

EDSGN 100  
Section 20  
Spring 2013  
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## The Smart Gutter



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**Note:** All team members contributed equally to the whole design and testing processes.

## Problem Statement:

Rural Kenya is in need of gutters and a way of attachment for catching rain water in a tank or irrigation system. The cross-section of the channel needs to be circular, rectangular, or “v-shaped” and simpler is better. In central Kenya, for the most part, gutters and other types of rainwater harvesting systems are only added to buildings as an afterthought because of existing bylaws and lack of awareness. In rural and slum areas of Kenya, more than 67% of households still have no access to clean and safe drinking water. This is becoming a serious issue because the human body needs about three to ten liters of water per day depending on climate and work load. In addition, this has led to problems with crop production (while 75-80% of workforce is in agriculture), bathing, cooking, cleaning and more.

On average it rains about 800 mm (31 inches) per meter a year in rural Kenya and the “dry season” lasts from June to October. The gutter system therefore needs to catch as much as possible because there is so little rain per year. It needs to be able to catch water in light and heavy rainfall and minimize overflow on the sides. The size and shape needs to reflect these conditions in order to perform best, keeping in mind that too large could mean too heavy and too expensive. Kenya’s economy has suffered greatly mainly due to inefficiency and government corruption and an estimated 50% of the population is unemployed, so most households cannot afford real fancy gutters. The design has to be cheap, functional and easy to replicate and maintain so it basically needs to be as simple as possible while still getting the job done. The simplicity of the design is also an important factor in the ergonomics of Kenya because the gutter production and attachments could take a step towards solving unemployment especially if the design is easy enough that a worker would not need to be too skilled to produce it.

Another thing to keep in mind is how to attach the gutter to the roof. Hooks are preferable but they still might not work as well as other ideas depending on the overall design. It has to be strong enough to hold the gutter at maximum capacity without tipping over and it has to stick with the theme of everything being easy and simple. Materials are also important in the challenge because the gutter has to cost less than one dollar per meter, cheaper is preferred. The channel also has to be made out of tin sheets so no bamboo or plastic is allowed. It is necessary to figure out the cheapest, easiest and most effective gutter possible.

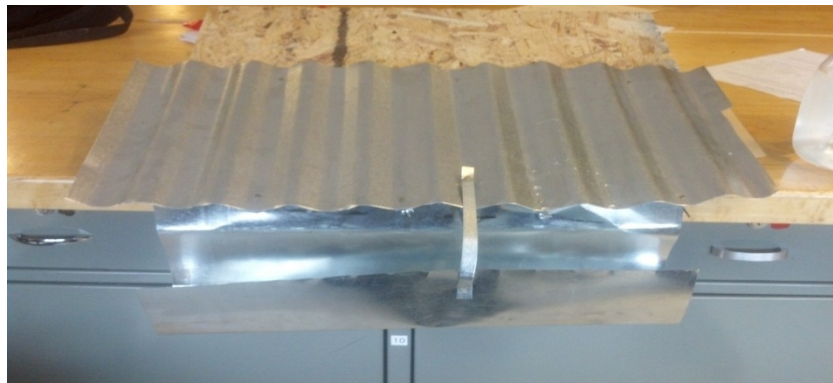
Health care and medical attention in Kenya is terribly understaffed and poorly supplied. Many people are unfortunately relying on traditional cures like herbal medicine and healing rituals because they cannot access health care. Life expectancy for Kenyans, one of the lowest out of the African nations, is only fifty-four years. Most diseases like AIDS are the cause of this, but lack of water is still an important factor in the human well-being. Diseases and other medical issues that result or persist partially due to lack of water can be solved with a gutter system so it needs to be available to everyone, requiring it to be incredibly cheap and easy.

## Concept Development:

Our team conducted research on the internet to find out about the conditions in Kenya. We discovered that many of the people we were designing gutters for lived in poor areas with minimal rain. We talked about how we wanted to incorporate factors like “easy to maintain,” “safe to install,” “initially low costs,” and more. In the end, our AHP table showed that we wanted a durable gutter that was cheap and easy to attach to the roof. In class, we were also told that the gutter should be able to funnel the collected rainwater into a storage bin.

Our design consisted of minimal materials, only nails and the tin needed for the gutter. The nail hooks were designed to be easy to install. We also included a small support strip, made from tin, attached to the roof and outside lip of the gutter. Prototype 1 was effective at directing the water into a bin. The only flaw of the design was the nail hooks that attached the gutter to the roof, these were sharp and unstable. Our group also determined that the support strip was unnecessary and should be removed from Prototype 2.

The name of Prototype 1 is the Smart Gutter. We chose this name because our gutter is effective and durable, and therefore the smart choice to make.



Prototype 1: The Smart Gutter

### Prototype 1 Closeup:



There were four nail hooks per two feet in Prototype #1. They were sharp and unreliable.

AHP Table:

	Catch As Much As Possible	Durable	Easy to maintain	Low Install Cost	Easy installation	Safe installation	Environmentally friendly	Appealing design	total	weight
Catch As Much As Possible	1	2	3	.5	2	3	3	3	17.5	.19
Durable	.5	1	2	2	2	3	3	3	16.5	.18
Easy to maintain	.33	.5	1	.33	.5	1	1	1	10.2	.11
Low Install Cost	2	.5	3	1	2	3	3	3	17.5	.19
Easy installation	.5	.5	2	.5	1	2	3	3	12.5	.14
Safe installation	.33	.33	1	.33	.5	1	1	1	5.49	.06
Environmentally friendly	.33	.33	1	.33	.33	1	1	1	5.32	.06
Appealing design	.33	.33	1	.33	.33	1	1	1	5.32	.06

Grand Total	90.3
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The AHP table showed that we were really concerned with factors like “catch as much as possible” and “durable.” On the other hand, factors like “environmentally friendly” and “appealing design” were lower on our list.

## Testing – Prototype #1

### Test One:

Our first test, shown below, consisted of pouring three liters of water onto the roof and observing how it flows into and out of the gutter and how much of it actually drains out. Right away we noticed that a significant amount of the water flew out over the edge of the gutter by about an inch or two which was obviously a major problem. However, about half of the water did make it into the gutter and out of that amount, less than .1 liters were left over and did not flow out. We repeated this two more times varying the amount and speed we poured the water out and got the same results.



### Test Two:

For the second test, we applied significant pressure to the gutter by pushing down on it in numerous spots. No matter where we pushed down or out on, the gutter held together. There was slight bending when we pushed out on it, so we noted that it could be improved, but it was not anything extreme. Another issue dealt with the nail ‘hooks’ because if we tried hard enough we could probably pull the gutter off them, which is obviously a big concern. We also noticed that there were some spots that we could not push down on because it was unsafe. For example, there were a lot of sharp edges and nails poking out, so we definitely had to make the next prototype a lot safer.

### Issues:

Our two biggest concerns after the two tests were the water shooting out over the edge from test one and the safety issues from test two. We obviously needed to change something in our design for it to catch as much water as possible, because that was our number one priority. We decided that the best way to do this was to change the shape of the gutter. We also knew that safety was an important factor in this challenge and we therefore had to make some major improvements in the next prototype. The easiest way to accomplish this is to use different materials, especially replacing our nail ‘hooks’.

### Impact on Design:

The test results impacted our design completely. When we found out there was water shooting out over the edge, we knew we had to make a change for it to catch as much as possible

(discussed later). The other big issue we noticed, mentioned above, dealt with how unsafe our design was. So our redesign incorporated a new safeness dealing with the materials. In addition to the safety factor, durability was a slight issue without design. Our nail hooks did not seem like they were going to last too long, so we knew they had to go. And we would use something safer and sturdier in the new design.

### New Focus:

Two factors that we will definitely keep include the angle of attachment because almost all of the water flowed out easily and the way the overall design maximized the amount of water the gutter can hold, other than it not being wide enough. Overall, we know that we will need to spend more time working on the prototype and making it look more professional and safe.

Looking around at the other gutters, we realized that we really had to focus on two factors: cheap and easy. Our gutter was far from the most ascetically appealing, so we knew we could work on that. We know that we can make more precise measurements and spend more time paying attention to the way it looks. However, it did not really matter who had the best *looking* or most *different* design, but the cheapest and easiest design while getting the job done. Our first prototype matched this description pretty well and after the tests, we knew what we had to change.

### Excel Chart:

DEM Project	Prototype #1 Testing	Team: 8
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Design Constraint [C] or Feature [F]	Test to be conducted; describe in detail	Results and notes
Catch as much as possible [C]	We filled our gutter with 2.7L of water over a bin. We saw how much water the gutter could actually catch and what could be improved. We will judge this on how much water actually lands in the gutter and how much water is able to drain out.	<b>Water left over:</b> about 1L <b>Problems:</b> Water shooting out over the edge of gutter <b>Success?</b> Yes & No - there is room for improvement
Durable [C]	We applied forces on the gutter by pushing down on it in different areas.	<b>Notes:</b> Nothing fell apart <b>Success?</b> Yes.
Easy to maintain [F]	We assumed how easy it is to maintain based on how it held through our various tests.	<b>Notes:</b> It held together <b>Success?</b> Yes.
Install Cost is low [F]	As we build our gutter and set it up for testing, we payed attention to how many and what kinds of tools and materials we use. We also compared our materials to other groups in the class.	<b>Notes:</b> Our materials used seem just as if not cheaper than other groups'. <b>Success?</b> Yes.
Able to be installed easily [F]	We based this off of how we built our gutter and set it up for testing. We kept in mind how it will be different setting this up with limited tools in Africa.	<b>Notes:</b> We could build it but we can still make it less complicated. <b>Success?</b> Yes but there is some room for improvement
Safe to install [C]	We based this off the way we built and set up our gutter and overall how safe it really is/looks.	<b>Notes:</b> There were nails sticking out in some places and sharp edges. <b>Success?</b> No.
Environmentally friendly [F]	We made sure that the materials and the building process did not have a negative environmental impact.	<b>Notes:</b> There were no noticable impacts. <b>Success?</b> Yes.
Appealing design [F]	Once we set it up, we each decided and shared our thoughts on how the gutter looked.	<b>Notes:</b> We all thought it needed improvement. <b>Success?</b> No.

## Design #2 Refinement and Testing:

### Design Process:

When our group was finished with our first prototype, we were pleased with the results, but also realized there were many things we could improve on. Our gutter was not very strong. The hooks we used to secure it were not only weak, but unsafe and hard to install. They also were not aesthetically pleasing. The walls of the gutter were also not high enough and water would sometimes overshoot the gutter as a result. After assessing these two main flaws we started constructing a concept selection matrix for each.

The first matrix assessed the mounting issue. We decided we could either use bigger nails to hang the gutter, iron eye hooks, or bolts and screws. Using the AHP matrix we constructed earlier, we used the constraints and their respected AHP weights to decide which design concept would be the best for our chosen wants and needs. In the end, the eye hooks and the bigger nails just weren't as durable, safe, or easy to maintain as nuts and bolts. This caused the weighted average of the nuts and bolts to beat out the scores of the other two design features.

The next matrix focused on the height and depth of the channel. To address this problem our group decided that we could either make a gutter that had a high backed triangular shape, a gutter with a wider base, or just get a new piece of aluminum and make an overall bigger gutter. Again, we used the AHP matrix to help us decide which would work best based on their AHP weights. After much deliberation our group decided that the larger gutter would be too expensive to produce. Therefore it was between a wider base or a taller back. It was close, but our group decided that because a triangular base would be more aesthetically appealing and more structurally sound it was an overall better design.

### Testing:

The main flaws in our first prototype were it was poorly attached to the roof and that water overshoot the gutter. Taking this into account, we decided we would test how much water the gutter loses when a 2.7L jug of water was poured on it and how much weight it could support.

For the first test we filled a jug with 2.7L of water and then poured it onto the gutter. We then collected the water that flowed out of the gutter in another similar jug. Finally, we computed the difference to find out exactly how much water was lost in the simulation. After performing the test we found that the gutter worked surprisingly well.





The picture on the left shows the water put in the gutter and the picture on the right shows the water collected. As you can see, the difference is barely noticeable. There was no available means at the time to measure the difference, but it was certainly under 10ml. It is also worth noting that the majority of water that was not collected flowed out the other side of the gutter, which would not be a problem if the gutter was around the whole roof. So overall the test was a success. The new prototype performed far better than the old prototype would have.

The next test was to test the durability and strength of the gutters new hanging system. For this test we used sand bags in the base of the gutter. We used Ziploc bags because at the time there was no available means to accurately measure the weight of objects. Therefore the only way we could get a controlled test was to fill a cups worth of sand into Ziploc bags and compare its volume to that of waters. After all was said and done the gutter supported a total of four bags of sand. This equated to about three pounds of water. Given current rain fall statistics in Kenya, it is safe to say that if the gutter can support these kinds of weight, it is more than capable of handling the heaviest Kenyan storms. So this test was also a success.

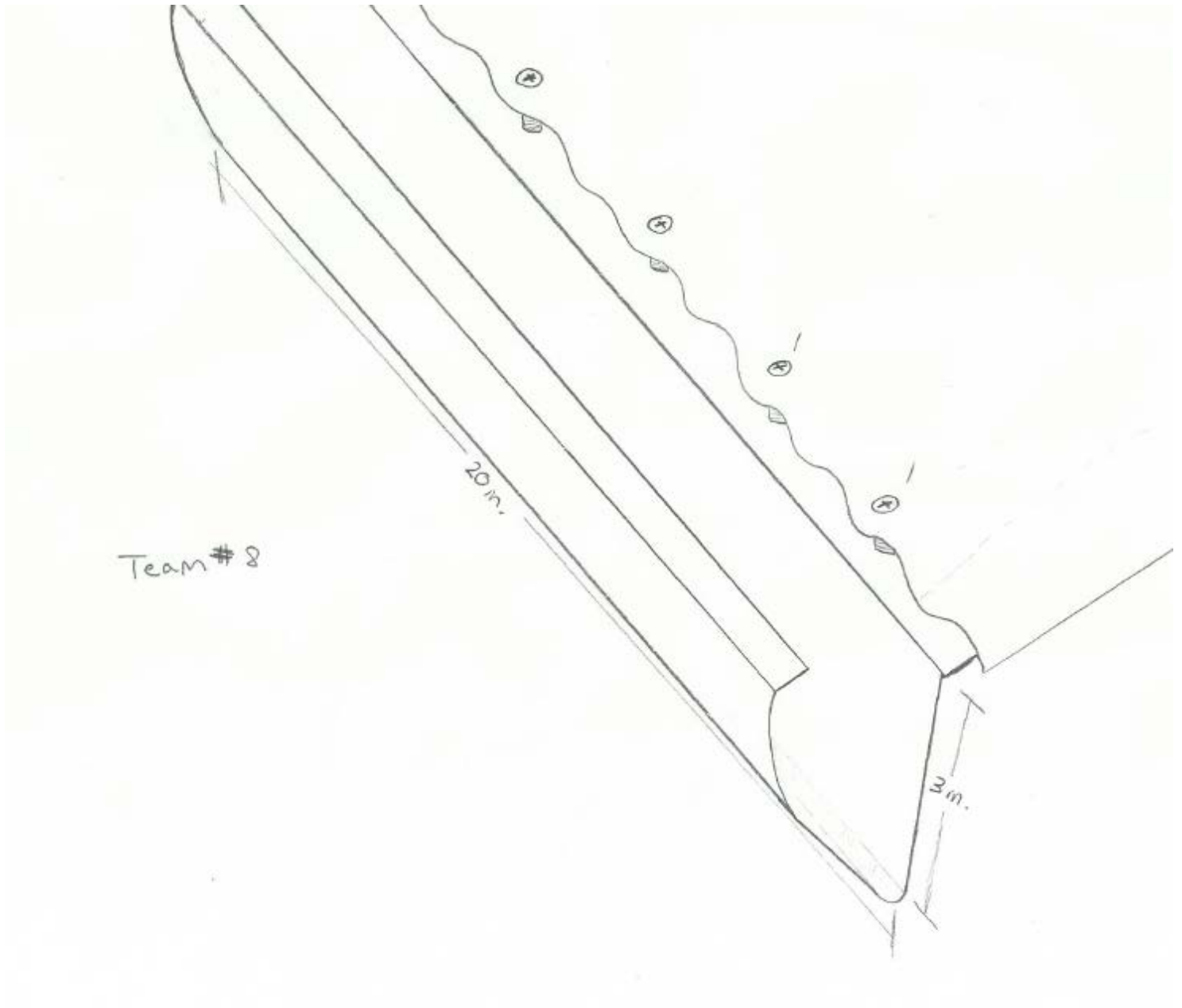


### Conclusion:

Our group believes that our new prototype is more than ready to be presented. By using the AHP and concept selection matrixes we were able to pinpoint the optimal solutions to our old designs flaws. We then put our new design concepts to the test and they all passed. Our prototype preforms very admirably and at a very efficient cost as will be shown in the next section.



Scanned Hand Sketch:



## Costing:

Our team met the goal of less than \$1 per meter with a cost of about \$0.84/meter. One US dollar is equal to roughly 86 KES (Kenyan Shilling). So, the total cost of the aluminum sheet, nuts, and bolts was about 1189 KES. Instead of using pre-made gutters in segments, our materials would consist only of the tin sheet and nuts and bolts. Along with the installation cost, where we assumed that cost of delivery would be minimal or zero and the gutter would be installed in the same amount of time every time, the installation would only take one day. This would cost 400 KES. The installation cost will most likely actually be less because it shouldn't take ten hours to install our gutter because of the simplicity of our design. The total cost of installing 32 linear feet of gutter on a standard Kenyan house is 1589 KES, or about \$18. This is a fair price because our design will last for years, and is easy to install and maintain. For this cost the user will not have to spend any extra money to care for the gutter and will have years of effective use.

### Another Picture of Prototype Two:



## Lessons Learned:

Overall, our gutter design was successful and there are very few changes that we would make if we had the chance to create another prototype. We would keep the same gutter shape because it effectively caught as much water as possible without bending and used a small amount of material. Possible changes we would make would be in the attachment of the gutter to the roof. We used nuts and bolts for our second prototype, so maybe we would experiment with using a lighter material such as wire. Something we noticed after finishing prototype 2 was in fact that we did not need so many nuts and bolts, so we could also stick with them and just use less. The gutter would most likely still hold up fine. We would also consider constructing a full sized gutter (8 meters long) to test how the gutter would actually work full scale.

Our team worked very well together and there were very few bumps that occurred along the way. Each member was willing to do the work and multiple times people offered to write up a report or organize test results without others forcing them. We also agreed fairly quickly and easily upon the designs we wanted to use for our first and second prototype. We were able to communicate our opinions without any argument and we were all open to each other's ideas. Given the chance, we would definitely work together again on another project.

On the other hand, there was very little that did not go well. There were a few times where two members would be doing a task and the other two had nothing to do. Consequently, we could work on time management, but we still got everything done on time with this problem. Also, it was never the same people doing work and the same people doing nothing. When this actually occurred, it was never a big deal for us. This is the only problem that we had.

This DEM project was an interesting challenge and was engaging because it had a real world application. Experimenting with different gutter designs was nice, but really all we had to do was bend a piece of metal into a shape that would hold water. It was a good introduction to the design process and all the thought engineers put into their work, but the project could have been improved if it involved more complicated parts or restrictions. It was interesting that we were making something that could help real people, but designing gutters isn't the most demanding project that we could have done. This DEM project could have also been improved by having an actual full scale test of either all the gutter designs or the class favorite. Seeing the gutter in action during actual rainfall would spark many new ideas in terms of design. Overall this DEM activity provided a good introduction to EDSGN and our team has learned many things about how to work together to create the best product.

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