

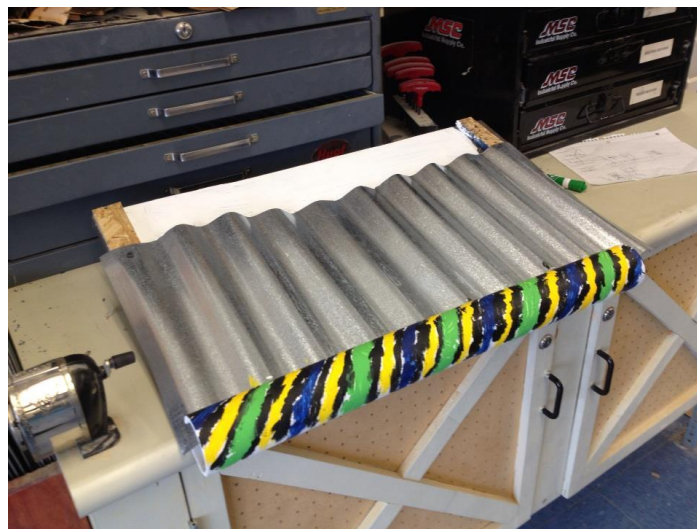
EDSGN 100, Section 20, Group 5, The Green Elephants
Spring 2013

Elizabeth Kisenwether

Design for Emerging Markets: Kenyan Rainwater Gutter System



The Kenyan Color Gutter



Brennan Heiser – Research and Cost
Analysis Section 2, 3, 5, 6

Jacob Wallace – Designing prototypes
and Cost Analysis Section 5, 6

Alex Yanovich – Information
Recorder, Research, Final Editor, and
Continuity Checker Section 1, 4, 5, 6

Dan Deegan – Prototyping, Team
Photographer, Video Recorder Section 6, 7

Problem statement: To produce a gutter system attachable to a corrugated tin roof that supports needed rain water harvesting in Kenya only using local materials with a total cost of \$1 per meter of gutter.

Concept Development

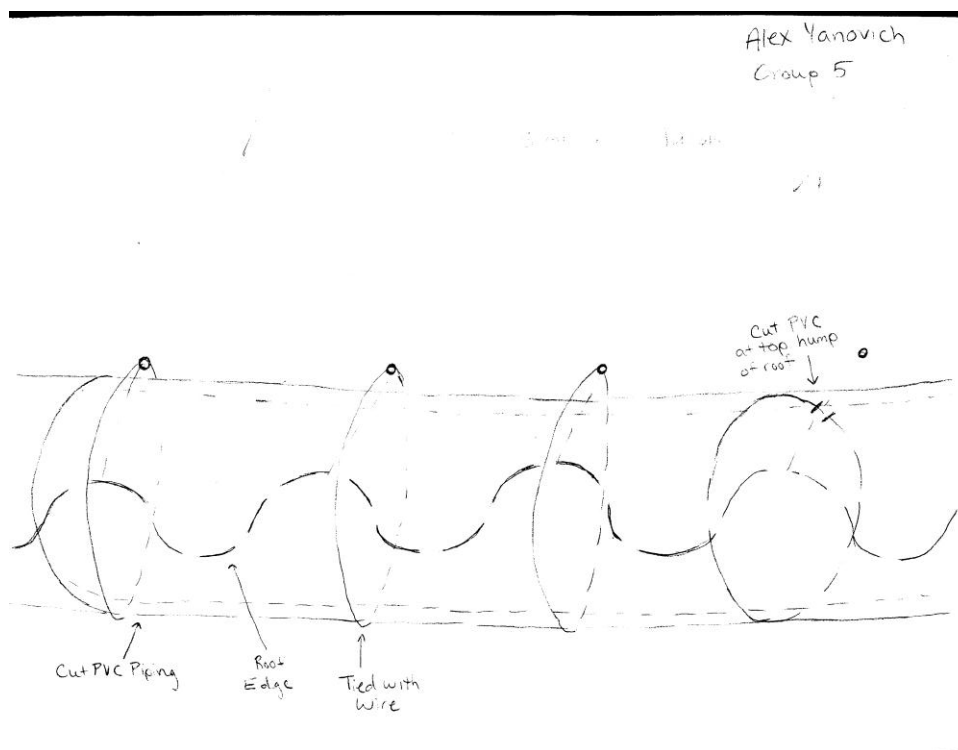
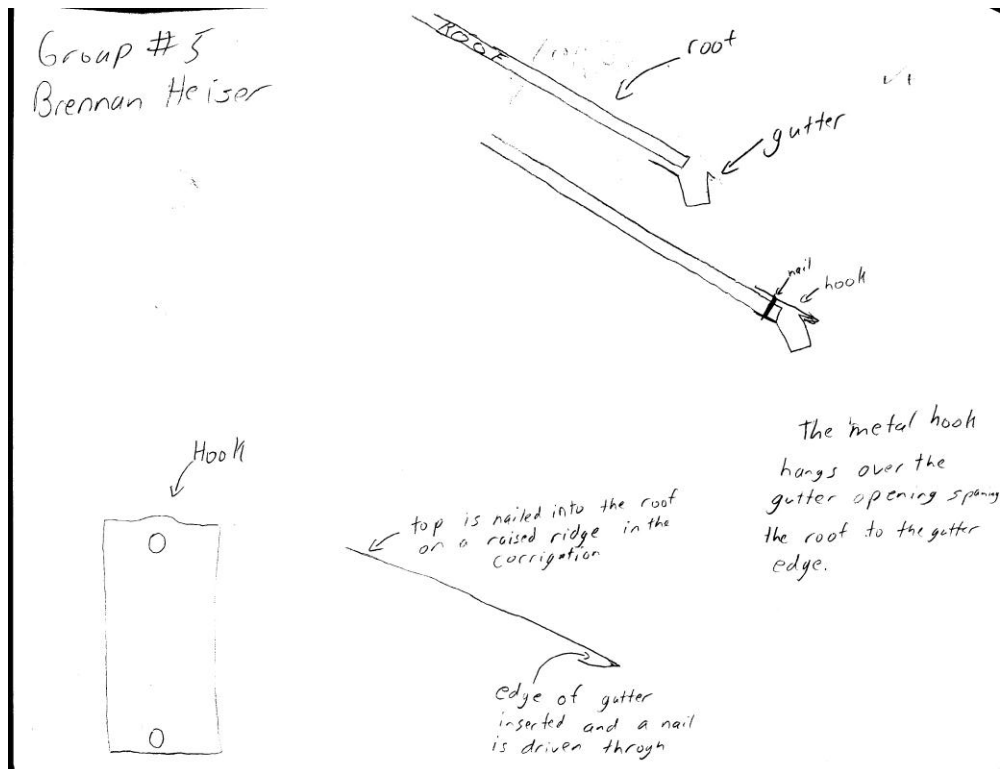
Collecting Information: In order to gather adequate information about Kenya (the environment, the average income, and the general materials and technologies available) the team began by researching how the tin roofs in Kenya were constructed. This information would provide a base for all further research on the gutter design. A simple Google search provided a plethora of images of how the corrugated tin roofs were attached to the houses in Kenya. From these images the environment our design had to adapt to was ascertained. From this point our team split into researching the maximum rain fall in Kenya and the materials readily available there.

From the information gathered about the setting our design had to function in, and after reviewing the requirements our design had to meet; the group came up with the following design features to be included in and tested by prototype #1.

Desired features of prototype #1: The design uses a minimal amount of materials, the design only uses materials available in Kenya, the design is functional all over Kenya, the design can be maintained with simple tools, the design efficiently diverts water to a possible rain water harvesting system, the design is durable enough to last for at least ten years with minimal maintenance, the design is easy to repair at low costs. The following Analytic Hierarchy Process table was the final result of the research done.

	minimal amount of materials	local material s	functional all over Kenya	maintained w/ simple tools	efficient	simple	sturdy	ease of repair	TOTAL	Weight
minimal amount of materials	1	0.5	1	0.5	0.5	1	0.33	0.5	5.33	7.03%
local materials	2	1	2	2	0.5	0.5	0.5	1	9.5	12.53%
functional all over Kenya	1	0.5	1	2	0.5	2	0.5	2	9.5	12.53%
maintained w/ simple tools	2	0.5	0.5	1	0.5	0.5	0.5	1	6.5	8.57%
efficient	2	2	2	2	1	2	1	2	14	18.46%
simple	1	2	0.5	2	0.5	1	0.5	1	8.5	11.21%
sturdy	3	2	2	2	1	2	1	2	15	19.78%
ease of repair	2	1	0.5	1	0.5	1	0.5	1	7.5	9.89%
								Grand total=	75.83	

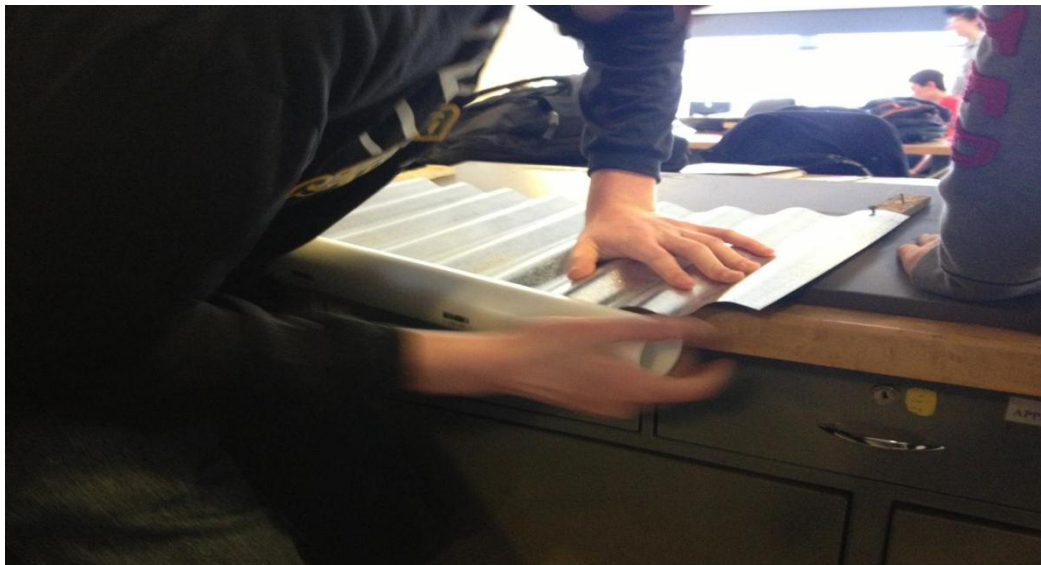
From this analysis of the research done so far, the following sketches were developed by the team:



You may have noticed from the above sketches that two main materials were considered by the group: tin sheets to make the gutters and PVC piping. When the final Prototype design was discussed, the group came to the conclusion that the simpler the design would produce a better gutter. Therefore, PVC piping was the final material decided upon for Prototype #1, because it did not involve any complex metal work.



After choosing to use a simple pvc pipe for our gutter design, we determined that cutting out a thin section and attaching it to the roof would be the simplest and most effective gutter design.



Here we are weaving the pvc piping through the corrugated roofing for a firm attachment to the roof. Using a hand saw made the attachment slightly more difficult to attach but a clean cut with power tools would make the attachment easy and timely.



Here is a close up of the pvc attached to the gutter ready for testing. Naturally wanting to form a ring, the pvc pipe has a firm grip on the roof and water can easily fit between the corrugations to be redirected.



This is the inclined prototype #1 design that we ended up with from the side view. As you can see, part of our design was having an adjustable roof so we could test water flows at different angles.

Testing - Prototype #1



This is a picture of our group testing the gutter in Prototype #1

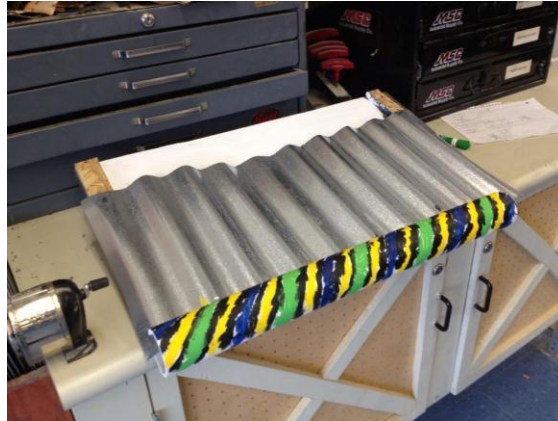
Prototype #1 testing resulted in a lot of information and brought with it newer ideas and designs that could possibly make our gutter more efficient and/or cost effective. Once our design was built, we took gallon jugs and started pouring water at a rate of $\frac{1}{4}$ gallon of water per test, to determine if the gutter worked at all. Our tests resulted in a working gutter that effectively redirected rainfall in a new path along the roof section that we built. As you can see in the picture above, the water is entirely redirected to the sides of the gutter and falls out downward at a steady rate. We also tested the waterfall at different roof angles to see if the water would still follow the original path from the first few runs. Only when the angle was very steep (approximately 60 degrees to the horizontal) did any run over the top of the pvc piping. Later, we determined that it was mostly because the rate of water we were pouring was way more than the average rainfall in Kenya over that tests time period.

This first prototype really gave an idea on what we had going for us and inspired new ideas to be tested for prototype #2. After seeing how this 2 inch pvc pipe gutter worked, we wanted to test both a smaller design and larger design to see if they worked just as well, or worse. We saw during this first prototype that cutting the pipe with a hand saw was effective, but left edges in the pipe that hindered our ability to attach it very easily. The results from cutting different sizes of gutters would really affect our final decision for pvc piping size.

Next, we wanted to test if we could dent the gutter along the attached edges for a more stable hold to the roof as well. We had not done any testing in prototype #1 on how much weight our pipe could hold so we decided that if the gutter could not hold up to 15 pounds, we would attempt to put dents in the corrugated roofing for a firmer attachment.

Lastly, we decided to do more research to find out the effects of UV radiation on the pvc piping to determine if anything needed to be done regarding a coating of some sort. Knowledge on the durability of the pvc pipe would really give us a better idea of how long this design would be capable of lasting in the Kenyan environment. With longevity for this gutter system on our minds, we prepared over the following week for prototype #2 testing.

Design Refinement (Prototype #2) and Testing



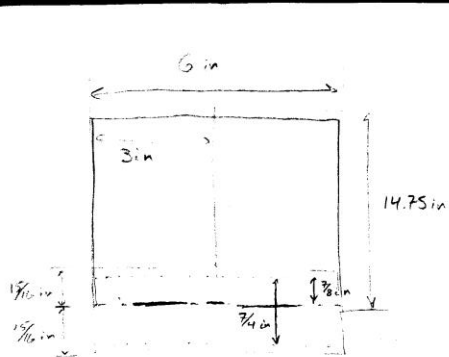
This is a picture of our final gutter Design after Prototype #2

We used the AHP to determine that there were two main things that were wrong with our prototype #1. The first thing that was wrong with our first prototype was the overall cost. The piping we were using was more expensive than a smaller diameter pipe that we could possible use instead. In the end moving to a smaller diameter piping would require much longer construction times, because we could not cut the smaller diameter pipe with the basic tools we had.

The second problem with our first prototype was the degradation of PVC in UV lighting. To fix the UV lighting we decided that painting it with generic paints would add a small cost to the overall construction while greatly adding to the life of the piping as well as the visual appeal. The paint on the PVC piping was a big success. It did not cause any change in how well the gutter collected the water but it did add a great visual appeal that most people would comment on when they walked past.

After addressing these problems we encountered with our first prototype and improving our design to address these problems, we wanted to include addition improvements into prototype #2. These included denting the tin roof so that the pipe would be even more secured on to the roof, and maybe installing wire to hold the pipe on if the pipe could be easily detached from the roof. Upon testing the denting strategy we quickly discovered that denting the roof is very difficult to do without flattening the entire roof along with it. This idea of denting was deemed too difficult and out of the realm of possibility with the simple tools we were using.

Before we attempted anymore improvements on our design at this point we decided to test how securely the pipe was attached to the roof. We did this by running wire through the pipe and attaching that wire to weights, then suspending the roof so that the only thing supporting the weights off of the ground was the pipe itself. We preformed this test with 25 pounds and no movement or instability was observed with regards to the gutter system. At this point the tin roof itself began to bend. With this information we concluded that no further attachment or modification would be necessary to hold the pipe to the roof, since the roof itself began to bend before the pipe showed any sign of becoming detached.

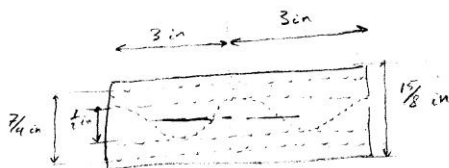


$$\sin \theta = \frac{1}{\sqrt{2}}$$

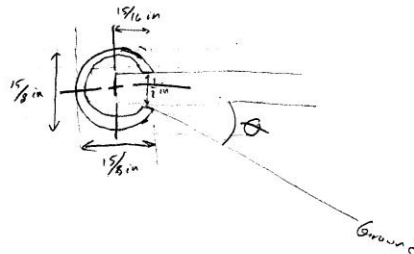
$$\theta = 11.735^\circ$$

Group 5

Please buy for us: 2 in diameter pvc pipe
metal flexible wire
Draft Test on back.



Good Section



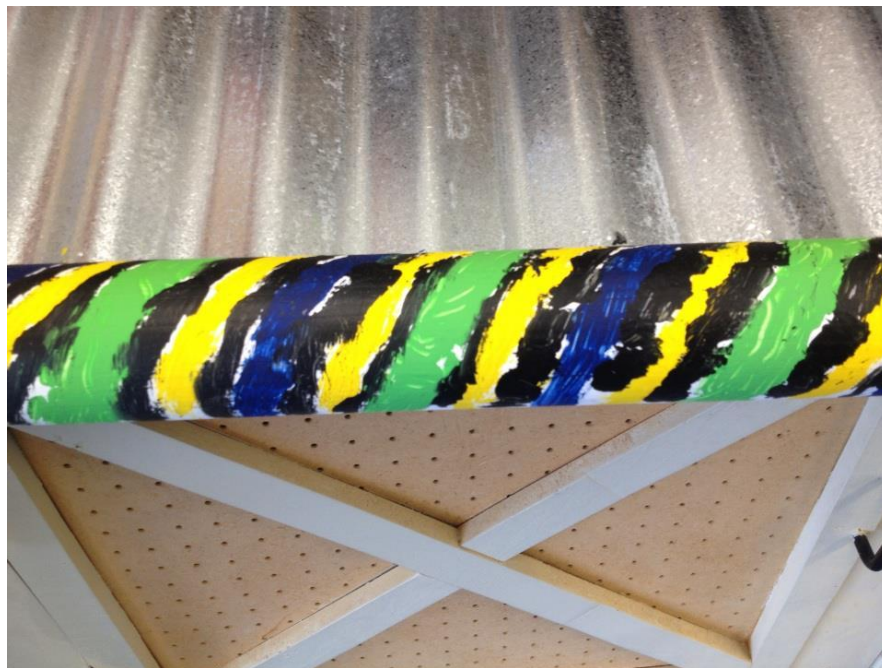
Here is a hand sketch of our final dimensions for the pipe on our gutter system. This does not include the paint, simply the final structural design of our gutter system.



When we attempted to use a smaller sized pvc pipe to save on some of the costs, we found that it was a lot more difficult to cut and decided to stay with our original 2 inch pipe.



To test durability of our final design we decided to hang some weights from the gutter and manipulate the angles of the roof. No matter what angle we chose, the pvc pipe still hung on strong and was not altered at all. This is one of the major successes of our final design.



This is our final gutter design after painting. A second major success to our gutter system is the ability to personalize it and make Kenyan houses look colorful and welcoming while still redirecting water during a rainfall.

Costing Analysis

Our gutter design is primarily pvc piping, cut along one side to fit onto the corrugated roofing of Kenyan houses. An additional cost of UV resistant paint is added to maintain the quality of the pvc pipe and increase the longevity of the gutter system.

To attach our gutter system to an 8 meter by 8 meter roof, we need about 32 meters of pvc piping to completely divert all of the water during a rainstorm.

Estimates: Total cost of pvc piping material is 140.16 Kenyan Shillings (this is when we order in bulk from Alibaba.com—a piping manufacturer in China that ships to Kenya for US \$0.10 - 3 / Meter. This includes the cost of shipping to Kenya. This assumes that the piping is bought in bulk 3 kilometers at a time.)

Total cost of UV resistant paint is 2956.50 Kenyan Shillings (this is for number of gallons of paint to cover the entire surface area of the attached gutters. This cost is based off of a 25 gallon can of exterior semi-gloss paint from Home Depot in the U.S.).

The price of 1 meter of gutter is: 96.75 shillings per meter (\$1.10 USD)

To install all 32 meters of gutter, we assume that one skilled laborer can easily use a saw and/or electric tools to cut all of the pvc and weave it through the corrugated roofing. 1 day of work will cost an additional 400 KES.

Total Project Cost: 3500 Shillings (\$40 USD)

The total cost for our gutter design is definitely inflated in these figures due to the cost of our one gallon of paint from Home Depot in the United States. We assume paint will be cheaper in Kenya and does not have to be the greatest quality for the corrugated roofing gutter exterior. Taking this into account, the labor to quickly paint the pvc pipe along the edge of the roof will not cost very much and could even be done by the homeowner for only the cost of the paint. We have determined that the actually cost for our gutters will fall well below \$1 per meter.

Lessons Learned

If we had time for a prototype 3, we would definitely try to make a life size model as well, with a realistic length of the roof/gutter. This would allow us to test how easy the PVC attaches when using a larger size, which was one of our concerns. Weaving the PVC onto the corrugated tin was a challenge at times after we cut them, so testing this would ultimately be the next task for our team. This would also be helpful in determining how well the PVC stays attached to the roof when the pipe is filled with water. Although our gutter system held over 25 pounds earlier, it would be comforting to be positive that it could hold water along the entire roof.

Our team did an excellent job of dividing up tasks in order to complete all tasks. We usually had two people working on prototyping while the other two worked on cost analysis, selection matrices, etc. We also switched up who was doing which job in order to ensure everyone's ideas were being included to make the best product possible. Everyone got along excellent, which was essential for solving problems and increasing communication between our group. We also thought our final product turned out very well as it met all requirements and was relatively simple. The gutter caught all water, was durable, and usable all throughout Kenya.

Overall, we had a lot more go right for our project than went wrong. However, we did not win the showcase as we had hoped. During the showcase a judge asked us how our gutter was safe from being stolen, which was a situation we never even thought of before, so we had no real answer for that question. Not being able to test our model on a full size roof was also a problem because we are not positive that it would be effective. Finally, we never found a UV and water resistant paint for a cheap enough price to keep the cost of gutter under \$1 per meter.

The DEM activity could be improved by having more options for projects to choose from. The showcase was not as exciting as anticipated because all gutter systems were extremely similar. Having another option or two to choose from would make the showcase much more entertaining and lead to more original ideas. Teams seemed to be copying other teams' ideas in order to just complete the task. If there were more projects being worked on, teams would really have to think outside the box to complete their project, which would lead to more creativity.