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Introduction

In Guatemala, over half the population is living below the extreme poverty line. Additionally, Guatemala suffers from the highest rate of chronic malnutrition in Latin America, the fourth highest in the world. The Appropriate Technology Collaborative, a nonprofit organization dedicated to helping low-income people with sustainable technologies, has a goal to improve this situation by building a macadamia nut husker for Guatemalan farmers. Macadamias are a rapidly growing industry, as well as a good source of several important nutrients.

After macadamia nuts are harvested, the husk must be removed within a twenty-four hour window, or mold will begin to grow. Macadamia husks also become hard and more difficult to remove after this time period. It is also important not to break the shell of the nut during this process, because it must undergo a drying period to remove the moisture before being cracked. Currently, many farmers sell their macadamia nuts in-husk, resulting in a lower profit. Those with access to hand-powered huskers mostly produce B-Grade broken nuts. Additionally, husking by hand is a tedious and laborious process.

Our team’s goal for this project was to create a device that can quickly remove the husks of the macadamias without breaking the nut inside, which will ensure that Guatemalan farmers will not lose any of their harvest. By improving the efficiency of this process, the farmers can maximize their profit, which will help to improve their quality of life.
Design Specification

In developing a problem definition, numerous design parameters were examined. Each were given a weight on a scale from 1 to 5, 1 being unimportant, and 5 being extremely important. The design parameters are as follows:

Design Parameters

<table>
<thead>
<tr>
<th>Function/Performance</th>
<th>Spatial constraints</th>
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</thead>
<tbody>
<tr>
<td>Product cost</td>
<td>Aesthetics</td>
</tr>
<tr>
<td>Size</td>
<td>Personnel</td>
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<tr>
<td>Weight</td>
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<td>Delivery Date</td>
<td>Noise radiation</td>
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<tr>
<td>Energy consumption and reliability</td>
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<tr>
<td>Materials and Maintenance</td>
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<tr>
<td>Safety</td>
<td>Health issues</td>
</tr>
<tr>
<td>Transportation</td>
<td>Government regulations</td>
</tr>
<tr>
<td>Quantity</td>
<td>Shelf-life storage</td>
</tr>
<tr>
<td>Environmental Issues</td>
<td>Operating costs</td>
</tr>
<tr>
<td>Quality</td>
<td>Environmental conditions</td>
</tr>
<tr>
<td>Mechanical Loading</td>
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</tbody>
</table>

Function/Performance (5):

The function of the device is to increase the productivity of farmers in Guatemala by removing the husks of 100 pounds of macadamia nuts per day. It is also desired that the device produces Grade A nuts, meaning there is no damage to the shell of the nut. With current devices, Grade B nuts are often produced. This parameter was given a weight of 5. It is of the utmost importance that the device performs the way that it is supposed to and reaches its output goal. If it cannot function the way it is supposed to, the target user will have no desire to use it.
Product cost (5):

It is desired that the final product cost is as low as possible. The device should cost about $100 USD. If the device is made too cheaply, it will lack in longevity, capability, and overall quality. As this device is required to be sturdy and robust, a lower cost target would not be acceptable. Further, if this device can improve the macadamia nut output significantly, at $0.78 a “wet” pound, this device will return its investment quickly. However, if this device is too expensive, it will lack in extended influence, and other farmers will be deterred from investing in or assembling their own. It is the hope that this device will pose as a sound investment for the users and lead to increased profit at the end of the day; moreover, a simple, reproducible design will enable other farmers to make the same investment. Additionally, the device will be shared between several families, making it even more affordable, as each family will only pay a fraction of the total cost.

Size (4):

The device should be able to traverse narrow trails on the macadamia nut farms in Guatemala, meaning it should be no more than about 32 inches in width. It should be large enough that it will be durable enough to handle removing the husks of 100 pounds of macadamia nuts per day, but small enough that it can be easily transported by the user.

Weight (3):

The device should be 100 pounds at maximum. It is ideal that the device is as light as possible to facilitate easy movement of the mechanism; however, this isn’t as inherently critical as other parameters, as the device will likely be on wheels making it much easier to move. Also, the device will be stationary most of the time and will not require the user to overcome its weight for the purposes of using the machine but when they want to transport the machine. It is desired that the device still be light enough that were the transportation aiding mechanisms to break down, or get stuck, two individuals would be capable of lifting it and getting it to a more desirable position/location.
Delivery Date (5):
The device needed to be fully completed and fully functional by Design Day, December 11, 2015. It was extremely important that the device be completed on time.

Energy consumption and reliability (3):
Initially, it was decided that to make the device more reliable, manually powering the device would be the best solution, most likely by bicycle power. If the farmers did not have access to electricity, they would still be able to power the device. However, after learning that a generator would be available and manual power would be less desirable to potential users, it was decided that the device would be motor driven. The option to power the device manually would still be available if a bicycle attachment were to be manufactured.

Materials and Maintenance (4):
Any materials used to build the device were to be easily accessible in Guatemala. They should also have access to any tools or machinery used in the manufacturing process. As long as they have access to the correct materials and tools, they should be able to repair the device if it needs maintenance, as well as reproduce the device from scratch.

Safety (5):
Safety of the device was also considered, as safe use of the device is of the greatest importance. The device was designed to be as safe as possible for farmers in Guatemala to use. It was decided that there should not be any openings where people could get their hands caught. There should also not be any sharp edges for people to cut themselves on. The device will be a finished product that people can feel safe using. No one should be injured while using the device.

Transportation (4):
Since the device will likely be shared between several families, it is important for the device to be portable. In order to accomplish this, large, durable wheels will be installed that
will be capable of traversing rough terrain in Guatemala. It should be as easy as possible for users to move the device from one location to the other.

Quantity (3):

Desired output of the device is 100 pounds of macadamia nuts per day. The price of macadamia nuts, for wet-in-shell basis, was 78.0 cents per pound for the 2011-12 crop year. As long as the output goal is reached, the users of the device should be able to make a profit of $78 per day. If the cost of the device is indeed $100, this profitability offers a good return on investment for the user.

Environmental Issues (3):

Macadamia trees are very beneficial to the environment. They are fast growing trees that do not exhaust the soil, convert 63 cubic feet of carbon dioxide, and release 55 gallons of water vapor into the atmosphere every day. A big issue in Guatemala is deforestation, with over 50% of the country’s forests destroyed since 1890. We hope that the device will help to promote Guatemala’s reforestation efforts.

Quality (3):

Quality of the macadamia husker involves reaching the goals of all of the other parameters listed. A higher quality product may cost more, but it will operate more efficiently and for a longer time before maintenance becomes a factor. We hope to deliver the highest quality product possible to our end users.

Mechanical Loading (2):

Mechanical loading was not an important factor for the macadamia nut husker. The macadamias are harvested as they fall onto the ground. Once they are gathered, they are placed in the hopper of our machine to be husked. Future design concepts may include a macadamia bailer, however at this point, mechanical loading is not an important design parameter.
Spatial constraints (4):

Spatial constraints are extremely vital to our macadamia nut husker. Conditions that farmers work under in Guatemala include narrow paths, and dirt roads. Our husker must not be wider than the trails that are travelled as macadamias are harvested from one tree to the next. A smaller machine will cost less to manufacture and be easier to transport while in use. Larger designs may benefit the quantity of macadamias husked in a given time, therefore we must design the largest machine that fits previously stated spatial parameters.

Aesthetics (2):

Although it would be ideal for our device to be visually appealing, the aesthetics of the macadamia husker are not vital to its performance. However, it is still important that we try to make it somewhat aesthetically pleasing, as this quality will help to make the device more desirable to customers.

Personnel (4):

This device will be designed with the farmers who will be using it in mind. By increasing their productivity, we hope that we can improve their quality of life in some small way. Although there are cultural, location, and communication barriers, our goal is to design a device that performs the way that they want it to.

Service life (4):

It is desired that the device is capable of providing effective service for at least 5 years. The device will have far succeeded in paying itself off in this time and will have lasted long enough for the users to be exceedingly familiar with its operations. The hope is, because the device will be made from locally available materials, that the users will be able to easily make repairs to the device should any functionality be compromised.
Noise radiation (2):

The device will not exceed 85 dB in noise radiation. Given the other parameters considered with this project, noise radiation does not rank high in priority. The device will be used by farmers outside where noise is easily dissipated and noise radiation will likely not be an issue. However, it will be ensured that the device does not exceed 85 dB as prolonged exposure to noises at that level could cause damage to the user’s hearing.

Operating instructions (4):

It is extremely important that there is a clear outline of instructions for how to operate, as well as manufacture, the device. Detailed drawings and photographs will be provided in order to convey instructions, since the language barrier will make it difficult to provide written instructions.

Human factors (1):

In order to eliminate as much human error as possible, the device will feature one area for loading the product, one force input device, and one output. The design will be as simple as possible and involve humans exclusively for loading the device. The device will perform all of the husking work in an attempt to minimize human factor as much as possible.

Health issues (1):

The health of the user is always important when considering a design. However, our device should not have any impact on the health of the user.

Government regulations (1):

Research has yet to produce any relevant government regulations that would hinder the development of this product. The team will keep the design of the product in compliance with any government regulations that should arise in the future.
Shelf-life storage (1):

Our machine will not be stored for long periods of time given that “nuts should be harvested at least every four weeks when the weather is rainy and less often in dry weather. This is to prevent losses from mold, germination, and pig or rat damage.” Due to the tropical climate of Guatemala, macadamia nuts are grown year round. Quality of the machine is a higher priority because of its constant use rather than it being able to weather storage for long durations.

Operating costs (3):

Users should not have to pay a large amount of money in order to use the device, since in creating the device, we are aiming to maximize their profit. The generator that they will have access to is only able to power a motor of up to 1 hp. Also, the device will likely not be operated for very long per day, no more than a few hours. Therefore, operating costs should be fairly low.

Environmental conditions (2):

As previously mentioned, the tropical climate allows for year round growth of macadamia nuts. The temperatures in Guatemala are very moderate, with lows of about 50-60°F and highs of about 70-80°F all year round. However, there is high humidity all year round, about 70-80%, which could cause some wear on the device. The device will need to be durable as to perform for the entire year.
The parameters that were deemed to be most important with their assigned weighting factors are listed in the table below:

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Function/performance</td>
<td>5</td>
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<tr>
<td>Product cost</td>
<td>5</td>
</tr>
<tr>
<td>Size</td>
<td>4</td>
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<tr>
<td>Delivery date</td>
<td>5</td>
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<tr>
<td>Materials and maintenance</td>
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<tr>
<td>Safety</td>
<td>5</td>
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<tr>
<td>Transportation</td>
<td>4</td>
</tr>
<tr>
<td>Spatial constraints</td>
<td>4</td>
</tr>
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<td>Personnel</td>
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<td>Service life</td>
<td>4</td>
</tr>
<tr>
<td>Operating instructions</td>
<td>4</td>
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</tbody>
</table>

Conceptual Designs

In order to design a device that would be capable of removing the husks of macadamia nuts, several design concepts were created. These designs were compared based on weighted parameters in order to determine which design concept would be the best solution to the problem at hand.

Rotating Wheel Design:

One idea that was considered for use in the project was a design that uses a rotating tire to remove the husks of the macadamia nuts. This idea is similar to a design currently being used at the Valhalla Experimental Station in Antigua, Guatemala, as shown in Figure 1 below.
First, macadamia nuts are poured into the hopper. Next, they fall in between the tire and a rebar frame built around the tire. The space in between the tire and rebar frame is slightly smaller than the size of the macadamia nuts in-husk, so the husk is removed. After leaving the space between the tire and the rebar frame, the macadamia nuts are shot up into an arch-shaped chute. This chute is grated such that the husks are allowed to fall through, but the nuts in their shells are not. Nuts in-shell are also heavier than their husks, and their momentum allows them to maintain a greater velocity as they travel through the chute. After traveling through the chute, the nuts finally reach the sorting table, whereas the husks are collected in a bag placed underneath the chute.

This device uses a 12 horsepower motor in order to rotate a tire rim of radius 15 inches. There is also a concrete flywheel in the center of the rotating tire frame in order to increase the momentum. A set of springs is installed on the rebar frame, which can accommodate different sizes of macadamia nuts.

One way that this design could be simplified would be to use a flat plane underneath the tire instead of the rebar frame. A flat grate placed on an incline could also be used in order to separate the nuts and the husks, instead of the large rounded chute of the Valhalla husking process.
device. Sketches of the Valhalla design and the simplified design with components labeled are provided in Figures 2 and 3 below.

![Figure 2. Valhalla Design](image)

![Figure 3. Simplified Design](image)

A disadvantage of this design is that it is quite large and heavy. Transportation of the device would be difficult, which may be necessary as it will be shared between several families. However, using a rotating tire to remove husks from macadamia nuts has proven to be a very efficient method; it does so quickly and thoroughly. Furthermore, it is a very simple design
which requires a minimal amount of maintenance. This method is used quite commonly, whether it is done by a device like the one built at Valhalla, or by a person driving their car over the nuts to remove the husks. Although this method has demonstrated its ability to work, it is not very unique or innovative on the team’s part, giving it the lowest score in the decision matrix for this category.

Belt Sander Attachment Design:

Inspired by a previously patented design (Patent US20130298785 A1 by Gary Estess and Russell Walker), this design aims to modify the concept to make it more compact and cheaper. Nuts are first loaded into the top of the device. They are then funneled down into the internals of the device where they are pulled downward by a spinning piece of sandpaper. Sandpaper
has a heavy grain and grips the nut, forcing it into sharp blades that are shown in figure 4E. These blades are sharpened to cut through the outside thick outer husk. Spacing between the blades is very important because if the spacing is too great then some of the nuts will slip through. If the spacing is too small then the nuts will not be cut as intended. The nuts will then fall down onto a hard plate, where they will be separated from the husk by the impact. Separated nuts will then roll down a chute that will separate the nuts by size.

This device will use an off-the-shelf hand belt sander as the main source of power for the machine. The belt sander will be mounted in an adjustable frame that can be adjusted to fit all sizes of nuts. An off-the-shelf belt sander is beneficial because it is readily available in country and parts are easily obtained and replaced. Sharpening of the blades will be an important part of the maintenance process. The blades will not need to be replaced regularly but they will need to be taken off and sharpened like any household tool. A major advantage of this design is that it is one of the cheapest and most compact of our designs. All of the components are easy to produce or are purchasable in country.

Disadvantages to this device are that it relies heavily on the force of the sander on the nuts. If the sander cannot produce enough force to pull down on the nut and push it against the blades, then the nuts will collect and clog up the machine. If the blades are not sharpened, the device will not run properly and many improperly cut nuts will pass through the device. As seen in the design matrix below, this design has scored the highest compared to all of the other designs.

**Dual Steel Roller Design:**

Inspired by SSI Shredders, the dual wheel roller concept uses two steel rollers that roll in opposing directions, against one another. These steel rollers must have a high tolerance to bending, as macadamia nuts are extremely hard and if any nuts were to lodge in between the rollers, they would be susceptible to bending if not strong enough. Rubber or any thin membrane material with a high coefficient of friction would surround the rollers used to strip the husk from the nut. Adjustability in the distance between the rollers is imperative, due to different sized macadamia nuts. Macadamia husks are a few millimeters thick, and when the
nut is de-husked it must fit between the rollers so not to crack the hard shell. Grade A nuts are qualified as husked, unshelled nuts, and are sought after by small farmer. After sorting different sized macadamia nuts, the distance between the rollers can be adjusted to a dimension just above the diameter of a de-husked nut.

Further design concepts using two steel rollers include one roller that has decreasing sized diameters as a tapered hopper sorts smaller to larger nuts into the appropriately sized diameter section of the roller. Sheet metal guards would orient the nuts and keep them from rolling off the wrong side of the rollers. Steel rollers would be advantageous because of their narrow overall width dimension and low maintenance quality. Using a rubber coating around the rollers would mean minimal cleanup is necessary after a season of husking. Because of the high orthogonal forces however, expensive bearing and housings for the bearings would need to be incorporated to this design. These parts would be the bulk of the cost.

Rotational speed for the rollers is important. If the rollers spin too fast, there will not be enough static friction to pull the husk off of the nut as the coefficient of static friction is higher than that of kinetic friction.

![Figure 5. Dual Steel Roller Design](image)

**Dual Belt Design:**

Another proposed design for de-husking the nuts was aptly dubbed the “Dual Belt Design” as it features two conveyer belts in its husk removal process. This design was nurtured
via a machine involved in the process of producing cider at a local cider mill. This machine is shown in Figure 6 below:

![Figure 6. Cider Mill Apple Pulping Machine](image)

This machine features rubber belts that follow each other through a winding series of rollers. Apples are fed between these rollers and increasingly compressed as they make their way through the system. The compression forces the juice out of the apple to be used for the cider product and the leftover pulp from the apples is discarded.

![Figure 7. Dual Belt Design](image)
The macadamia nut adaptation of this design would be extremely similar to the apple machine with a few exceptions. Compression of the nuts is useful in hemorrhaging of the husks; this is known as one of the current methods to removing the husks is to simply drive over the nuts with a vehicle. In an attempt to get more movement and even compression of the nut, the dual belt design, as shown in Figure 8, employs the top belt moving in the opposite direction of the bottom belt at a slower rate. The opposing direction will force the nut to roll around as it passes through the system and help to rip off the husk. The faster rate of the bottom belt will ensure that the nuts actually pass through the system and do not get stuck.

This design is beneficial in that it is novel in comparison to other husking machines on the market. The flexibility in the belts would allow for varying sizes of nuts and level of compression could be easily manipulated through the adjustment of the rollers, similar to a belt sander.

However, this device is more complex than others and could end up being quite large. Another drawback is that this device would require maintenance on the belts and it is uncertain whether this method will even be successful in removing the husk from the nut.

Steel Brush Design:

One of the preliminary designs proposed incorporated steel brushes in its method of husk removal. This design was inspired by the violent feather plucking process that occurs when butchering chickens. A device similar to the one responsible for inspiration is shown in Figure 8 below:
Butchered chickens, with feathers still attached, are placed in the container with a plethora of rubber fingers. The container, and subsequently the rubber fingers, are agitated. This agitation coupled with the high coefficient of friction attributed to the fingers causes the feathers to be ripped from the body of the butchered chicken. In this manner, the rubber fingers are able to efficiently remove the feathers but are not aggressive enough to tear the skin or damage the body of the chicken.

In order to adapt the method from chickens to macadamia nuts, the design incorporates a steel brush roller in lieu of rubber fingers. Also, rather than being agitated in a container, the nuts would pass through a series of rollers in a continuous motion of de-husking to sorting. The thin steel bristles act to cut through the husk and rip it from the nut while enacting minimal stress on the nut itself.
This is a unique design and research has yielded no similar designs on the market as it pertains to husking nuts. Due to the flexibility of the thin steel bristles, a variety of nut sizes would be efficiently husked through this design.

However, it is predicted that the husk remnants would quickly populate the spaces between the bristles and clog up the rollers rendering them less and less effective. This would require extensive and potentially laborious cleaning. Sources have advised that increased maintenance or increased work caused by a machine will likely condemn the machine to little to no usage by the farmers in Guatemala.

**Decision Matrix**

<table>
<thead>
<tr>
<th>Decision Matrix for Designs</th>
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<tbody>
<tr>
<td><strong>Factors:</strong> Simplicity</td>
</tr>
<tr>
<td><strong>Weights:</strong> 2</td>
</tr>
<tr>
<td><strong>Valhalla Wheel</strong></td>
</tr>
<tr>
<td><strong>Dual Steel Roller</strong></td>
</tr>
<tr>
<td><strong>Belt Sander Attachment</strong></td>
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<tr>
<td><strong>Dual Belt</strong></td>
</tr>
<tr>
<td><strong>Steel Brush</strong></td>
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The table above is a collection of our group’s individual rankings of each of the designs. A great score for a category scored a 5 whereas a very poor score received a 1. Each of the members in our group filled out a matrix individually and without input from other members in the group. Each of the design concepts were ranked in order to compute which of the designs had the most merit and should be chosen as the final design. The Belt Sander design ranked the highest with a score of 76, with the Valhalla Wheel design as a close second with a score of 73.25. The Dual Belt design ranked the lowest with a score of 44.75, and the Steel Brush design ranked second lowest with a score of 47.5. The Dual Steel Roller design ranked in the middle with a score of 57.25. Predicted functionality and maintenance were two of the highest weighted categories in the design matrix. Therefore, since the Belt Sander and the Valhalla
Wheel design were the most simple, the most functional, and required the least maintenance, they received the highest scores. Since the Dual Belt and Steel Brush designs were complex and required a lot of maintenance in order to keep the machines functioning at full capacity, they received the lowest scores.

The criteria for this decision matrix were selected as these attributes displayed the most disparity between the five primary designs and thus the most significant points for comparison. Each design had associated pros and cons, but with this decision matrix, the team was able to quantify these differences with weights that displayed how critical each characteristic was in the development of a quality final product. For example, it is valuable to the team to come up with a novel idea; but it is inherently more valuable that the product is actually functional.

**Initial Prototype**

Moving forward with the choice of the Belt Sander Attachment design, the team proceeded to create an initial prototype. The first prototype consisted of a 1 hp belt sander with a belt that had a width of 4 inches, which is shown in the figures below. Several different blade configurations were tested in order to see what would be most effective in slicing through the husk of the nut. Housing for the blades was created in a way that allowed the blades to be removed and replaced with other configurations for easy testing. Black walnuts were used as a substitution for testing the blades, as they are very similar to macadamia nuts.

![Figure 10. Initial Prototype](image)
The first blade configuration was a series of blades placed parallel to the sander, as shown in the figure below. This first configuration proved that the method of slicing the husks would be effective. However, the husks were still attached to the shells when they came out of the sander. When the nut was rotated 90 degrees from the first pass and was sent through the husker again, the cuts in the opposite direction removed the husks more effectively.

![Figure 11. First Blade Iteration](image)

Testing by passing the nut through the device in different orientations inspired the next set of blade configurations. The first involved using blades going in two different directions, first perpendicular to the sander, then parallel to the sander, then perpendicular again, shown in the figure below. The idea was that the opposing blades would make cuts in opposing directions, which would more effectively slice and remove the husks. This design also used a “crab claw” mechanism with sharp edges on the end of it, which was meant to rip the husks off of the nut as it was shot out of the device.
The other configuration in the next iteration of blade design incorporated a 45 degree wall between two sets of blades that were parallel to the sander, shown in the figure below. With this design, instead of reorienting the blades, the wall reoriented the nut itself. When the nut passed through the first set of blades and hit the wall, it was rotated before hitting the next set of blades. This process ensured that the second set of blades would make cuts in a perpendicular direction to the first set of blades.
Revised Prototype

After testing various blade configurations on the belt sander, a revised prototype was created (see Figure 14). Potentially the most significant change that is seen in the revised prototype is that it features a smaller, lighter belt sander. It was found that having multiple nuts side by side under the blade plate could be detrimental to the performance of the machine; furthermore, the increased output gained by processing multiple nuts side by side was unnecessary. Feeding the nuts in a single linear fashion easily achieves and exceeds the desired 100 lbs/day output goal without any issues. With these findings, the team was able to decrease the size of the belt sander to feature a 2” belt and a ¾ horsepower motor.

A frame stand was manufactured to hold the desktop belt sander featured in the new prototype. This frame features two wheels at the bottom back side of the frame which facilitate easier transportation and sharing of the device. Four bolts hold the sander to the stand allowing the sander to be easily removed with a hex wrench.
A blade housing attached to a strut holds two blade plates. The blade housing is adjustable up and down the strut in order to customize the machine for nut size or perforation preference. Die springs are located between the blade plates and the blade housing to allow for small variations in nut size. The blade plates and die springs are attached in a manner so that the plates can move independently from one another; this is pertinent in that it facilitates multiple nuts in a linear fashion without detracting the cutting capability.

Pillow blocks serve as the attachment point for the strut to the belt sander. The rigidity and bearings in the blocks allow the strut to swing out away from the belt. This movement allows for easier maintenance and access to the blade plates. Moving the blade plates away
from the belt also enables the user to re-attach the table to the belt sander and use the machine as it was originally intended. An ergonomic latch allows the user to fix the strut in the upright “husking” position.

Analysis of Chosen Design

When the final design was chosen, the first question that needed to be addressed was whether or not it would reach the requested output goal of 100 pounds per day. The following equation was used in order to calculate the time it would take in order to de-husk 100 pounds of macadamia nuts.

\[ t = \frac{Output\ goal}{Nut\ weight \times Speed} \]

In this equation, time is in hours, output goal is in pounds (100 pounds), nut weight is in pounds per nut, and speed is in nuts per hour. From testing with the initial prototype, it was determined that the nuts were passing through the device at about 5 nuts per second, which translates to 17,581 nuts per hour. For the weight of the nut, an average of 2.58 grams per nut was used, which converts to 0.0057 pounds per nut. The result of this calculation was a little under 1 hour, meaning that the goal of 100 pounds a day will be reached very quickly. This also means that the device will not be heavily operated throughout the day.

Another question that was raised was how much the operating cost for the device would be. This was an extremely important question, since the cost of operating the device should definitely not outweigh the profit. In order to calculate the operating cost, the following equation was used:

\[ Operating\ cost = hp_{motor} \times \frac{0.7457kW}{hp} \times t \times cost \]

The belt sander has a 0.75 hp motor. Also, a time of 1 hour, calculated previously, and an average electricity cost in Guatemala of $0.26 per kWh were used. Performing the calculation with these values, the operating cost per day would only be $0.15. This operating cost is very low compared to the profit the farmers will make, determined earlier to be $78 per day.
A gross income of $78 per was calculated based off of statistics from 2011 - 2012 that reported a value of $0.78 per wet pound of macadamia nuts. Wet pound simply means that the nuts are still in their husks when they are weighed.

\[
\text{Profit per day} = \text{wet lbs processed per day} \times 0.78
\]

Through the previous calculation that it would take just under an hour to process 100 nuts, it can be seen that this machine will be able to keep up with a high production rate. It must be taken into consideration that this is not the only step in the process, there is much more involved in the total method. Thus, it would be erroneous to state that with this machine, the farmers will be able to net $78 per day minus the cost of running the husker ($0.15). However, in finding that the machine can reach the 100 lbs per day goal in just under an hour, it was appropriate to conclude that this machine will facilitate a high production rate and will ensure that the husking process is not the limiting factor on the total output of macadamia nuts.

Finally, the final cost for the materials needed to manufacture the device was calculated. The following materials that were used to build this device are listed below, along with their corresponding costs.

**Table 2: Cost of Materials**

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clamp-on Shaft Collar (2)</td>
<td>$4.22</td>
</tr>
<tr>
<td>Self-Lubricating Aluminum-Mounted Bronze Bearing (2)</td>
<td>$24.57</td>
</tr>
<tr>
<td>Spring-Tempered Steel Die Spring (8)</td>
<td>$38.40</td>
</tr>
<tr>
<td>¼” Alloy Steel Shoulder Screw (10)</td>
<td>$10.80</td>
</tr>
<tr>
<td>Nut for Strut Channel with Spring, Zinc, for 1-¾” Deep Strut, ¾”-16 Thread (pack of 5)</td>
<td>$6.38</td>
</tr>
<tr>
<td>Cover for 1-¾” Single Strut</td>
<td>$1.12</td>
</tr>
<tr>
<td>U-Bolt Pull-Action Toggle Clamp</td>
<td>$19.47</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$104.95</strong></td>
</tr>
</tbody>
</table>
Future Plans

Future plans for this device include implementing a hopper as well as a sifter. The hopper would be constructed from a 5-gallon bucket, which are often used by farmers as a way of collecting nuts. By cutting the correct size hole in a 5-gallon bucket lid, the farmers could simply place the lid onto their collection bucket, and place it upside down into the housing. The housing would include a funnel that would direct the nuts onto the correct position. No modifications would have to be made to their current collection buckets.

When the nuts and the husks come out of the other end of the belt sander, there needs to be a method to sort the nuts from the husks. This would be accomplished by using a bingo-cage design to collect the nuts. The slots in the cage would be small enough that the nuts in the shell would stay in the cage, but large enough that the husks would fall through. A sketch of this design can be seen in Figure 18 below.

Conclusion

“For decades, the main model of Third World aid has been the obvious: Give stuff to poor people...you need to figure out what they really want. That means treating them as equals. Charities don’t have to do that.” This device seeks to empower the impoverished macadamia farmers in Guatemala, not by giving them a handout, but by giving them a tool and a design that can nurture a sustainable income. With this machine, macadamia farmers can
increase their output of macadamia nuts and can increase their profits. In the big picture, this yields a world of possibilities for the end users.

The team is not done with this device. There is always room for improvement and the team seeks to further iterate the machine with a trip to Guatemala to test the device, interact with the farmers, and formulate design improvements necessary for proper diffusion of the device. This project quickly transferred from an obligation to a project of passion. A vision for the possibilities and potential implications of this device has been running vividly in the minds of the four creators. However, the harsh truth is that if one does not get to work making their vision more than an abstract, imaginary device, they will soon find themselves occupied making someone else’s vision a reality.
Works Cited


