Improved Greens Harvester

This should be a brief description of your whole project written for a general audience – the text should communicate to instructors, managers, non-technical co-workers, cost account managers, supply management personell, etc. This should be approximately 200-300 words.

MEMS 3110: Machine Elements, Spring 2020

Kieran Natarajan
Dean Ryan-Simmons
William Braley
Matthew Donaldson

Contents

List of Figures

List of Tables

1 Introduction

EarthDance Organic Farm School is an educational farm in Ferguson, MO that produces sustainable and USDA Certified Organic and sustainable vegetable, fruit, and livestock [1]. Many of its 14 acres are dedicated to growing food, and the farm currently has one semi-automated greens harvester to assist in cutting and collecting vegetation. The existing device is a handheld machine that cuts the leaves of greens as the user walks along a row of crops. Primary drawbacks of this model are that the operator is forced to bend at an unnatural angle to support the machine, the accuracy in cutting at a consistent height is low, and the harvester storage is limited.

Several options exist for cutting and harvesting greens that vary from fully manual cut and collection to wheeled and automated. The major issue is cost and capacity. EarthDance's crop beds are approximately three feet wide and the greens grow between three and six inches tall. Commercial greens harvesters either are not feasible to purchase or do not fit EarthDance's scope.

For this project, the goal is to design an improved greens harvester that will exceed the ergonomics, accuracy, and efficiency of the current "Quick-Cut" model.

2 Problem Understanding

The first step in the design process is to become familiar with existing designs as well as relevant patents, codes, and standards that could influence the design. Interviewing the customer to identify their wants and needs for the products is also essential. The results of this research are presented in this section.

2.1 Existing Devices

Three existing devices that are related to the design are presented. These products are all used in the organic agriculture industry and can help provide inspiration for the design. A brief description of each device is also provided.

2.1.1 Existing Device 1: Johnny Seeds Harvester ($280)

Figure 1: Johnny Seeds Harvester (Source: Johnny Seeds Harvester)

Link: `https://www.johnnyseeds.com/tools-supplies/harvesting-tools/greens-harvester/`
Description: The Johnny Seeds Greens Harvester is a completely manual harvester that comes in various sizes to fit the width of the plant bed. The operator moves the device back and forth in a sawing motion while walking forward so the stationary blade cuts the greens. As the user progresses along the bed, the greens fall

into the cloth basket behind the blade. Since the greens are expected to self-feed into the collection basket, the greens need to be dense and the saw blade must be sharp in order to cut the greens. Additionally, the user must control the height of the blade by physically bending over. At peak operation, this harvester can collect up to 100 pounds of material per hour.

2.1.2 Existing Device 2: Quick-Cut Greens Harvester ($560, not including power drill)

Figure 2: Quick-Cut Greens Harvester (Source: Farm Friends LLC)

Link: `https://farmersfriendllc.com/products/harvest/quick-cut-greens-harvester`
Description: The Quick-Cut Greens Harvester by Farm Friends LLC is the current design operating at Earth-Dance Organic Farm. A rope spindle is powered by a drill, and when it turns, it brushes greens against a blade and then sweeps the cut greens into the waiting collection basket behind it. The operator engages the drill with one hand and supports the collection device with the other, walking forward along the plant bed while maintaining a hunched over position. Because of the rope spindle, greens do not have to be densely planted for the harvester to be effective. The blade is also connected with a simple pin, so its position can be easily adjusted for cleaning and sharpening. Furthermore, because of the power drill, this harvester puts less strain on the user and is thus more efficient. This method can gather up to 175 pounds of plant material per hour.

2.1.3 Existing Device 3: Sutton Ag Harvest Star ($10,500)

Figure 3: HarvestStar Mini-Harvester (Source: Sutton Ag Enterprises)

Link: `http://www.suttonag.com/harvest_star.html`
Description: Sutton Ag's HarvestStar is a greens harvester that uses a band saw blade that can be adjusted between one and two inches off the ground to cut greens as the user pushes the cart attached to the blade across the farm bed. A conveyor belt style slanted surface lifts the freshly cut greens up and dumps them into a collection bin at the back of the cart. The source of power for the cutting blade is a 12 V motor. This is the most user-friendly design, but is also by far the most expensive of the three designs presented. It also compacts the bed after cutting the greens, which is not ideal for subsequent plant growth. This harvester can cut and collect up to 300 pounds of greens per hour.

2.2 Patents

In this section, two patents are described. This research was done to get a sense of which designs are protected under law and to serve as a baseline from which to generate ideas. Patents that relate to the scope of our project were explored, in particular. This was done to gain a better understanding of existing technology and how it might impact the way we design our project.

2.2.1 Harvester for Leafy Vegetables (US 9,021,775 B2)

This patent is for the device currently being implemented at Earth Dance Organic Farms. This device uses a common cordless drill to power a blade to oscillate and a brush to spin. This device is carried manually and actuated by depressing the trigger on the drill, which then transmits power to a shaft that rotates the blade. Power is transmitted to the rotating brush through a belt. This device stores leafy greens in a fabric pouch located in the rear.

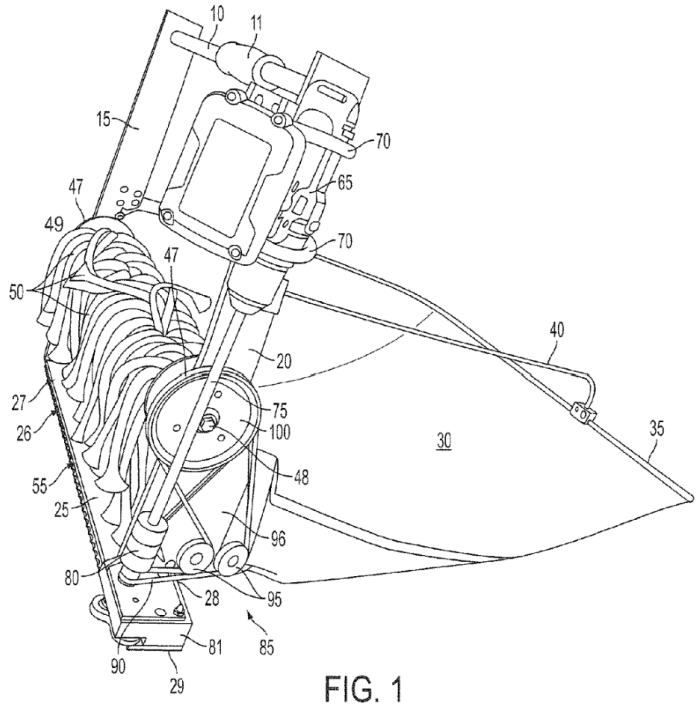


FIG. 1

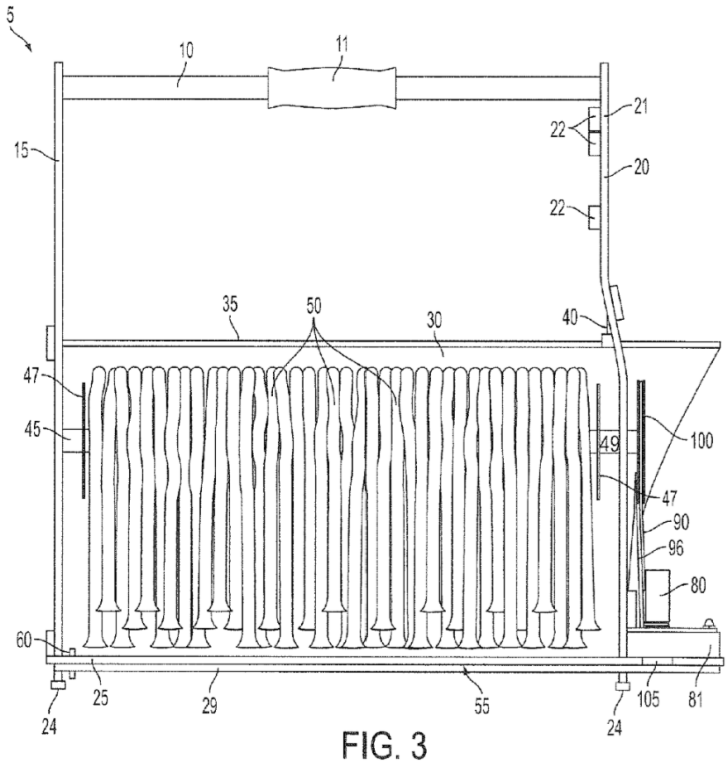


FIG. 3

Figure 4: Patent Images for Quick-Cut Greens Harvester

2.2.2 Baby Greens Harvester (Patent Number 5964081)

This patent is for a product similar to the one described above in Section 2.1.3. The Baby Greens Harvester, shown in Fig. 5, uses a horizontal blade to cut baby greens as it rolls across the length of a bede. Two parallel conveyor belts move the greens up to a chute which then deposits the leaves into a waiting basin. The top conveyor belt has finger-like attachments that guide the cut greens on to the bottom flat conveyor belt.

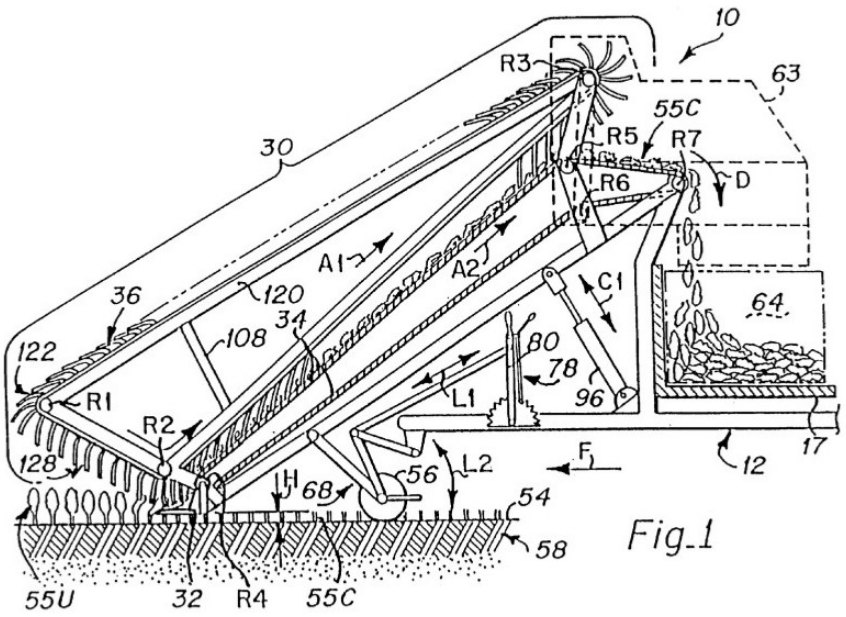


Figure 5: Patent Image for Baby Greens Harvester

2.3 Codes & Standards

Codes and standards that are relevant to the scope of this project are described in this section. Since the product will directly interface with food for human consumption, safety is a top priority. These codes and standards help establish constraints and other design considerations.

2.3.1 National Organic Program (NOP) (7 CFR Part 205)

This list of codes is in place to ensure that when a food is labeled 100% organic, nothing damages it. No harmful chemicals or materials, such as synthetic lubricants, are to be used on any of the food-handling equipment, as per section § 205.105. The Organic Materials Review Institute (OMRI) follows these standards to certify a product as organic, so it is essential that these requirements are satisfied.

2.3.2 NSF International Standard - Food Equipment Materials (NSF/ANSI 51-2017)

This international standard aims to protect the integrity of food by restricting any material that would adversely affect its odor, taste, or color. Such materials include mercury, lead, and arsenic cadmium. If aluminum is chosen to come in direct contact with the food, certain wrought alloys such as the 1xx, 3xxx, 4xxx, and

5xxx series are permissible. Since the improved greens harvester will directly contact food, it is essential that the materials used to build the machine are food-safe.

2.4 User Needs

An on-site interview was conducted with staff from EarthDance Organic Farm School. The ideal new design is an improved version of the current Quick-Cut greens harvester. The plant beds are between 30 and 36 inches wide and a wheelable harvesting device is preferred because it is not only more user-friendly, but also will not damage the crop beds. The blade's height should be adjustable by up to 6 inches to accommodate uneven surfaces and the opening to the collection basked should be likewise adjustable to fit shorter and taller leafy greens. The collection basket should be able to support between 5 and 10 pounds of organic material. Additionally, to meet organic standards, all materials that contact the greens must be food-safe and resistant to bacteria growth.

2.4.1 Customer Interview

Interviewee: Rae Liening and Cat Dunsford
Location: EarthDance Farms, 233 S Dade Ave, Ferguson, MO 63135
Date: September 6^{th}, 2019
Setting: The EarthDance staff showed Washington University design teams the crops that the harvester would eventually cut. They also demonstrated the current Quick-Cut model and pointed out areas for improvement. The interview lasted around 30 minutes.

Interview Notes:
How much product would you like to harvest in one trip?

- The current harvester weighs 15-20 pounds when full and can hold 5-10 pounds. More capacity would be nice, and being able to harvest an entire row would be amazing.

How do you feel about the machine rolling or going over plants?

- It should not touch the bed because that will damage the bed.

What are typical terrain conditions for the harvester?

- Beds are typically ∼30 inches wide and 4-6 inches higher than the surrounding footpaths. Footpaths are ∼20 inches wide.

What are the biggest problems with the machine you have now?

- The belt-drive power system is unreliable. The band used around the pulley is prone to slippage and is not water resistant enough.
- Having to bend over and constantly hold the drill is tiring and uncomfortable for the operator.
- The harvester tends to "jam" when trying to cut larger greens.
- Some harvested crop falls out of the side and has to be picked up by hand later.
- The current model is too narrow to sweep the entire bed in one pass.

Would you prefer something manual? Electric? Gas-powered?

- The current power system is handy and efficient, as the batteries are easily available. Efficiency is key.

What are any specifications you cannot compromise on?

- The materials used must be food-safe as per FDA standards and OMRI-certified.

– The harvester must cut a 30-36 inch bed and must not roll over the soil of the bed. The wheels may roll on the footpaths.

What features of the current model should be maintained?

– The new model should also make use of a cordless drill that uses a rechargeable battery.

– The synthetic rope material is antimicrobial and does not retain water in order to avoid bacterial contamination.

What new features would you like to see in the redesign?

– A removable and replaceable blade could allow for easier servicing with less downtime.

– The machine should be more adjustable to accommodate greens and beds of various heights.

Based on the interview with EarthDance staff, a list of customer needs was created and rated on a 1 to 5 scale, with 5 representing a highly important need and 1 representing the least important needs. These needs and rankings are displayed in Table 1.

Table 1: Interpreted Customer Needs

Need #	**Interpreted Customer Need**	**Importance**
1	The IGH is comfortable for the operator	5
2	The IGH is reliable	4
3	The IGH can cut the full width of a bed	5
4	The IGH is food-safe	5
5	The IGH does not touch and damage the bed	4
6	The IGH is energy efficient	3
7	The IGH's height off the ground is adjustable	4
8	The IGH's opening height is adjustable	4
9	The IGH uses a cordless drill as the power source	5
10	The IGH is lightweight	5 if carried 3 if not

2.5 Design Metrics

To address each of the interpreted customer needs in Table 1 above, specific design metrics were established. Ideal and minimum acceptable specifications were determined and are itemized in Table 2.5.

Table 2: Target specifications

Metric #	Assoc. Need	Metric	Units	Acceptable	Ideal
1	1	“Ease of use" rating from staff	score	$> 3/5$	$> 4/5$
2	2	Operating time before major repair	hours	> 80	> 300
3	2	Part replacement frequency	times/month	3	1-2
4	3	Width of cutting mechanism	inches	> 30	> 36
5	4	Food safety and OMRI certification	binary	Complies	Complies
6	2,6	Capacity of crop container	pounds	> 10	> 40
7	6	harvested rows on one battery charge	score	> 1	> 4
8	3,5	Number of ground touches per full row	avg #	< 4	< 2
9	7,8	Adjustability of opening	inches	> 4	> 6
10	10	Total weight	pounds	< 45	< 10

2.6 Equipment Notes

For this design project, a specific cordless drill is requested: a DeWalt 20V DCD777 cordless drill, pictured in Fig. 6 [2]. It should ideally be paired with a 4 Amp-hr battery. Models of these are available on GrabCAD for ease of design.

Figure 6: DeWalt DCD777 Brushless Drill

2.7 Project Management

The Gantt chart in Fig. 7 was used to manage project progress and deadlines.

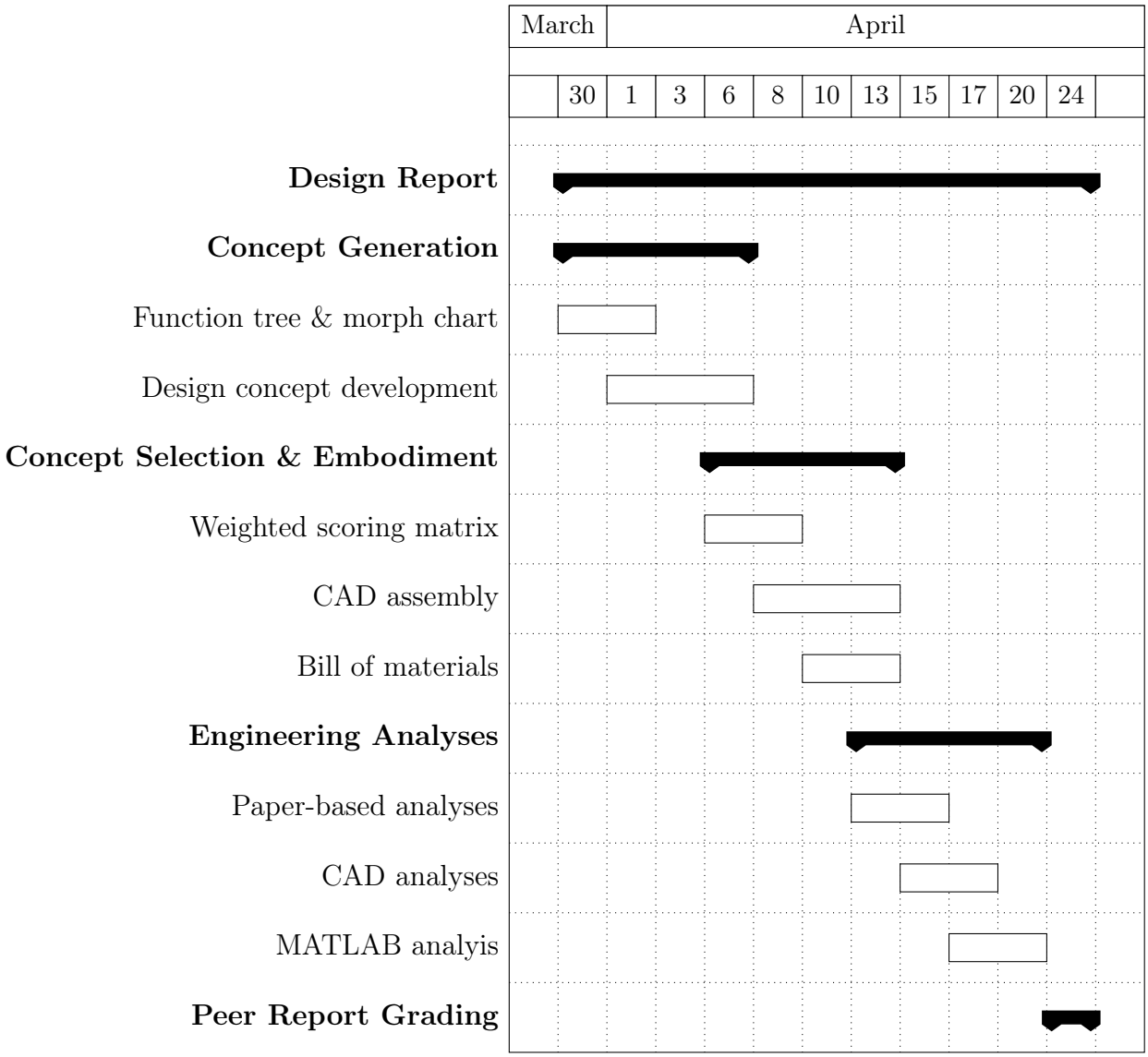
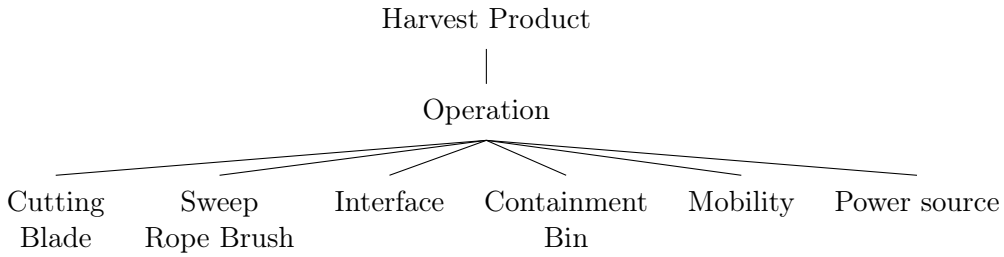


Figure 7: Gantt chart for design project

3 Concept Generation

3.1 Function Tree

Function tree for the Greens Harvester alternative design concept. Figure 3.1 depicts the functions from the base concept of operation.



3.2 Morphological Chart

More placeholder text. Use $\backslash ref\{\}$ command to refer to Figure 8.

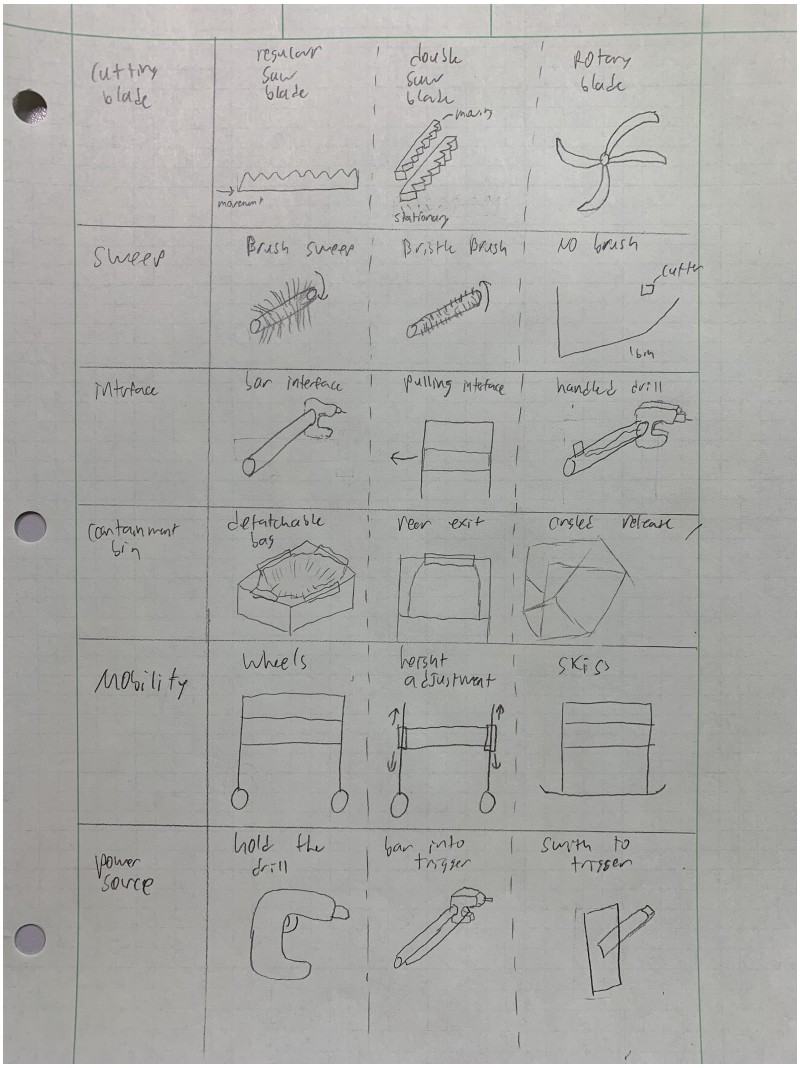


Figure 8: Morphological chart

3.3 Design Concept #1: (Ski Borrow)

3.3.1 Illustrations

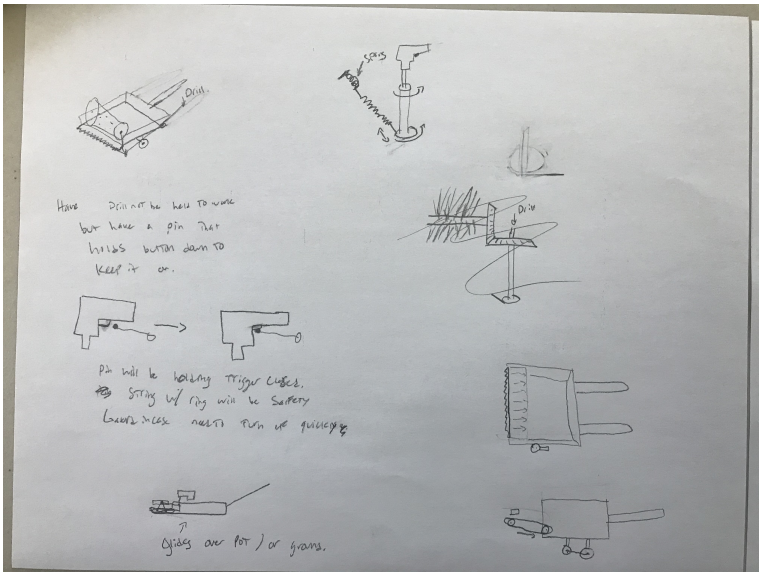


Figure 9: Sketch 1 (Matthew Donaldson)

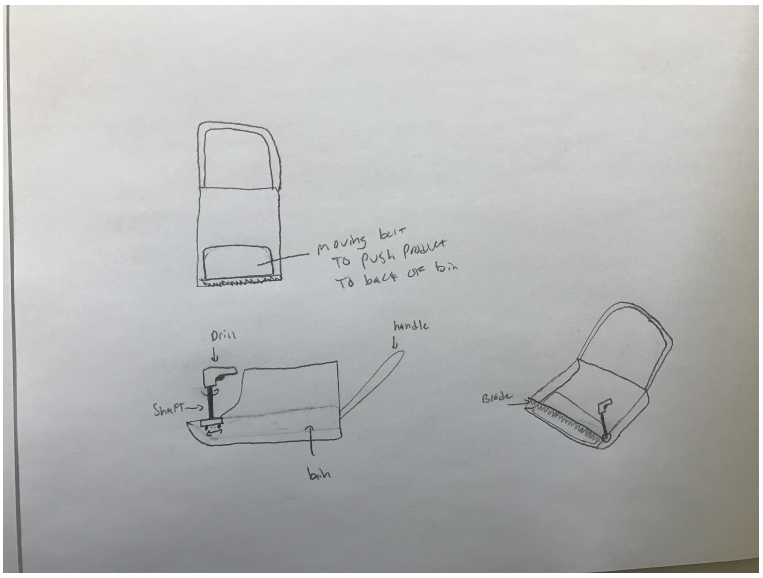


Figure 10: Ski-Barrow (Matthew Donaldson)

3.3.2 Solutions from Morph Chart

- The drill is kept on by a little bar
- The blade moves back and forth cutting the product
- A roller pushes back the product into the bin

- A roller pushes back the product into the bin
- The ski shaped bottom allows you to glide over the surface where the product is
- The handle is used to push the machine forward

3.3.3 Description

This concept is based on the greens harvester machine. The idea come partly from the using skies to help glide the cutter across the product. The roller, which is based off of a conveyor belt, pushes the product to the back of the bin, which the can be de-attached and transported for removal. As seen in figure 10, the ski part allows for a glide over the soil or pots that the fruits and vegetables or grass are on, and the blade will cut the produce at a fairly low level where then a little belt will push them to the back of the bin.

3.4 Design Concept #2: (Project Damocles)

3.4.1 Illustrations

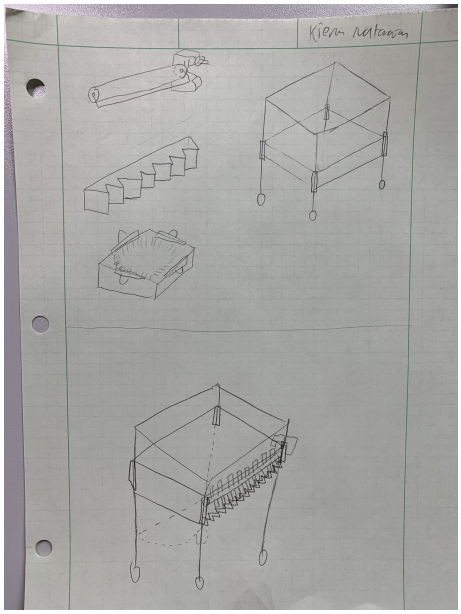


Figure 11: Rough preliminary sketches of Project Damocles (Kieran Natarajan)

3.4.2 Solutions from Morph Chart

- Double Saw Blade Cuts the plants
- Brush Sweep Pulls produce back
- Bar Push Push powered interface
- Rear Exit Bag produce can be pulled from the rear
- wheels ease of mobility
- switch to on switch to turn on drill

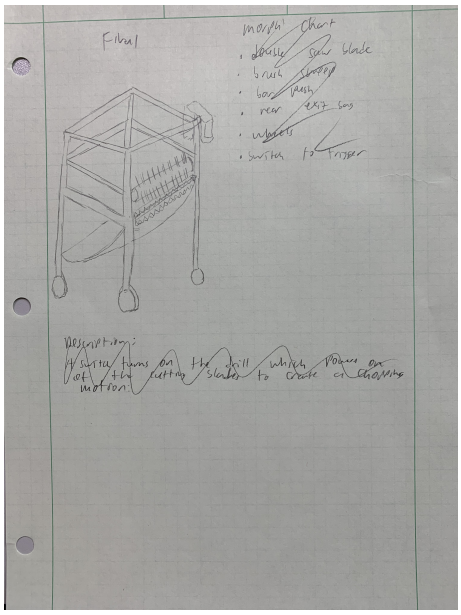


Figure 12: Final sketches of Project Damocles (Kieran Natarajan)

3.4.3 Description

This concept is based partly on the Greens Harvester machine, which serves a very similar purpose in harvesting fruits and vegetables without the aid of heavy machinery. As shown in Figure 12, it uses a double saw blade and brush to cut produce and move it into the containment bin. The frame allows for easy movement over different plots of different heights. The rear of the containment bag can be opened to allow for easy removal of goods.

3.5 Design Concept #3: (Deans Preferred Design)

3.5.1 Illustrations

3.5.2 Solutions from Morph Chart

- Rotary Blade Cuts and moves product.
- Wheels For mobility.
- Push Handle Ease of mobility in the direction over the plant bed.

3.5.3 Description

This concept is based partly on the Greens Harvester machine, and manual lawn mowers, which serve a very similar purposes within green house farming. As shown in Figure 14, it uses two slotted strut towers over large R/C car rubber wheels. A triangular frame to support the weight of the drill and clippings, and to provide structure for the rear wheel. The rear wheels are also supported by slotted struts. The catch basin and the two main uprights (supporting the blade and gearbox) are the same as the Greens Harvester machine (where patent allows). The blade for this system is similar to that of a manual push mower, incorporating both the brush and cutting surface in one piece. The gear box is on the side of the system and houses a series of gears to transmit the power from the power source. Above the gear box is a small shelf to set the trigger of the power source on, allowing it to run without human input. Two straps for security would probably be needed

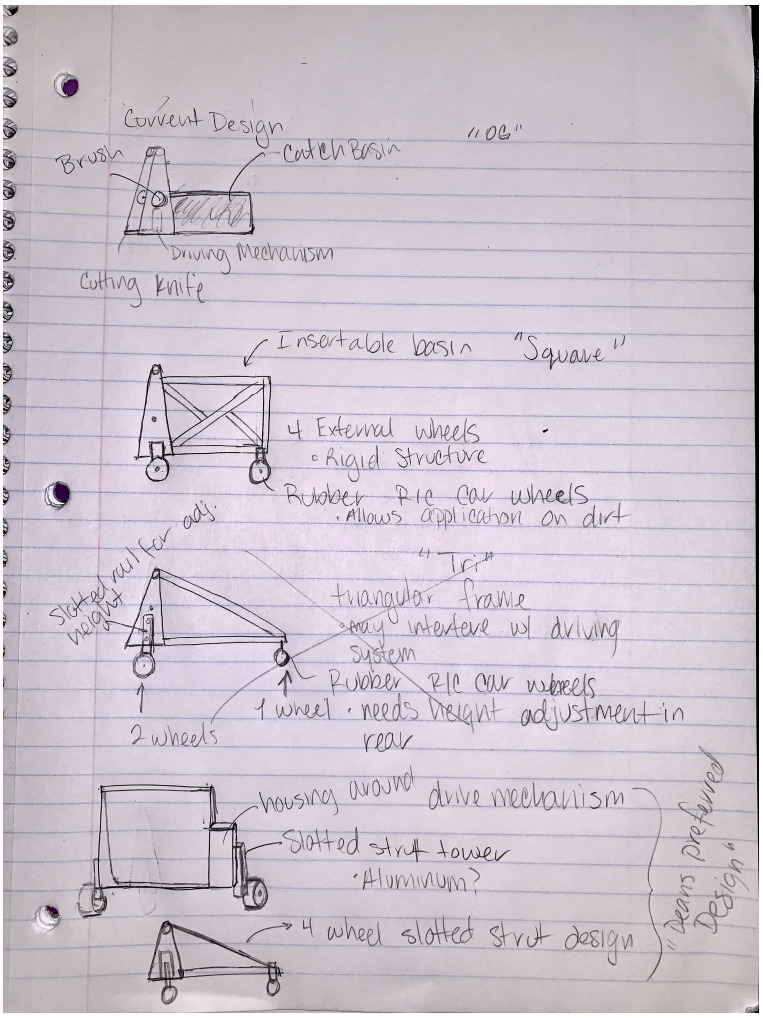


Figure 13: Rough preliminary sketches of "Dean's Preferred Design" (Dean Ryan-Simmons)

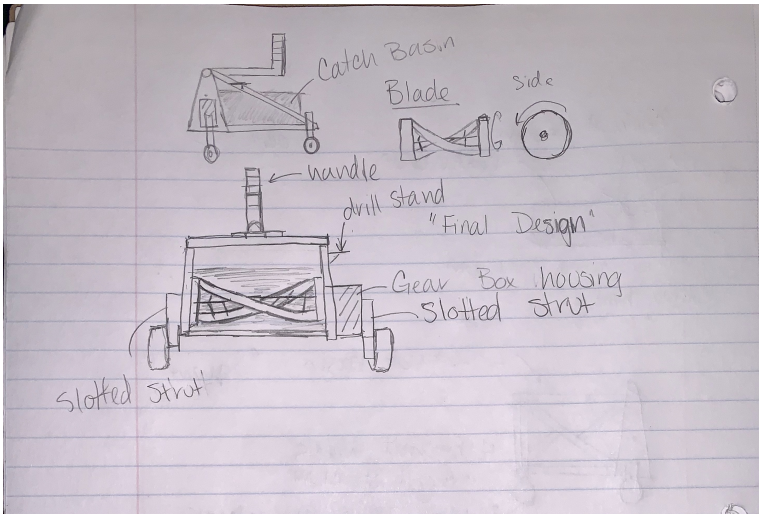


Figure 14: Final sketches of "Dean's Final Design" (Dean Ryan-Simmons)

to ensure there is not movement of the power source. The vertical handle allows the operator to stand by the

side of the apparatus and push the apparatus of the plant bed.

Floatbarrier

3.6 Design Concept #4: (Name of Concept 4)

3.6.1 Illustrations

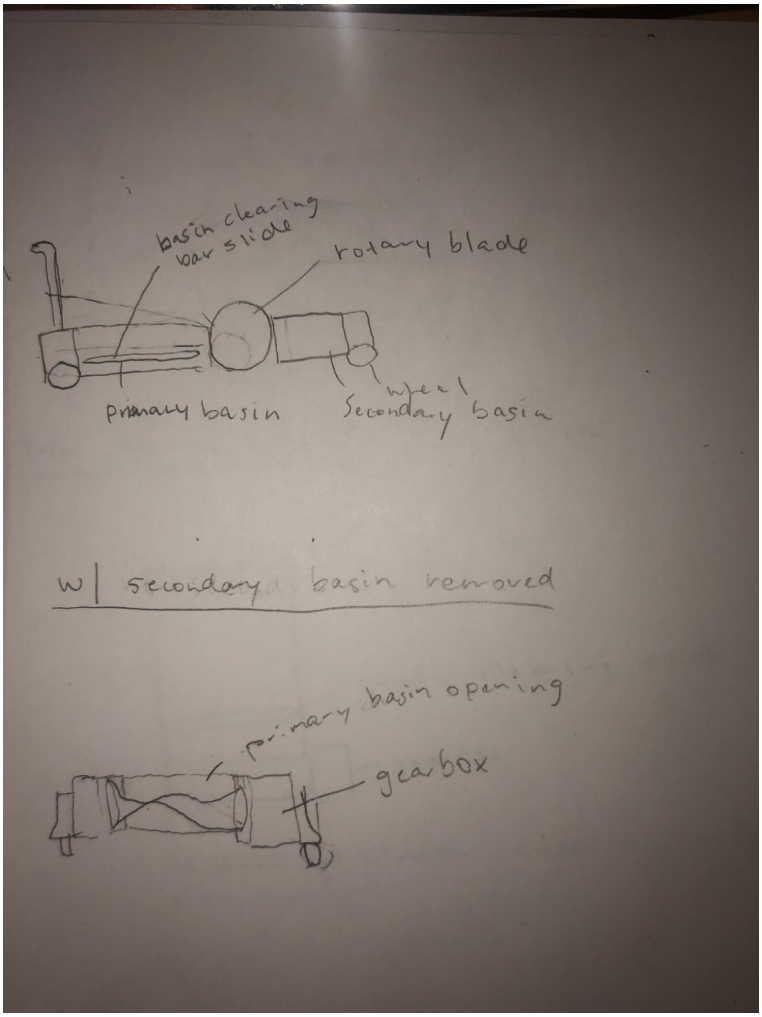


Figure 15: Rough preliminary sketches of "The Decapitator" (William Braley)

3.6.2 Solutions from Morph Chart

- Rotary Blade cuts the product
- Wheels allow for mobility
- Handle allows for user to direct mobility path
- Secondary Basin allows for increased carrying capacity

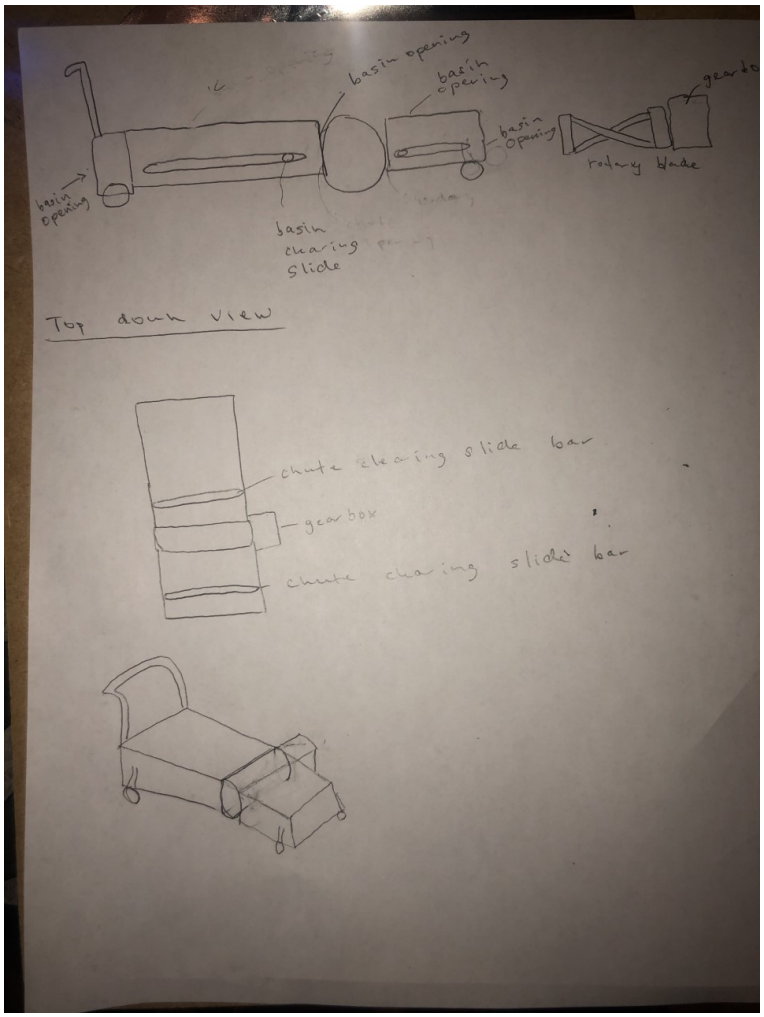


Figure 16: Final sketches of "The Decapitator" (William Braley)

3.6.3 Description

This concept is based partly on the greens harvest machine and the lawnmower I own, which serves a very similar purpose in effectively cutting and collecting greens or grass. As shown in Figure 16, it uses a rotary blade driven by the gear box on the side. The rotary blade lifts some of the greens into the front opening of the primary basin located closer to the user on the first half rotation. On the second half rotation the remainder of the greens are thrown into the secondary basin on the far side of the machine. Both basins have a metal slide that is used to move the greens to the front or back of the basins to make room for more greens. The wheels are mounted on the side of the basins and close to the basins to allow for the blade to make primary contact with the greens.

4 Concept Selection

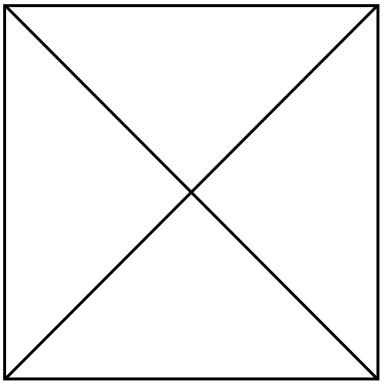


Figure 17: Weighted scoring matrix

4.1 Scoring Results & Discussion

Interpret the results of Figure 17. Which concept "won?"

For only the top ranked concept, give a brief explanation of its scores for all criteria. Try to use design-specific reasons (Concept A was thought to be lighter/cheaper/faster/stronger than concepts B or C because of a specific feature). Explain any counterintuitive scores. For example, explain why Concept C was scored much better than the reference concept for portability, but not weight.

5 Concept Embodiment

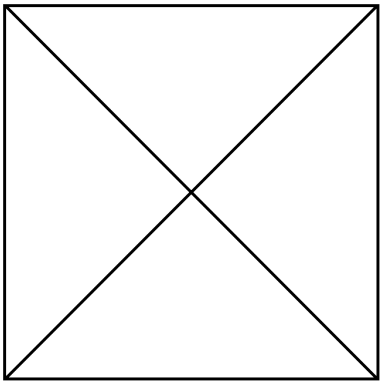


Figure 18: Assembled projected views with overall dimensions

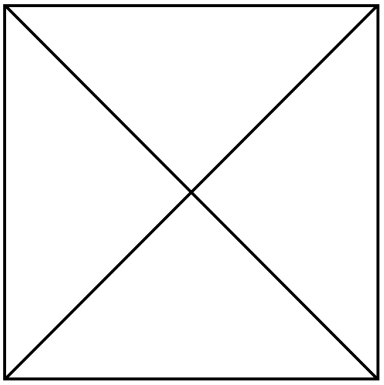


Figure 19: Assembled isometric view with bill of materials (BOM)

Maybe say a few words about the CAD models and assemblies shown in Figures 18-19.

6 Engineering Analyses

6.1 Stress at a Critical Location

6.1.1 On Paper with Overconservative Assumptions

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

6.1.2 On Paper with Underconservative Assumptions

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

6.1.3 In SolidWorks with Finite-Element Analysis

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

6.1.4 Factor of Safety

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

6.2 Deflection at a Critical Location

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

6.3 Analysis with MATLAB (change this to something more descriptive)

(Put code into Appendix A).

A MATLAB Code

```
% This MATLAB program does something interesting

clear all;
close all;
clc;

I = imread('dk.png');
figure;
imshow(I);
hold on;
pause(2);
J = imrotate(I, -30, 'bilinear', 'crop');
imshow(J)
```

Bibliography

[1] EarthDance Organic Farm School. Mar. 2020. URL: https://earthdancefarms.org/about/.

[2] DeWalt. 20V MAX* Compact Brushless Drill/Driver. Mar. 2020. URL: https://www.dewalt.com/product-repository/products-dewalt/2016/11/15/02/19/dcd777c2.