Cambodian Field of Dreams

Team 16
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Engineering 340 Senior Design Project
Calvin College
15 May 2014
Executive Summary

World Renew is a non-profit organization active all around the globe, responding to the needs of people suffering from poverty, hunger, disaster, and injustice. The mission of this organization is to “engage God's people in redeeming resources and developing gifts in collaborative activities of love, mercy, justice, and compassion.” Cambodia, a country where World Renew has a strong presence, is heavily reliant on agricultural industry, but their seasonal yields have been far surpassed by those of their neighboring countries. Dr. Roland Bunch, a leading agroecologist (a scientist that studies ecological approach to agriculture) and Director of Sustainable Agriculture and Rural Livelihoods at World Neighbors, conducted a study of the country and proposed a cover crop as the solution to this problem. A cover crop is a biological fertilizer that, instead of being harvested after it grows, is tilled into the malnourished soil to reintroduce nutrients. Dr. Bunch recommended legumes for the cover crop. In order to do this, Calvin College received the task of designing a piece of equipment capable of planting the cover crop in untilled soil. The planting must be done in a way that fosters the best possible growth, meaning the surrounding soil must be broken up to enable the legume roots to develop.

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1. Introduction

1.1 The Team

Brittainy Claire Phillippi (ME) grew up in central Indiana. She went to school and lived in Greenfield, IN. She began her passion for mechanical engineering while camping and fishing. Claire has always been fascinated with machines and took them apart to better understand how they worked when she was young. She is working in the hydraulics industry currently, but hopes to work in the mission field after she finishes her seminary degree. In her free time Claire enjoys fixing her motorcycle, gardening, and living in intentional community.

Joshua Vanderkamp (ME) is a native Grand Rapidian. He enjoys playing sports, reading, a classic video game or two, and camping with friends or family. He grew up loving how things function and has continued on that path here at Calvin College. Following graduation he is working in Holland as a design engineer. In the future Josh hopes to do more mission-related engineering work similar to this project in Cambodia.

Schieffer Kwong (ME) is an international student from Hong Kong with a US citizenship currently pursuing a Bachelor of Science in Engineering, Mechanical Concentration with International Designation. In his time at Calvin, he was a three year member of the Student Martial Arts Club (Kicks for Christ Federation) studying Tang Soo Do Kyohoe Kwan. He has taken four belt tests and passed all of them. During the summer of 2013, Schieffer worked as an intern in TRW Automotive in Koblenz, Germany in the department of Actuation. He developed vacuum consumption theory and designed a ball screw tolerance test rig. When he graduates, he plans to work in the American industry as a Mechanical Engineer, hopefully in the field of aviation.
1.2 The Project
The soil nutrition and yearly rainfall in Cambodia is quite poor. The main rice season usually yields a harvest from 1.5 to 2.5 tons per hectare, whereas the surrounding countries with similar conditions produce yields up to 5 tons per hectare. World Renew researched techniques to improve the agricultural output of Cambodia. Dr. Roland Bunch is a leading agroecologist and Director of Agriculture and Food Safety at World Vision International and he assisted World Renew in addressing this issue. It was decided that a biological fertilizer would significantly increase Cambodia’s rice yields to possibly a consistent 3 tons per hectare. “Cover crop” is the term used to describe a biological fertilizer. Increasing the food in this manner would be fantastic for the farmers’ livelihoods. The goal of this project was to produce equipment capable of planting this biological fertilizer in unutilized, dry ground prior to the main planting season.

1.3 The Partners

1.3.1 World Renew
The project was proposed by World Renew, a relief and development organization of the Christian Reformed Church. The organization responds to the needs of people around the world who are suffering from poverty, hunger, disaster, and injustice. The mission of this organization is to “engage God's people in redeeming resources and developing gifts in collaborative activities of love, mercy, justice, and compassion” (worldrenew.net).

1.3.2 Cambodian Community
Cambodia is a country in Southeast Asia with a population of about 15 million people. Cambodia shares borders with Thailand, Laos, and Vietnam. The government is a Unitary Parliamentary Constitutional Monarchy, meaning there is shared power between a king and a senate. The official religion is a type of Buddhism, which is practiced by about 95% of the populace. Civil war ravaged the country during the early 1970’s, followed by Vietnamese occupation from 1978 to 1993. (cia.gov) It wasn’t until the turn of the century that reconstruction finally began to improve the country. This project will involve the people of this culture and background. The project was designed to be culturally appropriate, so that the Cambodian people would take ownership of the practice of using biological fertilizers.

2. Project Management

2.1.1 Team Organization & Method of Approach
It was important to establish roles for each team member. These roles were based on each persons’ experiences and interests, thus the team would run efficiently, and with each person performing tasks most enjoyable to them. Each member focused on designer one sub system. This included brainstorming designs, then testing and building them.

Claire Phillippi is acquainted with members of World Renew. She was the team’s main contact with them. She has extensive experience with Solidworks, and created most of the team’s 3D models. Her roles: World Renew contact, CAD modeler, system designer, budgeter.
Schieffer Kwong thoroughly enjoys learning about subject matters and research for the various significant components of the project. His knowledge of Dreamweaver allowed him to manage the team’s website. His roles: system designer, researcher, troubleshooter, webmaster.

Josh Vanderkamp is very detail-oriented and enjoys writing. He assembled reports with the assistance of team members, and put them in the proper format with appropriate organization and grammar. His roles: system designer, troubleshooter, report writer.

The team was assisted by various other personnel as well. The organization chart below summarizes these interactions.

Team meetings were held weekly, varying depending on need. Topic meetings were held at the beginning and the person who brought the topic up would lead discussion. Solutions and notes were recorded on the team’s white board and later sent to each member by email, detailing what tasks each member was
currently working on and any major decisions made. Frequently, a member would present sketches or CAD drawings. These were collected and stored to reference later.

2.1.2 Schedule
Starting the fall semester Claire Phillippi made a Gantt chart based on prior experience in manufacturing and product development. This was updated halfway through the fall semester when it was determined that additional research was needed to decide which overall design would be best. After an industry consultant meeting the scope of the project changed and the Gantt chart was again updated for the new semester. After the spring Gantt chart change the project shifted to a list of tasks to be done each week with important dates outlined by the class calendar. This task list was updated every week with each member taking responsibility for a single task to complete. The time devoted to this project per week is outlined in the table below.

<table>
<thead>
<tr>
<th>Table 1. Number of Hours per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Semester</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Claire Phillippi</strong></td>
</tr>
<tr>
<td><strong>Josh Vanderkamp</strong></td>
</tr>
<tr>
<td><strong>Schieffer Kwong</strong></td>
</tr>
</tbody>
</table>

2.1.3 Budget
The first budget was written up in excel with the cost of proposed parts based on Claire’s experience with quoting. This gave the team a starting point. Each design in the decision matrix was given a theoretical cost value. An excel chart was made to keep track of all purchases in relation to the overall budget and how much was allocated over time for each section of the project. Each purchase was added to the budget excel chart and the budget was recalculated. All new ideas where speculatively priced out and then checked against the budget allowed for that section of the machine. If a system was donated, the money that system was going towards that would be made available for a different portion of the project. This meant unallocated budget would shift towards an under budgeted part. There was room in the budget for a broken piece in the machine or unforeseen expenses.

3. Background

3.1 Current Labor Conditions
The focus of our project targets female workers who help the household by doing agricultural work besides their daily main job. To understand their everyday life, one must understand Cambodia’s economic lifeline. The following table shows 2007 economic data of Cambodia (Economic Institute of Cambodia 1 - 30).
From this table, one can see that the agriculture sector has the most employment, however it has the lowest wage in USD per worker. Cambodia’s economy is also dependent on her industry, particularly garment production, and service, especially tourism (Economic Institute of Cambodia 1 - 30). The table below shows the agriculture “Paddy” growth, or farming growth, for these years and also how the other key industries are growing as well.

Table 2. GDP, Employment and Output (2007)

<table>
<thead>
<tr>
<th>Sector</th>
<th>GDP</th>
<th>Employment</th>
<th>Output/worker(US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>31.9%</td>
<td>58.1%</td>
<td>511</td>
</tr>
<tr>
<td>Industry</td>
<td>26.8%</td>
<td>14.7%</td>
<td>1,691</td>
</tr>
<tr>
<td>Service</td>
<td>41.3%</td>
<td>27.2%</td>
<td>1,417</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>931</td>
</tr>
</tbody>
</table>

Source: Data compiled from NIS and CSES 2007

Table 3. Cambodia's GDP Growth (% using 2009 prices)

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>-1.0%</td>
<td>15.5%</td>
<td>5.5%</td>
<td>5.1%</td>
</tr>
<tr>
<td>Paddy</td>
<td>-12.2%</td>
<td>43.7%</td>
<td>4.3%</td>
<td>7.5%</td>
</tr>
<tr>
<td>Industry</td>
<td>17.0%</td>
<td>12.9%</td>
<td>18.4%</td>
<td>8.4%</td>
</tr>
<tr>
<td>Garments</td>
<td>24.9%</td>
<td>9.2%</td>
<td>20.4%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Services</td>
<td>13.2%</td>
<td>13.1%</td>
<td>10.1%</td>
<td>10.2%</td>
</tr>
<tr>
<td>Tourism</td>
<td>23.4%</td>
<td>22.3%</td>
<td>13.7%</td>
<td>10.3%</td>
</tr>
<tr>
<td>Total GDP</td>
<td>10.3%</td>
<td>13.3%</td>
<td>10.8%</td>
<td>10.2%</td>
</tr>
</tbody>
</table>

Source: Data compiled from Cambodia Economic Watch

3.2 Soil Nutrition
Cropping in Cambodia revolves around three seasons: early wet season from April to July; main wet season from July to October; and dry season from November to March (Nesbitt, 1997). Rice is the dominant crop in Cambodia, which ~90% of her agricultural land is used for (Nesbitt, 1997). Some rice are harvested in sandy soils, however, the dominant rice ecosystem in Cambodia is rain-fed lowlands (Wade et al. 1999). Within a single farm, the upper terraces maybe classified as a drought-prone sub-ecosystem, and the lower terraces may belong to submergence-prone sub-ecosystem. In other words, 1) fields in upper terraces lose large amount of water, especially after heavy rainfall, through subsurface lateral water movement and surface runoff. And 2) lower terraces would intercept and absorb water flows
from the upper terraces (Fukai et al. 2000). Such classification is mostly in part due to the erratic rainfall, topography and the dominance of sandy textures in the rice crop’s root zone.

“Drought, waterlogging, and inundation are significant water-related hazards that influence the growing of field crops in lowland soils. In addition, soil fertility constraints in the early wet season and dry season will likely differ from those encountered by rice due in part to the different soil water regime they encounter. In particular soil acidity, low nutrient status, hardsetting and shallow rooting depth have been identified as significant constraints for field crops.” (Seng, R.W., P.F., N., S., and W. 42 - 48)

Figure 2. Generalized geology map of Cambodia. Source: Mekong River Commission

World Renew has been in Cambodia for several years, working closely with individual communities. The goal is to enable Cambodian communities to help themselves with problems. World Renew worked with a different organization to figure out that a pre-season of legumes would be worth it. The problem is that it is very difficult to dig holes and put seeds in the ground when only the older women are around. We are going to make this task easier with our machine. World Renew helped identify the problem, and as a team, we would like to provide a solution to it.

4. Requirements
The goal of this project was to plant legume seeds in dry, un-tilled clay at a specified depth of 5 to 10 cm (2 to 4 inches) with an additional 5 to 10 cm of plowed soil underneath it. The figure below illustrates the ideal end product.
The process needed to be very repeatable and consistent over an entire rice field. Each seed should be roughly 60 cm (24 in) apart, with spacing between rows around 90 cm (35 in).

The machine should be durable, light, fast, intuitive, and affordable while producing the field seen above. These variables, among others, played a part in the decision matrix discussed later. The purpose of this equipment is to plant the cover crop that will fertilize the rice fields and, according to extensive research (discussed later), increase rice yields.

The purpose of this project is to introduce the idea of a cover crop to the Cambodian people. This idea can improve soil nutrition and crop yields as well. So the task for the senior design team was to build a machine that enables the Cambodian’s to do this.
5. Design
The machine was divided into four main sub systems: the frame, digging system, driving mechanism, and seed distribution system.

5.1 Digging System
The primary decision to be made was which basic method would be implemented to dig or plow the soil to meet the requirements. This was tricky because what is standard in the US is not functional in Cambodia due to the incredibly hard soil.

5.1.1 Criteria
Several important criteria were selected to evaluate various options.

*Force Used*
A machine should be able to be moved across the field with as little force as possible. Exerting the proper force should not be so difficult that our user becomes very tired while using it. This part of our criteria was denoted by the force used. The ease of the system is the most important part of the design. The user should be able to dig a hole, place the seed, and cover it with minimal effort in comparison to conventional means. The team defined ease as force required by user to move dirt. It was important that the future users could *trust* this machine. The machine needed to be intuitive to understand and use.

*Simple Use*
The use of the machine must be simple for the end user. Some machines require more than pushing a planter so these were compared to the easiest system. A machine was given a good rating if it was as simple as pushing a planter across a field. It was important that the future users could *trust* this machine. The machine needed to be intuitive to understand and use.

*Filler soil*
A criterion given to us from the customer was to have soil in the hole before the seed was planted so the seed would root well. This criteria also describes if a design put soil back into the hole after the seed was placed. A design received a good rating if the hole was dug and half-filled in before the seed was placed.

*Cost*
The cost of production and cost to the user was covered by cost in the decision matrix. A good cost would be a low production cost and a low cost to the consumer. All of the designs met the production cost and customer cost. This meant that designs were compared to themselves.

*Durability*
Machines should be durable enough to last ten years. If a design did not meet this criterion then it was given a low rating. To receive a high rating the machine just had to last the ten years. This criterion was denoted by durability.

*Ergonomics*
The user should also be comfortable when using this machine which is denoted by ergonomics. The user should not be bending down or standing at odd angles to operate the machine. A good design was one that allowed the user to use the machine at their own designated height.
**Simple Maintenance**

The machine should be so simple that it is very easy to understand how the machine works. This will help the user fix something if it broke on the machine. The machines were given a good rating if they had a simple mechanism. It was important that the future users could trust this machine. The machine needed to be intuitive to understand and use.

**Replaceable**

The machine should be easily fixed when broken. The designs were judged if they could be fixed with pieces that are found in Cambodia. If the entire machine had to be replaced than this would mean the design is not a replaceable machine. A high rated machine would have parts in Cambodia to replace if they were broken.

**Speed**

The length of time it takes for the seed to get into the ground and covered with soil was denoted by speed in the decision matrix. This was rated as a good speed or a bad speed if it was faster than hand digging each hole with a shovel and planting the seed.

5.1.2 Alternatives

The two major categories were handheld devices and push devices.

5.1.2.1 Injection Hand Seeder

This design was the simplest solution to the presented problem. A hollow shaft connects the seed storage at the top to a pointed bottom component capable of opening upon contact with the ground.

There are several pros to this design. There are only 3 main components – the seed container, body (or shaft), and injection end – so the cost to produce it would be very low. It was estimated around $23 to produce, not including labor or machining costs. It was also very simple to use. This straightforward design is very user friendly and intuitive. Because of this maintenance is also very simple, there are few components to replace and replacing them is easy. It is also very durable.

One of the cons to this design was the amount of effort it takes to heft the device and bring it down with force into the ground. That was an important requirement: that it doesn’t cause back problems or other related injuries with repeated use. This was the main reason why this design was not selected.

5.1.2.2 Auger Hand Seeder

The auger hand tool was another somewhat simple solution, with a hollow shaft connecting to an auger and a seed container at the top. The auger is inserted into the ground and rotated until it is 15 cm deep, it is then pulled out and hovers over the hole while a lever is flipped and several seeds fall down the shaft and into the hole.

One of the most important benefits of the auger design is that it breaks up the soil well and provides a perfect situation for the seed to grow. The seed is dropped directly on this churned soil. Its cost is also low, as with the injection hand seeder. The main difference is the $20 premade auger which makes it slightly more expensive, but more durable. It is also simple to use and requires less force.

Lifting and carrying this device was still a concern. Again, that was one of the most important criteria and was the biggest factor as to why this design was not selected.
5.1.2.3 Industrial Push Seeder

This push seeder is the most common seeder used for smaller-scale situations. The team visited a local organic farm in Zeeland to see firsthand how it worked. A simple hoe creates a furrow in soft ground and directly behind this, seeds are dropped in. A gear is located inside the seed container and as the wheels of the device turn, they turn this gear too. At each turn several seeds are captured and deposited. A chain or rigid piece of metal drags behind the device by a few centimeters to pull the displaced soil back over the seeds. A modification was designed for the front hoe, because the soil in Cambodia is far more dense than the lush soil in Zeeland, MI. The proposed front was either a sturdier hoe device or two rotary discs overlapping one another.

A pro of this device is that it was used one simple motion: push the device in a straight line. The speed of the device would be good because it is one continuous motion and not broken up at each hole. The posture of the user would be healthy due to the motion, with no unnatural bending of the back.

On the other hand, the cost of this device would be higher.

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>$25.00</td>
</tr>
<tr>
<td>Steel Pipes</td>
<td>$7.00</td>
</tr>
<tr>
<td>Steel Angle</td>
<td>$4.90</td>
</tr>
<tr>
<td>Seed Container</td>
<td>$5.00</td>
</tr>
<tr>
<td>Spring</td>
<td>$5.00</td>
</tr>
<tr>
<td>Seed Device</td>
<td>$20.00</td>
</tr>
<tr>
<td>Labor</td>
<td>$100.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$166.90</strong></td>
</tr>
</tbody>
</table>

Because of the component used to break up the soil, there would be significant force required by the user. Also, there is little or no filler soil underneath the seed. This would hinder the entire ideology behind the project of growing these legumes.

This was a good design and was expected to score highly on the decision matrix. However, it was not the best choice based on all of the variables.
5.1.2.4 Plow Push Seeder

The plow push seeder combines the idea of the industrial push seeder and an old fashioned plow. Using the weight of a solid metal plow to break down the soil, a furrow would be created. The components following would be similar to those of the industrial seeder for the seed dropping and furrow filling. There would be only one wheel and it would be located on the front with long handles coming straight back to the pusher. Dragging behind the wheel would be the plow. Opening up the soil would then become a simple process of just pushing the machine across the field. It is very durable and cost effective because the front is simply a heavy piece of welded steel. One of the biggest problems is again the lack of filled-in soil underneath the seed. This equipment would also require a great deal of force to drag such a heavy object across a field.

![Figure 6. Wheel Push Seeder](image)

5.1.2.5 Wheel Push Seeder

The wheel push seeder is a design already on the market but not widely used. It is a wheel with two handle bars protruding straight back for the user to push. Seeds are stored inside the wheel and there are injection “beaks” along the outside which open when planted in the ground. As the beaks are in the ground, the lever, which trails behind each beak, then comes into contact with the ground with the rotating wheel. The lever is engaged by contact with the ground. This is a sturdy, simple to use device which requires little force. The parts would be more difficult to access due to its compact nature, and the cost would be higher as a result of the more intricate parts. Also, this design does not encourage filler soil. The image below is the product from the competitor, discussed under Marketing Study.

![Figure 7. Wheel Push Seeder](image)
5.1.2.6 Plow

The modern seeders, found by the team at a local organic farm, use a plow to dig a trench and then place seeds based on the turn of the wheel in front of the plow. All of these devices are used with easily-tilled soil. None of these seeders are used in Cambodia due to the very hard ground.

5.1.2.7 Auger

The team looked into devices that are used on hard ground. This is where an auger came from. The angle of attack on augers are made to make it easier to dig into any type of soil.

![Auger Image]

Figure 8. Auger

5.1.3 Decisions

5.1.3.1 Digging Method

A decision matrix was made to weigh the design alternatives.

<table>
<thead>
<tr>
<th>Decision Variable</th>
<th>Weight</th>
<th>Industrial Push Seeder</th>
<th>Auger Push Seeder</th>
<th>Wheel Push Seeder</th>
<th>Plow Push Seeder</th>
<th>Auger HandSeeder</th>
<th>Injection Hand Seeder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force Used</td>
<td>20%</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Simple Use</td>
<td>18%</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Filler Soil</td>
<td>15%</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Cost</td>
<td>13%</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Durability</td>
<td>10%</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>8%</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Replaceable</td>
<td>6%</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Simple Maintenance</td>
<td>6%</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Speed</td>
<td>4%</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5. Digging System Design Matrix
The auger push seeder was chosen from the team's decision matrix. This design consists of an auger which is hand cranked and a wheel for the push seeder. To make the pushing of the seeder easier, a cam was designed to raise and lower the auger as the machine moves along the ground. This way, as the person cranks the auger the auger will push itself into the ground and back out again. Then, when finished with the hole and the wheel is moved the optimal three inches from the hole, a seed will be dropped into the hole.

5.1.3.2 Vertical Pressure
An auger will dig itself into the ground with little additional downward force, but most auger systems have the auger moving up and down regardless. This means that an easy to use mechanism needed to be designed to push the auger into the ground and pull it back up.

5.1.3.2.1 Drill press mechanism
A drill press mechanism uses a screw gear and a hand with a spur gear to drive a drill press down while it spins. An example of this can be seen in the figure below. The user would have to operate the drill press mechanism at the same time as operating the treadle to spin the auger. The team thought this was a legitimate idea, but only to be used if nothing better worked.

5.1.3.2.2 Straight rod
A straight rod would be attached to the auger axel support and the user would push down on it while operating the treadle to spin the auger. The handle on the straight rod proved difficult to integrate with the rest of the design. It seemed always to be in the way of the user. The team liked this idea, but wanted something that the user would not have to operate simultaneously.
5.1.3.2.3 Cam mechanism

Many systems use cams to move levers and arms for different functions. A cam could be designed to match the movement the team wanted out of the auger. The cam designed based on the displacement graph seen below.

The cam displacement graph was drawn with a dwell, rise, and fall. The time that it takes for these actions to work is based on number of turns of the auger to number of turns of the cam. The ideal ratio was 16 auger turns to 1 cam turn. The displacement graph is shown below. A test was to understand how many auger turns it took to dig a hole and pull the auger back out of the soil. In order to simulate Cambodian soil hardness properties, the test was done during Michigan winter. The purchased auger was attached to a handheld drill press for this test. The test proved that it took 8 to 10 turns of the auger to dig a hole. Once a dwell and fall period was added the total time to dig a hole was 16 turns of the auger.
5.1.4 Integration, Test, Debug
This system was tested in several different ways. The initial idea was tested with the handheld auger as described previously. The auger and cam systems themselves were also modeled in CAD to test and integrate them with the rest of the system.

![Proof of Concept Auger](image12)

**Figure 12. Proof of Concept Auger**

5.1.4.1 Auger Model, Test and Integration
The design was modeled in CAD. Below is an image of an incomplete prototype which includes the auger, cam, and frame. This enabled the team to test if the systems fit together properly.

![Auger Integration into Frame](image13)

**Figure 13. Auger Integration into Frame**
Since the goal of our project was to make it simple for a Cambodian farmer to operate this device the team decided that the cam mechanism would require the least amount of work on the side of the user, because it is the only device brainstormed by the team that does not require the user to do two things at once. The cam is using to rotation of the auger axel to spin at a rate slower than the auger. This gear rate reduction was accomplished by bicycle gears.

5.2 Frame

5.2.1 Criteria
The team decided early on that the frame needed to be very strong. The device needed to handle the harsh, bumpy conditions of a Cambodian “winter.” It also needed to be easily maneuverable.

5.2.2 Alternatives
Various frames were considered to accomplish the task of digging a hole and planting a seed. The two push seeders pictured below are standard in US agriculture industry.
Figure 15. Market Push Seeders

The picture on the right is more durable and allows the device to weigh more while still being easily maneuverable. Because of this, the team decided to also look into using a wheelbarrow type frame as well.

5.2.3 Decisions

5.2.3.1 Frame Type
The team decided that the weight of the machine should be used to dig the hole rather than the strength of the operator which would be used in Figure 15. This meant that our machine should be fairly heavy. A wheelbarrow is known to be a simple way to transport weight.

5.2.3.2 Frame Tires
Bike tires were chosen as for the front of the wheelbarrow design. They are cost effective, durable, easy to install, and simple in function. A spare car tire was considered, but after consideration of balance it was discarded. Using two wheels was more stable than one and would better handle the forces applied by the user when powering the auger.

5.2.3.3 Material
When looking at planting devices made today, many are made of plastics. Planting devices of the past were primarily made out of metal and lasted for season upon season of planting. The team decided that this planting device should last for a long time. This metal frame should be painted with rust resistant paint to stand up to the weather and humidity of Cambodia. Steel was chosen as the main material used. It is strong, very common, and cost effective. The tensile strength for steel can easily hold up under the calculated forces that will be applied to the system. The welded steel frame that was constructed is in the figure below.
5.2.4 Integration, Test, Debug
A cardboard prototype was built to test the ergonomics of a wheelbarrow design. After analyzing this design in perspective of an average size Cambodian, 5 feet 3 inches, operating this machine, the team decided to shrink the overall length of the frame.

Figure 16. Welded Steel Frame

Figure 17. Cardboard Ergonomic Test
The CAD model below shows an average Cambodian woman standing next to the altered frame.
5.3 Driving Mechanism

5.3.1 Criteria
The most important criterion of the driving mechanism was to translate sufficient energy to turn the auger. It was also very important to do this in a simple motion that was intuitive to the user.

5.3.2 Alternatives
Turning the auger by hand or using a pedal were the main designs pursued. A hand auger was simple in design but more difficult when trying to produce the proper amount of torque for the auger. The pedal design is used in manual lathes and sowing machines. It involves a 4-bar linkage and a properly weighted flywheel.

5.3.3 Integration, Test, Debug
A prototype of a lathe flywheel design was constructed out of wood as a test to show a foot powered lathe could work.
The figure on the right has the user stepping on a bar attached below. The figure on the left has a step also but the linkage is attached above the step. The flywheel design that functioned the best for the design was a combination of these two designs. An inverted step design was decided upon, with the step facing away from the user for support only, and the bar there for the user to apply force to. The flywheel is connected via bike chain to a horizontal shaft. This shaft translates the torque to the auger through a pair of bevel gears.

5.3.4 Decisions
The torque required to drive the auger was calculated to be 290 lbf-in. Testing the auger by hand drill supported this calculation. Creating this much torque by hand would be difficult, even if it were done using a lower force over a greater distance. The team decided to utilize the muscles in the legs because they are the strongest in the body, which would provide the most power. So the treadle peddle was chosen. Using EES and Solidworks a model was made that was calculated and tested for necessary torque and a smooth, user-friendly motion. The EES sheet is presented in the Appendix. The Solidworks model can be seen in figure 19.
The fourth linkage of this 4-bar system was the “ground” which is an imaginary piece from the end of the bottom linkage to the middle of the flywheel. In reality this is created by the frame that this system will be attached to. It was also necessary to weight the flywheel appropriately so the pedal raises again after the user pushes it down. The team discussed using a motor to power the machine. However, this project was intentionally approached in a sustainable manner, and it was hoped to avoid burning fossil fuel, etc.

The system was constructed and below is a picture of the final treadle.
5.4 Seed Distribution

5.4.1 Criteria
The team identified seven design criteria for the seed distribution system:

1. Light weight
The overall seed distribution system design had to be somewhat light weight because the system should not interfere with the balance of the frame. It was easier for a user to repeatedly pick up a balanced frame compared to an unbalanced one.

2. Replaceability using local parts
Another criterion involved how easy it would be to replace parts using in-country (in Cambodia) resources. This was important because the user could maintain the system if extra parts were needed. Further research into system alternatives indicated that parts for such systems were usually unique, hence it was unlikely that parts would be available off the shelf. However, the user could still make parts if they had access to tools. A failure in the system due to broken and irreplaceable parts should not impede the use of the whole design.

3. Operable by hand
The seed distribution system also needed to be operable by hand if the automated distribution were to fail. This criterion acted as a failsafe in the system. This failsafe should ensure that the user could manually operate the system if the automation were to fail.

4. Ergonomics, simplicity

Ergonomics and simplicity carried heavy weight in the design matrix because a complicated design would ensure the user’s dependency on replacement parts. The team wanted the design to encourage the user to be independent. The simplicity of the design and mechanisms should allow the user to understand the principle of the system without the help of a manual. The team also wanted the seed distribution system to be ergonomic, meaning it should be a simple, comfortable, and injury-free motion.

5. Terrain Friendly

Another criterion was that the design needed to be terrain friendly. Uneven roads should not cause the system to break down or spill the seeds. Seeds should also not spill when the user picks up the machine.

6. Durability

Durability was weighted heavily because the team wanted to minimize the need for maintenance. The system needed to be able to handle seeds of different sizes without breaking or jamming.

7. Cost

The cost of the seed distribution system should be kept to a minimum. This, in turn, would lower the overall cost of the machine.

5.4.1.1 Alternatives

5.4.1.1.1 Feeder Bowl System

Feeder bowl systems usually involves a shaker, cork screw delivery system. Examples and concepts are shown in the following patents: US 2654465 A; US 3125208 A; FR2634187-A1. These systems are used to single out components from bulk packages for further processing. The frequency and amplitude of the shaker would determine the flow rate of the material entering the delivery system. The delivery system, for example a conveyer belt, will bring the material to a different location for further processing.
5.4.1.1.2 Archimedean Screw

The team also considered utilizing the Archimedean screw to deliver seeds. US Patent 2612294 and EP 0185541 shows a seed hopper design that used the Archimedean screw. The screw is housed in a tight tolerance housing so that the delivery system would not leak. The screw sits at an angle from the horizontal and would bring up components from the bottom of the hopper, which holds the components. The patent drawing is shown below.

![Figure 23. US Patent 2612294](image)

5.4.1.1.3 Horizontal and Vertical Separation

Further research on different types of seed selection/separation systems shows that there is yet another system which uses a turning disk with holes to catch components and bring them to a chute. There are two types of such systems: vertical and horizontal. In a vertical system, the turning disk, installed perpendicular to the ground, has scoops around the holes such that the components could be scooped up, as show above. The components will then be dropped through a hole and delivered for further processing. The horizontal system has the turning disk installed horizontally respective to the machine, but at a slight angle to the ground. The disk turns counterclockwise and the components are secured in the holes of the disk. The brush then brushes away extra components that might be caught in the disk hole. The drop through hole is behind the brushes.
5.4.1.2 Decisions

Feeder bowl systems often involves expensive equipment components, electronics, and also a skilled worker for maintenance. These requirements make all such systems unsuitable for the team’s design because the team would like to minimize the cost of the design, not be dependent on electricity, and not require maintenance by a professional; hence the unsatisfactory scores for criteria 3, 4, 5 and 7. The system would not be lightweight as it is a complicated system with a motor. The system would also not be terrain friendly as the user would need to be careful about the delicate machinery. Durability also has a relatively low score because the delicate machinery would weather quickly.

The Archimedean screw design is easily operable by hand, simple, and durable. Hence criteria 3 and 6 are scored high. The use of the Archimedean screw also requires manual timing because seed delivery would not be instantaneous. Emptying the hopper would also require additional input from the user. Hence, criteria 4 is scored relatively high. This design is not lightweight, the screw will not be readily replaceable and the cost is high. This resulted in an unsatisfactory scores in criteria 1, 2, 4, and 5.
The horizontal seed plate system could be operable by hand, but additional gearing is required. This design also requires additional components such as the brush, thus the design would not be very simple. The locking component for the plate could also be easily lost. Because this design requires additional components the cost would be higher. Hence criteria 1, 3, 5, and 7 are scored low. Most of the parts could be replaced at local shops, compared to previous described alternatives. The durability of the system is also pretty good because moving parts are minimized, and the structure of the system is sturdy. The hopper of this system could be closed to prevent spillage when the user picks up the machine. Therefore criteria 2, 4 and 6 are scored high.

The vertical seed plate system had fewer parts in comparison to the horizontal one. With fewer parts, the system was lighter and had a relatively lower cost. This system could be operated by hand, but additional gearing was required. The system and its parts were simple and the basic principle of how it worked was easily understood. The durability of the system was also pretty good because moving parts were minimized and the structure of the system was sturdy. The hopper of this system could be closed to prevent spillage when the machine was picked up. However, the size of the hopper limited the maximum number of seeds it could take, as additional seeds may have impeded the effectiveness of the vertical seed plate. This concern was negated when the team consulted a local farmer who used the same system.

The final scoring of all alternatives showed that the vertical seed plate system was the best candidate. The team decided to use that system.

<table>
<thead>
<tr>
<th>Difference</th>
<th>Weight</th>
<th>Seed Plate Vertical</th>
<th>Seed Plate Horizontal</th>
<th>Feeder Bowl Systems</th>
<th>Archimedean Screw Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Light Weight</td>
<td>8%</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2 Terrain friendly</td>
<td>8%</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3 Operable by hand</td>
<td>11%</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>4 Parts replacability at local shops</td>
<td>14%</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5 Cost</td>
<td>14%</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6 Durability</td>
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<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7 Ergonomics, Simplicity</td>
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<tr>
<td></td>
<td>100%</td>
<td>3.25</td>
<td>2.47</td>
<td>0.5</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Table 6. Seed Distribution System Decision Matrix

5.4.2 Integration
The seed hopper has to be integrated into the frame in order to be part of the machine. The design of the seed hopper already allowed for two supports. The team decided to use the existing supports as they were designed to take strain. However, the original design was intended to be belt driven. Therefore, the team also decided to add a third support to further stabilize the seed hopper because of the forces involved using the bike chain.
To integrate the seed hopper, three supports were made out of 14 gage sheet metal. This specific gage was chosen because of its strength to weight ratio in this application. The critical dimensions of the support was determined by how the gear of the seed hopper is lined up to that of the drive shaft. Another design challenge was gear interference. The support cannot interfere with the operation of the gears and chains.

To spin the disk plate and still use bike gears as a driving mechanism, an adaptor was made in replacement of part 12, shown in the figure below. The material choice of the adaptor was steel because the bike gear was welded to the adaptor. The adaptor was attached to the hopper assembly via a lengthier part 13.

5.4.2.1 Test, Debug

A vertical seed box was donated by Earthway. Seeds were purchased to test its durability. A simple test was done to see how many seeds each scoop holds. The test result showed that the scoops had no problem picking up seeds. A maximum of two seeds and a minimum of one seed would be in one scoop. The results were satisfactory. The team decided to use a safety factor of two to ensure that even if one of the scoops somehow fails to pick up a seed, the other scoop would cover for the failure.

![Figure 26. Hopper Assembly](image)

After installment of the seed hopper to the frame, another test was conducted to test the performance of the seed hopper. This was because it was not installed perfectly horizontal respective to the ground, as it was designed for. Seeds were put into the hopper and the seed plate was spun to simulate the planting process. The results were observed and could be summarized into the following:

1. A maximum of one seed and a minimum of zero seeds would be in one scoop. The minimum occurs less than two thirds of a time in a three scoop cycle.

2. There exist threshold where a minimum amount of seeds is needed in order for the scoop to pick the seeds up. If the threshold is not reached, then the scoops will fail to pick up seeds.
To counter these problems, the safety factor was increased to three. This means that for each hole dug, three scoops of the seed plate would be used to bring seeds to be delivered. The user is also advised to check, and refill if necessary, the seed hopper every 30 holes.

Loose gear chains were also a problem. This issue is further discussed under Testing and Debugging.

5.4.3 Seed Delivery System

5.4.3.1 Criteria
The team identified five design criteria for the seed delivery system:

1. Friction and Blockage
The internal friction of the seed delivery system cannot be so great that it would hinder the rolling of the seed. Seed delivery must also work in different weather. Therefore, the exit of the system cannot be blocked under different weather conditions.

2. Flexibility
The seed delivery system cannot be too rigid as the system will be in contact with the ground. The ground is not perfectly even, therefore the system has to be non-rigid to dampen the response of the system to uneven ground. However, the system also had to be rigid enough to hold its position, in alignment with the auger.

3. Light weight
The overall seed delivery system had to be light weight because the system should not interfere with the balance of the frame. It was easier for a user to repeatedly pick up a balanced frame compared to an unbalanced one.

4. Durability
Durability was weighted heavily because the team wanted to minimize the need for maintenance. The system also had to work under different weather conditions.

5. Replaceability using local parts
Another criterion involved how easy it would be to replace parts using in-country (in Cambodia) resources. This is important because the user could maintain the system if extra parts were needed. A failure in the system due to broken and irreplaceable parts should not impede the use of the whole design.

6. Cost
The cost of the seed distribution system should be kept to a minimum. This, in turn, would lower the overall cost of the machine.

5.4.3.2 Alternatives

5.4.3.2.1 Steel Pipe
Steel pipes would last a long time. It has good structural strength, however it is heavy in weight. The inside of the pipe would stay rust free as long as the anti-rust paint stays on. As long as the inside is rust free, the ride of the seed should be smooth.

5.4.3.2.2 Aluminum Pipe
Aluminum pipes would also last a long time. Aluminum is more malleable and has a better weight to structural strength ratio. The seed would not be stuck, due to friction, in the piping.
5.4.3.2.3 PVC Pipe

The team also considered using PVC pipe for the seed delivery system. These pipes, similar to the previously mentioned metal pipes, has a relatively low friction surface. PVC pipes are also malleable and has good weight to structural strength ratio.

5.4.3.2.4 Flexible Pipe

Flexible piping were also considered because of its flexibility. The piping is extremely malleable and holds its shape well. However, it has a relatively higher friction surface than the previous three alternatives.

5.4.3.3 Decisions

<table>
<thead>
<tr>
<th>Difference</th>
<th>Weight</th>
<th>Steel Pipe</th>
<th>Aluminum Pipe</th>
<th>PVC Pipe</th>
<th>Flexible Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Friction and Blockage</td>
<td>8%</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>2 Flexibility</td>
<td>11%</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>3 Light Weight</td>
<td>15%</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>4 Durability</td>
<td>20%</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>5 Parts replacability at local shops</td>
<td>23%</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>6 Cost</td>
<td>23%</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

| 100% | 2.35 | 2.68 | 3.92 | 3.59 |

5.4.3.4 Integration

5.4.3.5 Test, Debug
6. Testing and Debugging

After the initial prototype was completed, there were three major problems that kept the machine from functioning as it was supposed to. The team spent significant time attempting to fix these problems, some solutions were implemented and others were theorized about.

6.1 Cam

The cam system was supposed to press the auger into the ground. It was not until after it was built and assembled that the team noticed that the cam pressed down on the auger plate in a way that tilted it one way instead of pushing it downward on it evenly.

The team proposed to use a lever that the user would push down in order to press down the auger, similar to a drill press lever. However, this would mean there were more inputs than initially desired. The initial design only required the user to peddle the treadle and then everything else was automated from there. Another idea was to have the cam press down in the middle of the four springs, this way the forces would be evenly distributed. This does not account for the force due to gravity, which would be offset from the center of the plate because the auger contains a significant portion of the subsystem’s mass. So the cam would have to push down in the middle of the box formed by the springs, but slightly more towards the auger so as to be over the center of mass for the plate.

6.2 Treadle

Treadle systems on sowing machines and lathes have large flywheels connected to them. Once they have started to spin, the mass of the flywheel keeps it in motion and the user continues to apply force intermittently to keep it going. The flywheels used in this machine were made from 1/8-inch steel and only 9 inches in diameter. The mass contained there was not enough to propel the flywheel around. So once the user pushed the peddle down, it would not continue to travel because it could not build up any momentum. Because the mass was insufficient, springs were attached to the peddle in an attempt to bring it back up.
These springs pull the peddle upwards and slightly forwards. The peddle itself must pass a certain point in its rotation in order for the springs to pull it in a way that completes a revolution instead of having it simply reverse its rotational direction and go back the way it came. The team thought that perhaps if the springs were combined with additional mass the system may function as it was supposed to. Heavy steel plates bolted to the lower half of the flywheels may do the trick.

6.3 Gears
The chain connecting the gears was about half a link too long. Bicycles have idlers to remedy this. When designing the placement of the axles it was not thought of to be sure to place them at distances that would keep tension in the chains. So to fix this problem, idlers would have to be placed in key places around the system. It would not work to relocate the axles because there are several which are interconnected and finding perfect distances between all of them would cause them to interfere with other components of the machine.
7. Maintenance
There is always a possibility with any project that problems will arise during production or it may break down several years into its use. The first product has been built here and shipped overseas.

7.1 Gears

7.1.1 Gears with broken teeth or worn down teeth

7.1.1.1 Large Gears (greater than 30 teeth)
1. Remove cotter pins from ends of axel gear is attached to
2. Loosen set screws from gear adapter
3. Slid off a gear adapter
4. Loosen bolts
5. Buy matching gear from bicycle store
6. Attach gear in reverse directions 1-4

7.1.1.2 Small Gears (less than 30 teeth)
1. Follow large gear instructions 1-3
2. Grind weld off small gear
3. Remove small gear from gear adapter
4. Buy matching gear from bicycle store
5. Slid on new gear and weld
6. Attach gear in reverse directions from large gear 1-3

7.1.2 Gears warped
1. Follow instructions from large gear removal 1-3
2. Place gears on flat surface
3. Hammer gears flat

7.2 Chains

7.2.1 Chains will not move

7.2.1.1 Chain is rusted
If chains are rusted they will need to be replaced
1. Remove chains with chain tool
2. Attach new chains based on length of rusted chains

7.2.1.2 Chain is caked with dirt
If chains are caked with dirt they will need to be cleaned
1. Follow chain rust removal step 1
2. Place chains in dirt removing cleaning agent diluted with water
3. Let sit for 45 min
4. Scrub chains clean
5. Oil chains
6. Place chains where they were removed

7.2.2 Broken Chains
1. Follow chain rusted step 1-2

7.3 Springs

7.3.1 Springs will not extend

7.3.1.1 Spring is caked with dirt or rust
1. Replace springs
2. Remove washer from bottom and top of spring
3. Pull spring out of auger support plates
4. Clean springs with dirt or rust remover
5. Replace springs
7.3.2 Broken springs
1. Follow spring covered in dirt instructions 1-4
2. Replace with 1 inch diameter springs of equal length

7.4 Bevel Gears

7.4.1 Worn down bevel gear teeth
1. Remove gear axel by large gear step 1
2. Replace gear with new

7.4.2 Broken bevel gear off axel
1. Contact distributer for help

7.5 Gear Axels

7.5.1 Axel will not spin
1. Remove axel by large gear step 1
2. Clean gear axel sleeve
3. Clean gear axel
4. Place axel back together

7.5.2 Broken Axel
1. Measure broken axel
2. Buy proper diameter CR steel rod
3. Cut to length
4. Drill 1/8 inch hole for cotter pin ½ inch from end of axel
5. Replace with new axel

7.6 Treadle Axel

7.6.1 Axel will not spin
1. Remove cotter pins
2. Slid rod out of sleeves
3. Replace bushings
4. Clean axel
5. Rebuild axel from reverse step 1-2

7.6.2 Broken Axel
1. Follow axel will not spin steps 1-2
2. Buy ½ inch CR Steel
3. Cut rod to length
4. Drill 1/8 inch holes for cotter pins at the same spots the broken axel has them
5. Replace old axel in reverse steps axel will not spin steps 1-2

7.7 Auger Axel

7.7.1 Auger axel will not move vertically
1. Unscrew disc on top of bearing
2. Remove set screws from auger
3. Remove auger
4. Slide auger axel out of bearing
5. Clean axel rods and holes
6. Replace axel with reverse steps 1-3

7.7.2 Auger will not spin
1. Check for obvious blocks around auger axel
2. Follow steps 1-3 for auger axel will not move vertically
3. Clean bearing
4. Remove blocks
5. Replace axel with reverse steps 1-3 for auger axel will not move vertically

7.7.3 Auger Axel is broken
1. Follow auger axel will not move vertically steps 1-3
2. Send auger axel into distributer
3. Wait for replacement
4. Replace axel with reverse steps 1-3 for auger axel will not move vertically

7.8 Wheels

7.8.1 Wheels are flat
1. Remove wheels from frame by unscrewing nuts
2. Use wheel tools to remove bike tire
3. Replace tube with new tube
4. Place bike tire using wheel tools
5. Pump up tire
6. Place wheel on frame by screwing nuts

7.8.2 Wheels are broken
1. Replace wheels with step 1 from wheels are flat
2. Buy new tires from bicycle store
3. Place wheels on frame by screwing nuts

8. Business Plan

8.1 Marketing Study

8.1.1 Competitive Analysis
There are two companies in particular, who pose a competitive threat to this project. The success of the project required differentiating this product from those of the competitors, and making the users aware of the benefits of a cover crop. In the end, it was uncertainty that would keep the people from buying a product like this. The previously mentioned competition takes the form of an immediate market competitor and a potential one.

8.1.1.1 Immediate Competitor
Zhengzhou AIX Machinery Equipment Co., Ltd. is a Chinese company that sells three different no-till hand seeders. However, they were all priced between $150 and $200 which would be out of the price range of the average Cambodian. The scope of the team was to create a model priced at $50; This would beat the competitions price. A strength of their company is that they have a very solid design and can mass produce it. There are two problems with these designs. One design doesn’t till the soil at all, it merely inserts seeds into the ground at a certain depth. This harms the seed’s ability to grow because the roots can’t expand well into the packed soil. The design does till the earth but relies on the user’s pure force to till a furrow into the soil. Our target user will be the women of rural Cambodia, and with how dense the soil is and the amount of push force the average woman can exert, this design is not favorable.

8.1.1.2 Potential Competitor
MekongAT is an Agricultural Machinery company that produces seeders. All of these seeders required the ground to be tilled before planting, which would not work in this instance. The potential is still there to redesign one of their present machines for such an application, but as of now they do not have such a design.

8.1.1.3 Competitive Strategy
The competitive strategy of choice was mainly based on cost and minor differentiation. Companies in the hand seeders market are either very expensive, or not fit for no-till situations when the soil is hard and dry. Team Cambodian Field of Dreams planned to provide a cheap alternative (price discussed more in depth later) and one that would work under the described circumstances.

8.1.2 Marketing Survey

8.1.2.1 Industry
Cambodia is a country in Southeast Asia with a population size of about 15 million people. Farming and agriculture accounts for over a third of the country’s GDP, and the main crop within this industry is rice. Cambodia is bordered by Thailand, Laos, and Vietnam, all of whom have higher rice yields, at about 5 tons/hectare, compared to the national average for Cambodia of 2.6 and furthermore the average self-employed, rural farmer who produces only 1.5 (Inserey). The soil nutrition in Cambodia is quite poor, even when compared to these neighboring countries who share similar seasonal weather patterns.
Cambodia itself has many agricultural equipment manufacturers to supply this market, however, they do not extend into the seeder market very well (discussed later in the report). Farming is a major part of Cambodian life and it is this industry that the company will attempt to break into.

8.1.2.2 Customer
The target customer will be rural farming villages, beginning with the immediate vicinity of Phnom Penh. Word Renew has a strong presence in this area and throughout Cambodia. Using this resource, business will expand throughout the country. World Renew and many other non-profit organizations work with farmers around the world to increase crop yields. In the future, it is hoped that products can be supplied to any of them and their surrounding region.

8.1.2.3 Barriers to Market Entry
The biggest barrier for entry for this market is the cultural attitude towards the idea of a cover crop. The demographic being marketed to have an annual income of $750 per year (worldrenew.net), so there is little room in their budget for experimenting with new farming. If the seeder can be made cheaply enough and marketed positively by local World Renew representatives and native farmers, it would be possible to overcome this barrier.

8.1.3 Marketing Strategy
8.1.3.1 Target Market and Demographic Profile
The company’s target market is Cambodian villagers that are willing to try cover cropping. The company aims to better the nutritional value of the soil and ultimately increase the rice yield. The company’s product should be designed in such a way that race, social class, and gender would not be an issue. However, the product is limited by age and location. The company’s product is not suitable for children below the age of 12. Because of the design, the user should refrain from using the product in locations that have harder soil than Cambodia’s during the dry season. The company would initially aim to sell specifically to females, as they are more available for implementing new and unproven ideas than the men in their culture.

8.1.3.2 Product Appeal and Promotion
The company will partner with World Renew to spread the cover crop concept. Once the concept is out, the company aims to convince farmers by giving them free trials of the seeder. Because of the cover crop strategy, the rice yield for that planting season should increase. With initial farmers convinced and feedback taken, the company hopes to advertise the product along with testimonies from local farmers. The advertisement strategy relies heavily on these customers testimonials.

The advertising and promotion of this product will be mainly through World Renew. The company would like to use local resources and other NGOs to reach out to farmers. The message would mainly focus on advertising and spreading knowledge of cover cropping. The initial budget for advertisement is covered because the company will be partnering with World Renew for advertisement, which the NGO will fund.

8.1.3.3 Market size and trends
There are an estimated 200,000 villages within Cambodia that the company would hope to sell the seeder. The company hopes to increase the production after initial feedbacks and extensive, specific, local village
research. Through this research, the company hopes to have several alternative designs of the initial seeder. The target of selling to 200,000 villages should be reached within 5 years.

8.2 Cost Estimate

The company would like to be seen as a leader in no-till farming solutions. We wish to put our product in the hands of every Cambodian village so that they may be able to increase soil fertility. We wish to be trusted to supply a quality product that takes copious abuse before it will break.

The no-till seeder we are proposing is $50, which is $100 cheaper than our closest competitor. We can sell it this cheaply because of our non-profit status. We are not trying to make money. We are trying to help our customer get the product that they need to have a thriving farm.

The gross profit margin on this product ranges from 20% to 25%. This is achieved by our very low overhead because we will be manufacturing in Cambodia. This gross profit margin will be going back to the company’s investors so the company can be self-sufficient and help the farmers with new projects.
9. Conclusion

When World Renew proposed this project it was very appealing because a majority of our group was interested in mission work and this project fit that vision incredibly well. World Renew is a great organization to work for. Claire Phillippi had interactions with them in the past and had great things to say about the experience. The proposed project combined creativity in machine design and agricultural techniques to create a great opportunity to work on the mission field domestically.
10. Acknowledgements
Partnering with CRWRC for implementation:
Rick Degraaf (rickdegraaf@worldrenew.net)
Rachel Brink (rbrink@worldrenew.net)
Kathleen Lauder (klauder@worldrenew.net)

Special thanks to:
Rick Degraaf, our main contact for this project
Rachel Brink for helping us with grant writing
Kathleen Lauder for being our World Renew contact
Ned Nielsen, our team’s advisor and counselor
Phil Jasperse for helping brainstorm ideas, build our prototypes, and find our way around the metal shop
And of course, Michelle Krul for all the organizational help she provides for the class
11. References


12. Appendix

12.1 EES - Force Calculations

"Soil mechanics
for Cambodia
for different tool widths
and tool angles" 

"Cutting force using cohesion"
"d=cutting depth"
"w=tool width"
"c=cohesion coefficient of soil"

"Based on soil classification"
gamma=1900 [kg/m^3]
d=30 [cm]
D_f=30 [cm]
w=10 [cm]
P=3 [in]
c=1.5
theta=30
q=1.2*c*N_c+gamma*D_f*m*N_q+6*gamma*R_m*N_gamma

N_c=20.1
N_q=18.4
N_gamma=22.4
w_m=w*Convert(cm,m)
d_m=d*Convert(cm,m)
D_f_m=D_f*Convert(cm,m)
P_m=R*Convert(in,m)
P_c=(gamma*g*d_m*N_Gamma+c*N_c+q*N_q)^d^w

"P_wedge=(sin(BETA+PHI))/(sin(alpha+beta+delta+PHI))*c^d^w"

c = 1.5                d = 30 [cm]                D_f = 30 [cm]                D_l,m = 0.3 [m]
d_m = 0.3 [m]            y = 1900 [kg/m^3]            N_c = 20.1            N_q = 22.4
N_q = 13.4            P_c = 1.064E+09            q = 12470            R = 3 [in]
R_m = 0.0762 [m]            a = 30            w = 10 [cm]            w_m = 0.1 [m]
12.2 EES - 4-bar Linkage Calculation

\[ r_1 = 17 \text{ [in]} \]
\[ r_2 = 2 \text{ [in]} \]
\[ r_3 = 5 \text{ [in]} \]
\[ r_4 = 15 \text{ [in]} \]
\[ \theta_1 = 0 \]
\[ \theta_2 = 90 \]

\[ \text{Weight}_{\text{person}} = 127 \text{ [lb_m]} \]
\[ g = 32.2 \text{ [ft/s^2]} \]
\[ G_c = 32.2 \text{ [lb_m*ft/s^2*lb]} \]

\[ r_{\text{flywheel/shaft}} = \frac{0.35}{2} \]

\[ r_{\text{gear,1}} = \frac{5.46}{2} \]
\[ r_{\text{gear,2}} = \frac{2}{2} \]
\[ r_{\text{shaft,2}} = \frac{0.75}{2} \]
\[ r_{\text{bar,1}} = \frac{1.4}{2} \]
\[ r_{\text{bar,2}} = \frac{3.2}{2} \]
\[ r_{\text{shaft,3}} = \frac{1.815}{2} \]
\[ r_{\text{auger}} = \frac{3.3}{2} \]

\[ r_3 = r_1^2 + r_4^2 + r_2^2 + 2 \cdot r_1 \cdot r_4 \cdot \left[ \cos (\theta_1 \cdot \cos (\theta_4) + \sin (\theta_1) \cdot \sin (\theta_4)) \right] - 2 \cdot r_1 \cdot r_2 \cdot \left[ \cos (\theta_1 \cdot \cos (\theta_2) + \sin (\theta_1) \cdot \sin (\theta_2)) \right] - 2 \cdot r_2 \cdot r_4 \cdot \left[ \cos (\theta_2 \cdot \cos (\theta_4) + \sin (\theta_2) \cdot \sin (\theta_4)) \right] \]

\[ \theta_3 = \arctan \left[ \frac{r_1 \cdot \sin (\theta_1) + r_4 \cdot \sin (\theta_4) - r_3 \cdot \sin (\theta_2)}{r_1 \cdot \cos (\theta_1) + r_4 \cdot \cos (\theta_4) - r_2 \cdot \cos (\theta_2)} \right] \]

\[ \theta_{4b} = \theta_4 - 360 \cdot 18 \text{ [deg]} \]
Figure 29. Angle of Step in 4-bar Linkage
12.3 EES - Torque Calculation

\[
F_{\text{input}} = g \cdot \frac{\text{Weight of person}}{G_c \cdot 3}
\]

\[
T_{\text{flywheel shaft}} = F_{\text{input}} \cdot r_2
\]

\[
\frac{T_{\text{flywheel shaft}}}{r_{\text{flywheel shaft}}} = \frac{T_{\text{gear,1}}}{r_{\text{gear,1}}}
\]

\[
\frac{T_{\text{gear,1}}}{r_{\text{gear,1}}} = \frac{T_{\text{gear,2}}}{r_{\text{gear,2}}}
\]

\[
\frac{T_{\text{gear,2}}}{r_{\text{gear,2}}} = \frac{T_{\text{shat,2}}}{r_{\text{shat,2}}}
\]

\[
\frac{T_{\text{shat,2}}}{r_{\text{shat,2}}} = \frac{T_{\text{bawel,1}}}{r_{\text{bawel,1}}}
\]

\[
\frac{T_{\text{bawel,1}}}{r_{\text{bawel,1}}} = \frac{T_{\text{bawel,2}}}{r_{\text{bawel,2}}}
\]

\[
\frac{T_{\text{bawel,2}}}{r_{\text{bawel,2}}} = \frac{T_{\text{shat,3}}}{r_{\text{shat,3}}}
\]

\[
\frac{T_{\text{shat,3}}}{r_{\text{shat,3}}} = \frac{T_{\text{auger}}}{r_{\text{auger}}}
\]

**SOLUTION**

**Unit Settings: SI C kPa kJ mass deg**

- \( F_{\text{input}} = 42.33 \text{ [lb] } \)
- \( G_c = 32.2 \text{ [lb ft/s}^2\text{lb] } \)
- \( r_2 = 2 \text{ [in] } \)
- \( r_4 = 15 \text{ [in] } \)
- \( r_{\text{bawel,1}} = 0.7 \text{ [in] } \)
- \( r_{\text{flywheel shaft}} = 0.175 \text{ [in] } \)
- \( r_{\text{gear,2}} = 1 \text{ [in] } \)
- \( r_{\text{shat,3}} = 0.9075 \text{ [in] } \)
- \( g_2 = 90 \text{ [deg] } \)
- \( g_4 = 87.7 \text{ [deg] } \)
- \( r_{\text{auger}} = 798.3 \text{ [in-lb] } \)
- \( T_{\text{bawel,1}} = 774.1 \text{ [in-lb] } \)
- \( T_{\text{gear,1}} = 1318 \text{ [in-lb] } \)
- \( T_{\text{shat,2}} = 181.4 \text{ [in-lb] } \)
- \( \text{Weight of person} = 127 \text{ [lb] } \)

- \( g = 32.2 \text{ [ft/s}^2\text{] } \)
- \( r_1 = 17 \text{ [in] } \)
- \( r_3 = 5 \text{ [in] } \)
- \( r_{\text{auger}} = 1.65 \text{ [in] } \)
- \( r_{\text{bawel,2}} = 1.6 \text{ [in] } \)
- \( r_{\text{gear,1}} = 2.725 \text{ [in] } \)
- \( r_{\text{shat,2}} = 0.375 \text{ [in] } \)
- \( \theta_1 = 0 \text{ [deg] } \)
- \( \theta_3 = 14.95 \text{ [deg] } \)
- \( \theta_4 = -5603 \text{ [deg] } \)
- \( \theta_{\text{auger}} = 338.7 \text{ [in-lb] } \)
- \( \theta_{\text{flywheel shaft}} = 84.67 \text{ [in-lb] } \)
- \( \theta_{\text{gear,2}} = 483.8 \text{ [in-lb] } \)
- \( \theta_{\text{shat,3}} = 439.1 \text{ [in-lb] } \)
12.4 EES - Number of Holes in Field and Required Volume of Seed

Team 16: Cambodian Field of Dreams
Senior Design Project
21/03/2014
Seed Volume Calculation

Holes per Area

\[
\begin{align*}
\text{Area} &= 0.25 \text{ [hectare]} \cdot 10000 \cdot \frac{m^2}{\text{hectare}} \\
\text{Area}_{\text{per, hole}} &= 90 \text{ [cm]} \cdot 50 \text{ [cm]} \cdot 0.0001 \cdot \frac{m^2}{cm^2} \\
\text{Holes} &= \frac{\text{Area}}{\text{Area}_{\text{per, hole}}} \\
\text{Actual Holes} &= \text{Holes} - 2 \cdot \sqrt{\text{Holes}}
\end{align*}
\]

Actual number of holes in field (because of how the calculation was made)

Estimated Volume of Seed

\[
\begin{align*}
w &= 15 \text{ [mm]} \\
l &= 5 \text{ [mm]} \\
t &= 5 \text{ [mm]} \\
\text{Vol}_{\text{seed}} &= w \cdot l \cdot t \cdot 1.0 \times 10^{-9} \cdot \frac{m^3}{\text{mm}^3}
\end{align*}
\]

Number of Seeds Needed

\[
\begin{align*}
\text{Seed}_{\text{per, Hole}} &= 1.5 \\
\text{Seeds}_{\text{Needed}} &= \text{Actual Holes} \cdot \text{Seed}_{\text{per, Hole}}
\end{align*}
\]

Total Volume of Seeds

\[
\begin{align*}
\text{Total Volume} &= \text{Seeds}_{\text{Needed}} \cdot \text{Vol}_{\text{seed}} \cdot 1000 \cdot \frac{\text{Liter}}{m^3}
\end{align*}
\]

Time

\[
\begin{align*}
\text{t}_{\text{hole}} &= 30 \\
\text{t}_{\text{field, sec}} &= \text{t}_{\text{hole}} \cdot \text{Actual Holes} \\
\text{t}_{\text{field, hour}} &= \text{t}_{\text{field, sec}} \cdot 0.000277778 \cdot \frac{\text{hr}}{\text{sec}} \\
\text{t}_{\text{field, days}} &= \frac{\text{t}_{\text{field, hour}}}{8} \text{ [hr/day]}
\end{align*}
\]

@8 hrs/day
<table>
<thead>
<tr>
<th>Unit Settings: SI C kPakJ mass deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Holes = 4494</td>
</tr>
<tr>
<td>Holes = 4630</td>
</tr>
<tr>
<td>Seed per Hole = 1.5</td>
</tr>
<tr>
<td>$t_{field, days} = 4.681$ [days]</td>
</tr>
<tr>
<td>$t_{hole} = 30$ [sec]</td>
</tr>
<tr>
<td>Area = 2500 $[m^2]$</td>
</tr>
<tr>
<td>1 = 5 $[mm]$</td>
</tr>
<tr>
<td>t = 5 $[mm]$</td>
</tr>
<tr>
<td>$t_{field, hour} = 37.45$ [hr]</td>
</tr>
<tr>
<td>$V_{cl,seed} = 3.750E-07$ $[m^3]$</td>
</tr>
<tr>
<td>Area per hole = 0.54 $[m^2]$</td>
</tr>
<tr>
<td>Seeds Needed = 5740</td>
</tr>
<tr>
<td>Total Volume = 2.528 $[liter]$</td>
</tr>
<tr>
<td>$t_{field, sec} = 134606$ [sec]</td>
</tr>
<tr>
<td>w = 15 $[mm]$</td>
</tr>
</tbody>
</table>
12.5  EES – Spring Calculations

\[ T = \text{ConvertTemp} \left( C, F, 20 \right) \]

\[ D_{\text{shaft}} = 1.810 \text{ [in]} \quad \text{Diameter of shaft} \]

\[ L_{\text{shaft}} = 9 \text{ [in]} \quad \text{Length of shaft} \]

\[ \rho_{\text{steel}} = \rho \left( \text{Stainless AISI316, } T = T \right) \cdot \frac{0.000576704}{\text{in}^3} \cdot \frac{1}{\text{in}^3} \]

\[ m_{\text{auger}} = 663.2 \text{ [g]} \cdot \frac{0.002204623}{\text{lbm}} \cdot \frac{\text{g}}{\text{lbm}} \]

\[ x = 8 \text{ [in]} \quad \text{Required displacement} \]

\[ N = 4 \quad \text{Number of Springs (in parallel connection)} \]

\[ SF = 2 \quad \text{Safety Factor} \]

\[ G_{3102} = 10195 \text{ [ksi]} \quad \text{Modulus of Rigidify / Shear Modulus Spring-Tempered Type 302 Stainless Steel (Austenitic)} \]

\[ S_{\text{TY}} = 45000 \text{ [psi]} \]


\[ S_{LT} = 100000 \text{ [psi]} \quad \text{Ultimate Tensile Strength, source same as above} \]

**Volume of Shaft**

\[ V_{\text{solid}} = \pi \cdot \left( \frac{D_{\text{shaft}}}{2} \right)^2 \cdot L_{\text{shaft}} \]

\[ V_{\text{guess}} = \frac{V_{\text{solid}}}{2} \]

**Mass of Shaft**

\[ m_{\text{shaft}} = V_{\text{guess}} \cdot \rho_{\text{steel}} \]

**Mass of Plate**

\[ V_{\text{plate}} = 10 \text{ [in]} \cdot 12 \text{ [in]} \cdot 0.125 \text{ [in]} \]

\[ m_{\text{plate}} = V_{\text{plate}} \cdot \rho_{\text{steel}} \]

**Total Mass**

\[ m_{\text{total}} = m_{\text{auger}} + m_{\text{shaft}} + m_{\text{plate}} + 0.75 \text{ [kg]} \cdot 2.2046226 \text{ [lbm]} \cdot \frac{\text{kg}}{\text{lbm}} \quad \text{Assuming } m_{\text{auger}} \text{ is accounted for in SF} \]

**Spring Constant calculation**

\[ k = m_{\text{total}} \cdot \frac{1}{x} \]

\[ k_{\text{final}} = SF \cdot \frac{k}{N} \]
Force Required to Achieve Displacement

\[ D_{\text{spring}} = 0.5 \ \text{[In]} \quad \text{Mean Coil Diameter} \]
\[ d = 0.047 \ \text{[In]} \quad \text{Wire Diameter} \]

\[ \text{RateConstant} = 3 \]

\[ \frac{\text{RateConstant}}{L_{\text{spring}}} = k_{\text{final}} \quad \text{Length of Spring} \]

\[ N_3 = \frac{L_{\text{spring}}}{d} \quad \text{# of Active Coils - Rounded to 0.25 coil} \]

\[ F_1 = m_{\text{total}} \cdot \left( \frac{\text{kg}}{\text{lbm}} \right) \cdot 9.81 \ \text{[m/s}^2\text{]} \cdot \frac{0.2248 \ \text{[lbf]} \cdot \text{N}}{1000 \ \text{psi} \cdot \text{ksi}} \]

\[ x = 8 \cdot (F - F_1) \cdot D_{\text{spring}}^3 \cdot \frac{N_3}{d^4 \cdot G_{\text{T302}}} \cdot \frac{1000 \ \text{psi}}{\text{ksi}} \]

Shear Yield Strength

\[ S_{US} = \frac{2}{3} \cdot S_{UT} \quad \text{Ultimate Shear Strength: P.793 Eq14.4} \]

\[ S_{SY} = \frac{2}{3} \cdot S_{TY} \quad \text{Shear Yield Strength: Assume above is true} \]

Force Required to Break the Spring

\[ C = \frac{D_{\text{spring}}}{d} \]

\[ K_w = \frac{4 \cdot C - 1}{4 \cdot C - 4} + \frac{0.615}{C} \quad \text{Wahl Stress-Concentration Factor P. 798 Eq14.9a} \]

\[ S_{SSystem} = K_w \cdot 8 \cdot F \cdot \frac{D_{\text{spring}}}{\pi \cdot d^2} \quad \text{Finds } F_{\text{break}; \ maximum \ Shear \ Stress \ Wahl \ Eq. \ 14.9b \ P. \ 798} \]

Force Required to Move the Plate

\[ \text{Force Required} = F \cdot N \]

Recommended Shopping Website: http://www.mcmaster.com/#extension-springs=/rdn004
Possible Manufacturers: http://www.springdynamics.com/extension-springs
http://www.wolverinecoilspring.com/springs.htm
Unit Settings: Eng F psi a mass deg

C = 10.64
D_{spring} = 0.5 \text{ [in]}
F_i = 10.85 \text{ [lb]}
K_{final} = 0.6778 \text{ [lbf/in]}
L_{spring} = 4.426 \text{ [in]}
m_{shaft} = 3.38 \text{ [lbf]}
N_a = 94.17
SF = 2
S_{Yield} = 45000 \text{ [psi]}
T = 68 \text{ [F]}
V_{solid} = 23.31 \text{ [in^3]}
d = 0.047 \text{ [in]}
F = 15.08 \text{ [lb]}
GT_{302} = 10196 \text{ [ks]}
K_w = 1.136
m_{auger} = 1.462 \text{ [lbf]}
m_{total} = 10.85 \text{ [lbf]}
RateConstant = 3 \text{ [lbf]}
S_{System} = 209961 \text{ [psi]}
S_{SS} = 56667 \text{ [psi]}
V_{guess} = 11.66 \text{ [in^3]}
x = 8 \text{ [in]}

D_{shaft} = 1.816 \text{ [in]}

Force_{Required} = 60.3 \text{ [lb]}
k = 1.356 \text{ [lbf/in]}
L_{shaft} = 9 \text{ [in]}
m_{plate} = 4.35 \text{ [lbf]}
N = 4
\rho_{steel} = 0.29 \text{ [lbf/in^3]}
S_{SSYield} = 30000 \text{ [psi]}
S_{UT} = 100000 \text{ [psi]}
V_{plate} = 15 \text{ [in^3]}