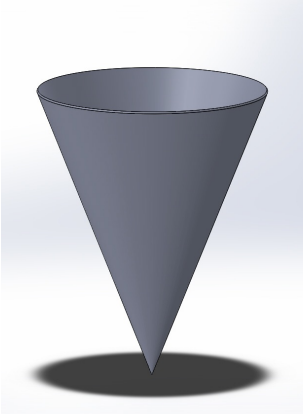


Figure 8: Conical Cup Prototype

because that is what we chose to be the material of choice for our cup design. This was done to look at the actual size of the cup, but also to see with was the easiest to manufacture. After going through these two tests it was decided the cone shape cup would be the best. The cone cup had a couple of advantages over the other designs. First, it would be the easiest for a runner to hold for that short time period he needs to in the race. Secondly, it has the best ability to minimize surface area while maximizing volume. This allows the cup to hold a maximum amount of material while minimizing the aluminum need to make the cup.

By going with a cone design, one other design aspect was added. A tray to hold the cups on the table was created (Figure 9). The material for the tray however would need a slightly thicker material than an aluminum foil style. It was decided a soda can style aluminum would be best. It is a lightweight aluminum that is still sturdy, and can minimize the material needed. Unlike other materials such as an aluminum alloy, the soda can style aluminum would not be needed to be cut from a block of aluminum. Sheets of aluminum could simply have holes punched out of it. This makes the trays very easy to manufacture, it greatly cuts down the aluminum that would've been wasted from cutting the trays out of a block of aluminum.

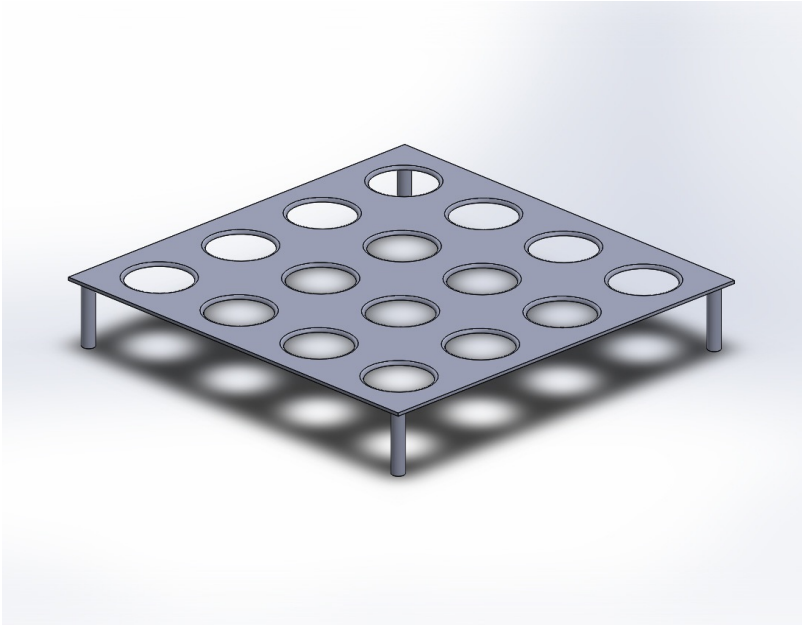


Figure 9: Aluminum Stand Prototype for Eco-Cone

Cost Analysis (see details in Appendix C)

There are two different ways to analyze the cost of the Eco-Cone. First is by the Excel sheet. According to the to the Excel sheet, the profit from the Eco-Cones will be around 35% if 500,000 units were manufactured at a price of $0.288 per unit. Also, the for the profit to be around 35% the annual cost is $99,600 which includes labor cost, energy cost and material cost added together and the first cost of the Eco-Cones is $75,200. This includes a new manufacturing machine, NRE engineer and a supervisor.

Another way to calculate the cost of the Eco-Cone is by calculating the surface area of both the Eco-Cone and a typical 12-oz soda can. This can be turned into a ratio and used to estimate the price of manufacturing the Eco-Cone out of the same aluminum as soda cans (assuming the instructor-provided price of $0.14 as the cost of manufacturing one aluminum soda can). By this calculation, the manufacturing price per cone would be $0.062 (see full calculations in Appendix C). This would allow the Eco-Cone to be sold at a retail lower price per unit.

Lastly, another factor in the cost of the Eco-Cone is the price that recyclers will pay for the aluminum after it has been used. The money made by selling the used Eco-Cones to recyclers could potentially offset some of the purchase cost of the Eco-Cone. Assuming the amount of aluminum in one soda can is 14 grams, using the ratio of surface areas between the Eco-Cone and soda can it was determined that each Eco-Cone would have 6.22 grams of aluminum. At a recycling buyback price of $0.14 per pound[3], for roughly every 73 Eco-Cones, $0.14 is paid back. This is the recycling buyback price of the Eco-Cones.

Conclusions

The Eco-Cone presents a more sustainable alternative to the typical paper cups that are used in today's races and marathons. Since it is manufactured from aluminum similar to that used in soda cans, it can be easily recycled. The impact on society and the environment therefore has the potential to be large. A total of 2.3 million cups are used in the New York City Marathon alone[1], and across the United States 570 marathons are held every year[4], along with thousands of other shorter races. Replacing paper drink cups with the Eco-Cone has the potential to divert millions of cups from the rapidly-filling landfills across the country.

The Eco-Cone effectively addresses the design feature of a high collection/recycling rate, since runners will be expected to drink from the cups and then throw them on the group or in designated containers, as is already the norm with paper cups. It would most likely be beneficial for race directors to designate and mark certain receptacles solely for the Eco-Cone and other aluminum.

Durability was a factor the team chose to de-emphasize while developing the Eco-Cone. It was viewed as unnecessary to create a very durable container when it will only be used once and then disposed of. If manufactured of aluminum sheet similar to that used in aluminum soda cans, the Eco-Cone is expected to be durable enough to withstand the one-time use by runners. Any effort to make the Eco-Cone more durable would likely have resulted in a less sustainable solution, as more aluminum would have to be used in the manufacturing process to make a stronger cone.

The team's analysis determined that despite the potential environmental benefits of the Eco-Cone, the driving force behind decisions is often economics. Aluminum is simply a more expensive material than paper, which is reflected in the projected cost of the Eco-Cone. With a 35% profit consideration, the Eco-Cone would have to retail for upwards up 20 cents per cone—potentially up to 30 cents. This is up to a tenfold increase over the cost of a typical paper cup, which Mr. David Eggler stated was about 3 cents per cup. In addition, another possible disadvantage of the Eco-Cone is it's shape; it cannot stand on its own, and it requires a stand to hold it in an upright position. (However, as discussed earlier, this design could actually be be more comfortable for runners to hold.) During marathons and races, drink cups are typically

lined up on tables for runners to grab as they run by. Race officials would not be able to distribute the necessary quantity of drinks if they had to hand the cups to runners, especially in large events such as the New York City Marathon. This stand is also an additional cost of the Eco-Cone, although it is noted that it is a one-time cost. However, for races and marathons that currently use paper cones to distribute drinks, the infrastructure to distribute cones (or hold them upright) is likely already present, so implementing the Eco-Cone would involve a lower additional cost than transitioning from paper cups to the Eco-Cone.

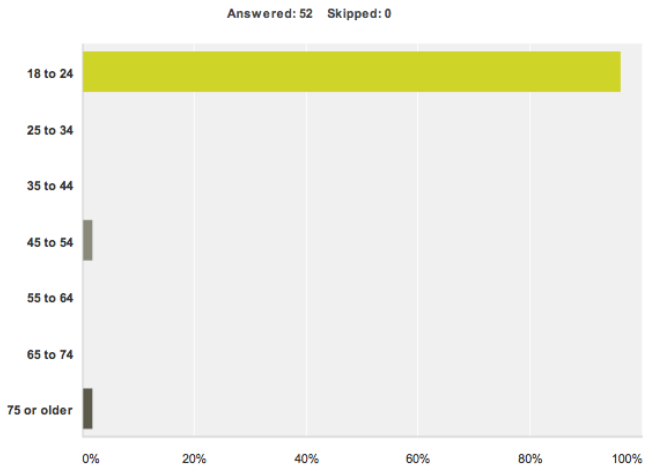
Although the Eco-Cone concept is a more sustainable alternative to the current paper cups, the team acknowledges that due to the high cost of implementation of the Eco-Cone relative to the cost of paper cups, stakeholders are not likely to adopt the product. One possible solution would be to investigating ways to further reduce the cost of the Eco-Cone, possibly by using thinner aluminum similar to heavy-duty aluminum foil. Another idea would be to create an aluminum drink container that can stand upright unaided. This would eliminate the need for a cone-stand, thus reducing the overall cost of implementation. However, it is noted that such a design would likely increase the manufacturing cost of the container itself. Overall, though, the team does maintain that race directors and coordinators could possibly be compelled to switch to a more sustainable alternative to paper cups if enough runners voiced their opinion regarding the matter. If a majority of runners were in support of a more sustainable cup design, it is possible that race directors and coordinators would consider such an alternative, even if there is a cost increase associated with it.

Appendix A

Table 1. Design Selection Matrix							
Weight	**Feature**	**Marathon Cups**		**Under-Bed Storage**		**Bed Risers**	
		Score	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**
3	Cost advantage	3	9	3	9	3	9
4	Rate of Recycling Potential	5	20	3	12	2	8
5	Impact on Society/ Environment	5	25	3	15	3	15
2	Overall Advantage vs Current Product	5	10	4	8	4	8
1	Durability vs Current Product	2	2	5	5	5	5
	TOTAL	—	66	—	49	—	45

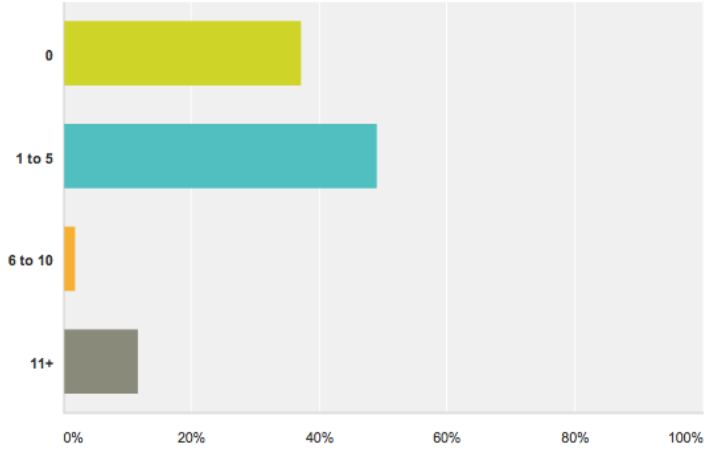
Survey Results - Marathon/Race Drink Containers (Survey 1) (conducted via surveymonkey.com)

Q1: What is your age?



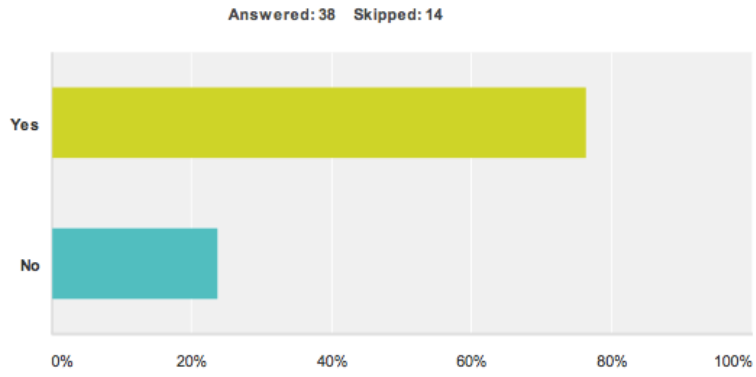
Answer Choices	Responses	
18 to 24	96.15%	50
25 to 34	0%	0
35 to 44	0%	0
45 to 54	1.92%	1
55 to 64	0%	0
65 to 74	0%	0
75 or older	1.92%	1
Total		52

Q2: How many races have you run in the last year?



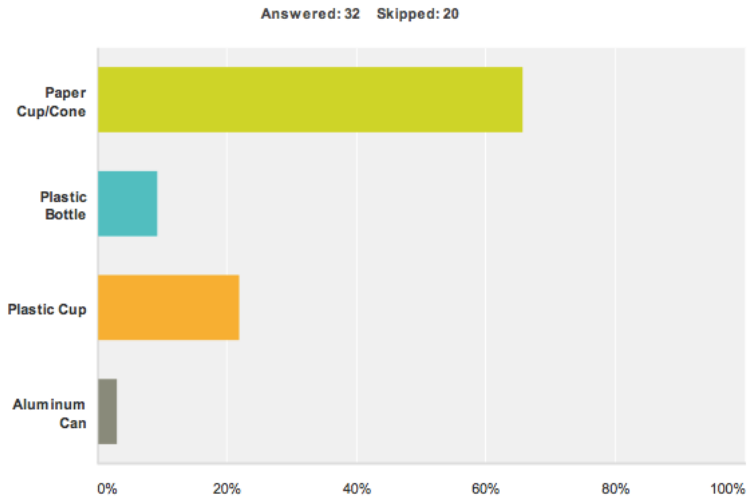
Answer Choices	Responses	
0	37.25%	19
1 to 5	49.02%	25
6 to 10	1.96%	1
11+	11.76%	6
Total		51

Q3: If you have run a race in the last year, were there drinking cups for water provided at the race?



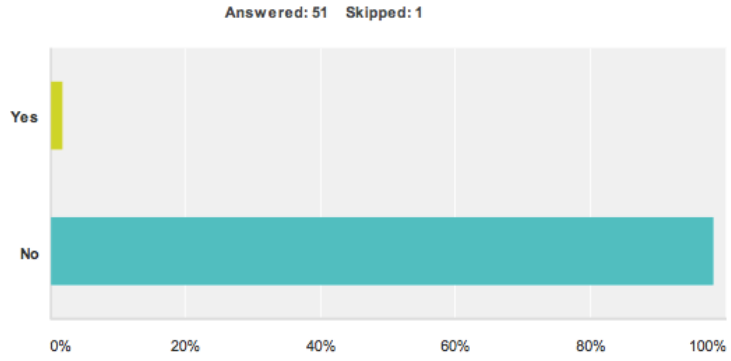
Answer Choices	Responses	
Yes	**76.32%**	29
No	**23.68%**	9
Total		38

Q4: If water was provided at the race, what type of container was used?



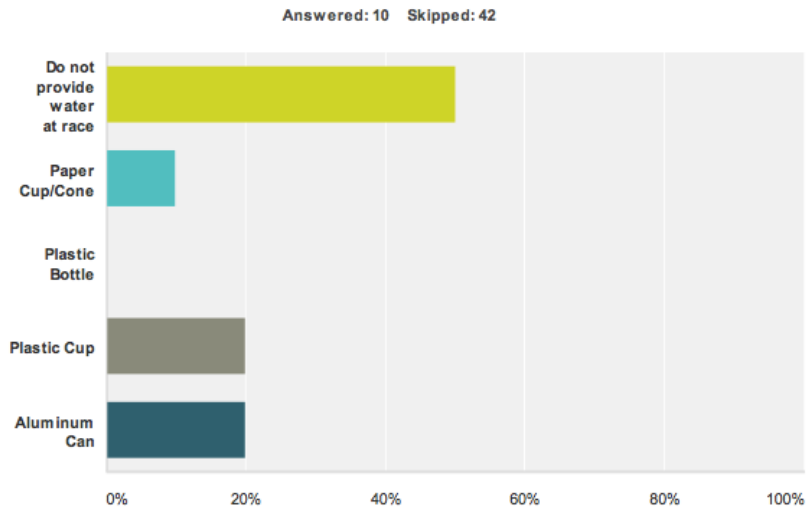
Answer Choices	Responses	
Paper Cup/Cone	**65.63%**	21
Plastic Bottle	**9.38%**	3
Plastic Cup	**21.88%**	7
Aluminum Can	**3.13%**	1
Total		32

Q5: Are you a race coordinator?



Answer Choices	Responses	
Yes	**1.96%**	1
No	**98.04%**	50
Total		51

Q6: If you are a race coordinator, what container do you use to distribute water at your races?



Answer Choices	Responses	
Do not provide water at race	**50%**	5
Paper Cup/Cone	**10%**	1
Plastic Bottle	**0%**	0
Plastic Cup	**20%**	2
Aluminum Can	**20%**	2
Total		10

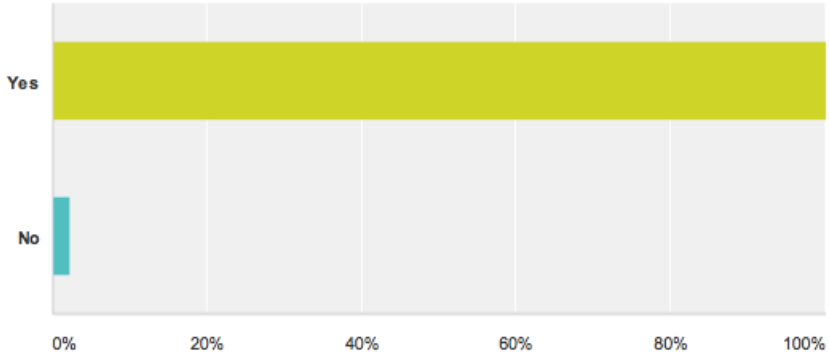
Q7: If you provide water at your races, (on average) how many containers do you buy per race?

The responses to this question were collected in text form. Unfortunately, most of the responses were either of an inappropriate nature or did not address the the question and therefore will not be reproduced within this report.

Survey Results - Under-bed Storage (Survey 2) (conducted via surveymonkey.com)

Q1: Are you a current college student?

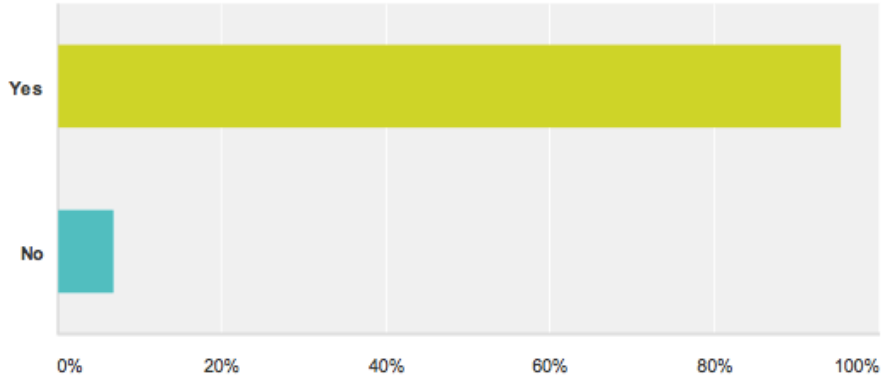
Answered: 43 Skipped: 0



Answer Choices	Responses	
Yes	**100%**	43
No	**2.33%**	1
Total Respondents: 43		

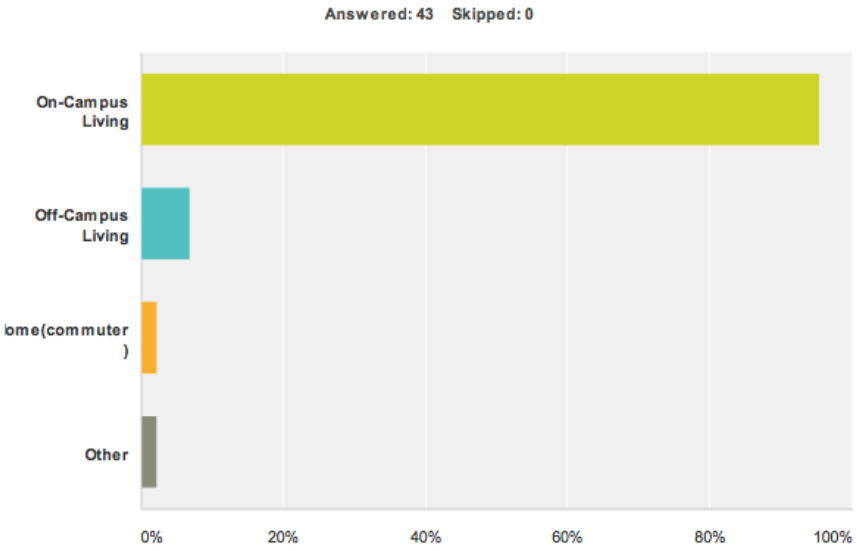
Q2: If so, do you attend Penn State?

Answered: 43 Skipped: 0



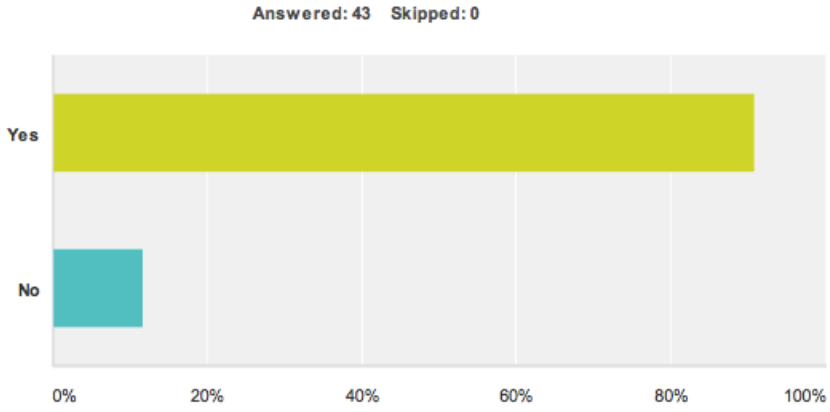
Answer Choices	Responses	
Yes	**95.35%**	41
No	**6.98%**	3
Total Respondents: 43		

Q3: What is your current housing?



Answer Choices	Responses	
On-Campus Living	**95.35%**	41
Off-Campus Living	**6.98%**	3
Home(commuter)	**2.33%**	1
Other	**2.33%**	1
Total Respondents: 43		

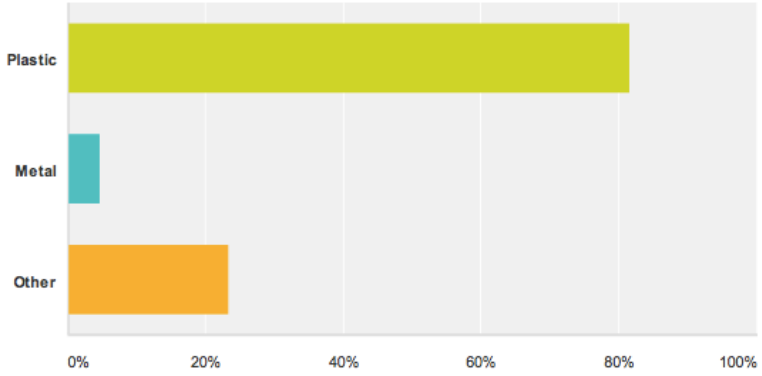
Q4: Do you currently use under bed storage?



Answer Choices	Responses	
Yes	**90.70%**	39
No	**11.63%**	5

Q5: If so, what material is it made of?

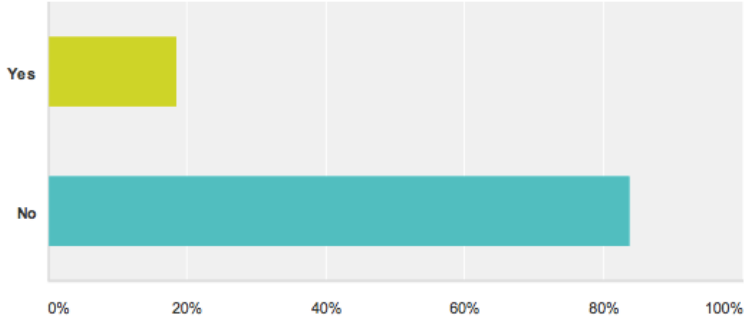
Answered: 43 Skipped: 0



Answer Choices	Responses	
Plastic	**81.40%**	35
Metal	**4.65%**	2
Other	**23.26%**	10
Total Respondents: 43		

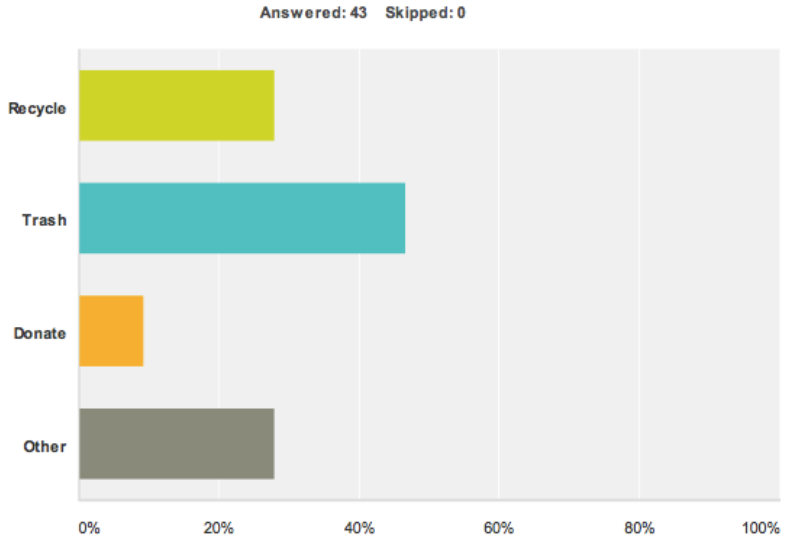
Q6: Have you ever experienced a problem with the under bed storage breaking?

Answered: 43 Skipped: 0



Answer Choices	Responses	
Yes	**18.60%**	8
No	**83.72%**	36
Total Respondents: 43		

Q7: If you had to dispose of the storage, how did you do it?



Answer Choices	Responses	
Recycle	**27.91%**	12
Trash	**46.51%**	20
Donate	**9.30%**	4
Other	**27.91%**	12
Total Respondents: 43		

Appendix B
Email Correspondence with Race Directors/Coordinators

"Typically paper cups are used. They are easier for runners to fold across the top (so water won't splash out while you are running -- runners don't like to stop completely while running) and it's felt (wrongly maybe) that they are recyclable. I figure one cup per runner per water station. A 5K race typically has 1 stop. Big city marathons have a station every mile. The Nittany Valley Arts Festival 10K has 4 stops. The NV Half Marathon has 3 stops. I'd be open to using recyclable aluminum. Maybe they'd be thin enough so they could be creased along by the top by a runner. Cost is a factor. A race director wants to save money wherever possible to maximize profit to whatever charity the race benefits. I buy paper cups at Sam's Club. 300 cups are $8 to $9, as I remember."

-Mr. David Eggler (Nittany Valley Running Club)
(Received November 19, 2013)

<u>Original Message</u>
Hi Mr. Eggler,

Professor Kisenwether of our EDSGN 100 course gave us your contact information and said you might be willing to answer a few questions for us. Our group's project will likely include an analysis and proposal of a more sustainable alternative to the disposable paper cups typically used at races to distribute water to runners. We noticed that the vast majority of these cups are used only once at races and then are disposed of by runners. However, many paper cups are coated with polymers or waxes and are therefore not easily recycled or composted. One possible alternative we have discussed is creating lightweight, one-time-use aluminum cups that are completely recyclable.

Mainly, we wanted to get a feel for:
-What types of cups are typically used at races (e.g. paper, plastic, etc)?
-How big are the cups?
-How many cups are typically used at a race (either total or on a per runner basis)? (We acknowledge that this likely depends on the length of the race)
-About how far apart are the water stations separated along the race route?
-Do you think Nittany Valley Running Club would be open to switching to a more sustainable/ recyclable container for distributing drinks during races?

Thank you for any and all answers and feedback, and if you know of anyone else who might be able to provide more feedback we'd greatly appreciate it if you could put us in contact with them.

Thanks again for your time,
Nick Caggiano
EDSGN 100-012, Team 1

”I'm not sure I can help you with this. The Gobble Wobble is 3.1 miles, it occurs inside Buhl Park, and we don't have any water stops on the race course. We have 1000 donated plastic bottles of water and 500 donated cardboard cartons of orange drink at the end. This was the last year for the orange drink. Next year we'll do all water.
We have large barrels (owned by the park) set out to collect the empty containers, and we sweep the finish area before we leave the park on Thanksgiving morning to make sure everything has been picked up. The park then disposes of whatever has been collected. It was cold this year, and we had very little to collect. Most of the participants, if they took water, didn't hang around too long and apparently took the bottles home with them.

While we toyed with the idea of a water stop, the weather on Thanksgiving is rarely so warm that the participants are getting over heated during the 3.1miles.

From personal experience, when I am in a race where water is available, usually longer races around here, many of the participants fold their cups to create a smaller opening to sip from. I like a smaller dixie cup, with maybe only a couple ounces of water in it. I ran a 10k in June in Beaver on a 3.1 mile loop course, with 2 water stops, so you hit each one twice. They used large 16 oz. cups with a couple of ounces in each cup. They were easy to hand out, but clumsy for the runner to handle while running, and a nuisance on the road. I ran a 10k on a hot day in August (the Panerathon in Youngstown) on a 3.1 out and back course, and they had one water stop at 2 miles, so you hit it twice, but it was under-staffed. They used smaller cardboard cups, which were harder to grab as you ran by, but easier to handle while running. They were also easy to trample as I ran through the water stop area. For a 10k in August, it was not enough water stops. I was looking for water with a mile to go.

If you think talking with me or e-mailing me would beneficial to your grad students, I'd be happy to help, but I don't have a lot of experience in designing water stops.”

-Mr. Gary Lackey (Race Director in western PA)
(Received December 4, 2013)

Original Message
Quick question: would you be willing to answer some questions from one of my first-year engineering students regarding use of drinking cups during road races? As a very experienced road race director, we would like to tap your insights into water stations, how the used paper and plastic cups are collected after use, and some new ideas the student team has about changing to 100% recyclable aluminum cups.

(sent by Professor Kisenwether)

Appendix C

Excel Costing Spreadsheet

Eco-Cone Cost Analysis - Team 1 Alcoa Project - Fall 2013

Discount rate	0.75%	Current U.S. discount rate (2013)
First Cost	$75,200	assumes $75,000 capital for maching life of 500,000 units and NRE cost of $43,500
Annual Cost	$71,000	assumes fuel & electricity to produce 1 can is $.14, material per can is $.04 and labor is $40k/year
Number of units sold annually	500,000	this is the output per machine….
Cost per Unit	$0.21	this number adjusted to get to ~ 35% profit

Year	First Cost	Annual Cost	Annual Income per Unit
0	$75,200	$71,000	$105,000
1		$70,471	$104,218
2		$69,947	$103,443
3		$69,426	$102,672
4		$68,909	$101,908
5		$68,396	$101,150
6		$67,887	$100,397
7		$67,382	$99,649
8		$66,880	$98,907
9		$66,382	$98,171
10		$65,888	$97,440
NPV	$75,200	$752,570	$1,112,956
Profit %			34.5%

For First Cost ($75,200):
1. new manufacturing machine = **$50,000** initial cost
2. Cost of land and buildings not included; assume the new machine is installed in exisiting factory
3. NRE based on one engineers each working 2 months for $5000/month wages + one supervisor working 1/4 time for 2 months for $8000/month. Total wages = $14,000 x 1.8 (Overhead) = **$25.2K**

For Annual Cost ($99600) :
1. Energy / electricity used to produce one can:
   a) energy saved in recycling one can = 100 watts x 4 hours = 0.4 KWh
   b) not recycling a can is equivalent to throwing away 1/2 can (or 5 oz.) of gasoline
   33.41 KWh/gallon of gasoline and 128 ounces per gallon

Effect of not recycling = 33.41 KWh/gallon x 1 gallon/128 ounces x 5 oz. = 1.31 KWh
So energy to produce one can = 1.31KWh - 0.4KWh = 0.91KWh
Average cost of electricity in U.S. is $.12 / KWh
Electricity Cost to produce one can = $.12/KWh x 0.91 KWh = $.1092

2. Material costs
   a) aluminum per can = $0.01
   b) but virgin aluminum must be added to process because we don't recycle 100% of cans…
   c) assume total material cost per can = $.01

3. Sum of energy and material costs per can = $.1092 + $.01 = $.1192 / can
   Cost for production run of 500,000 cans = $.1192 / can x 500,000 cans = **$59600**

4. Annual labor cost: assume one person at **$40,000** per year (overhead included)

Alternate Costing Method

Dimensions of the Eco-Cone: cone with 4 cm radius (r = 4cm), 10 cm height (h = 10cm)

Surface area (SA) of Eco-Cone = $\pi r\sqrt{r^2 + h^2}$ = 135 sq. cm

Typical 12-oz soda can: cylinder with 1.25 in radius, 4.75 in height

Surface area of soda can = $2\pi r^2 + 2\pi rh$ = 47.1 sq. in = 304 sq. cm

Therefore: SA Eco-Cone/SA soda can = 135/304 = 0.444 (in other words, the amount of aluminum in one Eco-Cone is .444 times the amount of aluminum used in a soda can and should be .444 times the cost as well)

So: if a soda can costs (.444)(.14 cents/can) = $0.062 per Eco-Cone to manufacture

Soda can: 14 grams of aluminum

(source: http://voices.yahoo.com/how-recycle-aluminum-foil-6709014.html?cat=57)

Eco-Cone: .444(14g) = 6.22g

Recycling buyback price: $0.14 per pound

1 pound = 0.454 kg = 454g

454g/6.22g = 73 Eco-Cones per kg

For roughly every 73 Eco-Cones, $0.14 is paid back by recyclers.

References

[1] http://www.thirteen.org/metrofocus/2011/11/everything-you-always-wanted-to-know-about-the-marathon/

[2] http://www.epa.gov/osw/conserve/materials/plastics.htm

[3] http://peninsulasanitationservice.com/recycling/buy-back-recycling-centers/

[4] http://www.statisticbrain.com/marathon-running-statistics/