# Final Presentation

## Improving and Increasing Safety of Palm Oil Harvesting Techniques

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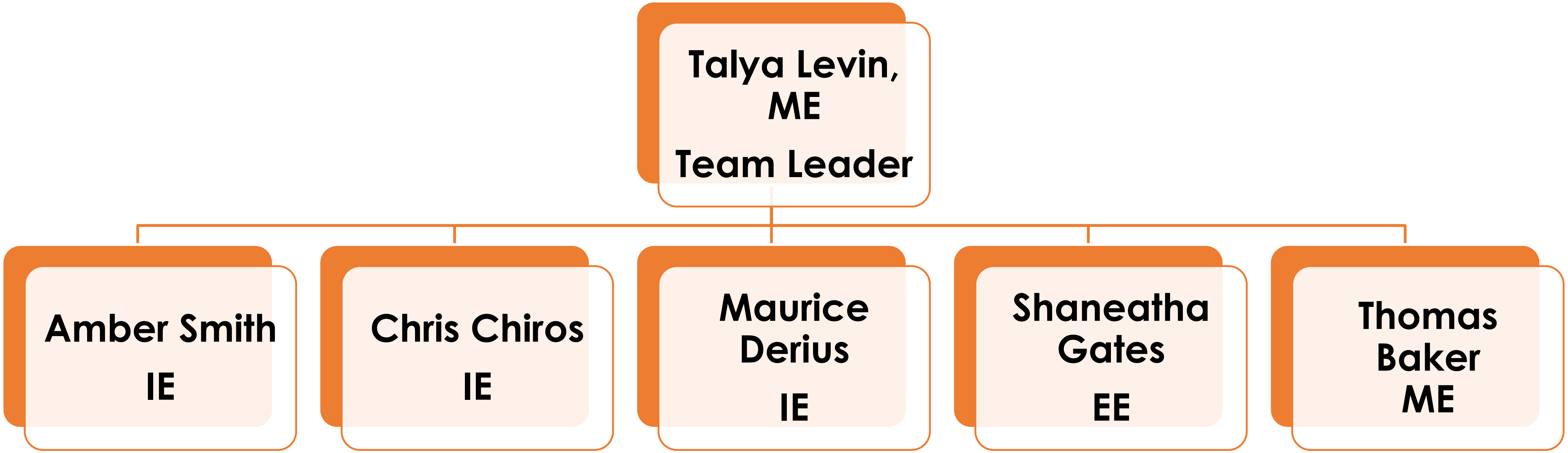
# Outline

- Introduction
- Background
- Main Objectives
- Methodology
- Improvements
- Procurement
- Building
- Results
- Business Case
- Lessons Learned
- Conclusion
- Future Recommendations

# Introduction: Team Organization



# Introduction: Sponsor Information

- Dr. Okenwa Okoli
  - Chair of the Department of Industrial and Manufacturing Engineering
  - Professor and Associate Director of HPMI
  - Received his PhD. at the University of Warwick [2]

[2]

# Background: Palm Fruit Information

- What is an oil palm tree?
  - Typically 40ft tall Palm Tree[3]
  - Grows in tropical environments
  - Grows bunches of palm fruit
- What is the significance of palm fruit?
  - Contains palm oil used in high demand products
- Applications:

[4]


[5]


[6]

# Background: Current Harvesting Methods

[7]

[8]

# Background: Project History

[9] 

2011-2012

[10] 

2013-2014

# Main Objectives

- Improve previous palm harvester mechanism
- Needs for mechanism:
  - Safe
  - Affordable
  - Competitive to current harvesting methods
  - Reliable
  - Efficient

# Methodology

DMAIC

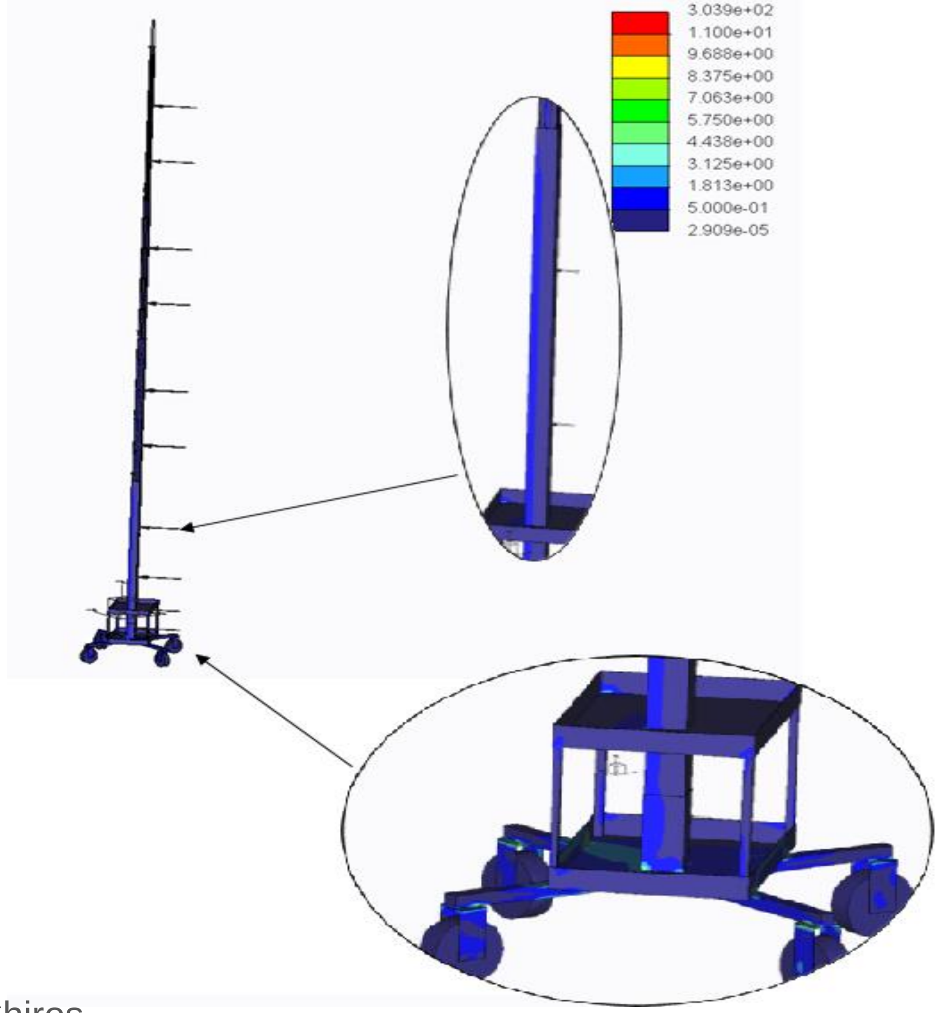
- **Defining** the problem
- **Measuring** the baseline
- **Analyzing** the cause of the problem
- Implementing **improvements**
- **Controlling** the improvements

# Improvements

- Motorize telescoping process
  - Minimize user effort
- Lower center of gravity
  - Increase stability
- Change telescoping pole material
  - Increase ductility
- Replace wheels
  - Increase mobility

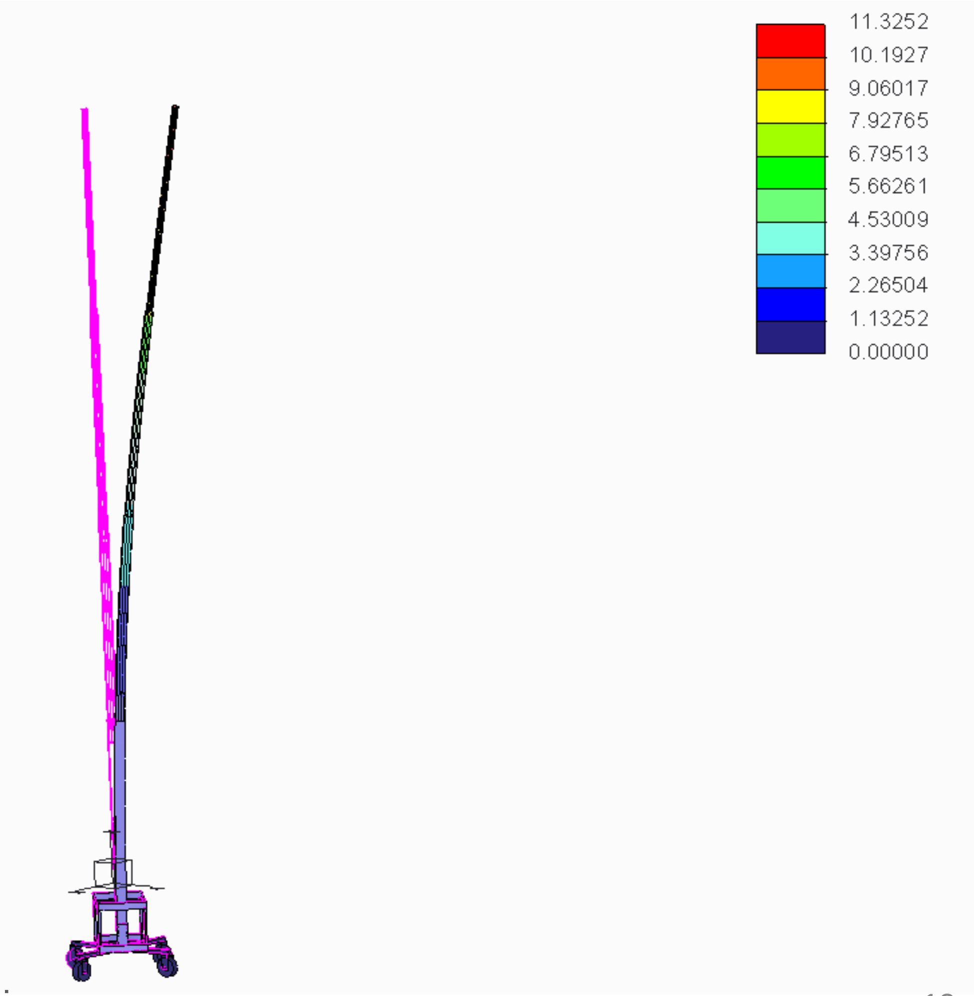
# Stress Analysis

- Largest stress distribution occurs on top of wheel brackets
- One side of the telescoping pole experiences a mild stress due to the wind force
- Stress occurs on the bottom shelf in the shape of the crossbar



# Deflection Analysis

- Deflection occurs due to the wind force applied on the pole
- Maximum deflection occurs at the top of the pole
- Maximum deflection of less than 12 mm does not cause a concern



# Procurement

- Parts ordered:
  - 2000lb 1Hp Trakker Winch Motor
  - Solid Polyurethane Never Flat Tires
  - 10ft AL-6063 Square Tubes:
    - 5”x5”, 4”x4”, 3”x3”, 2”x2”
  - Super Start Deep Cycle Marine Battery

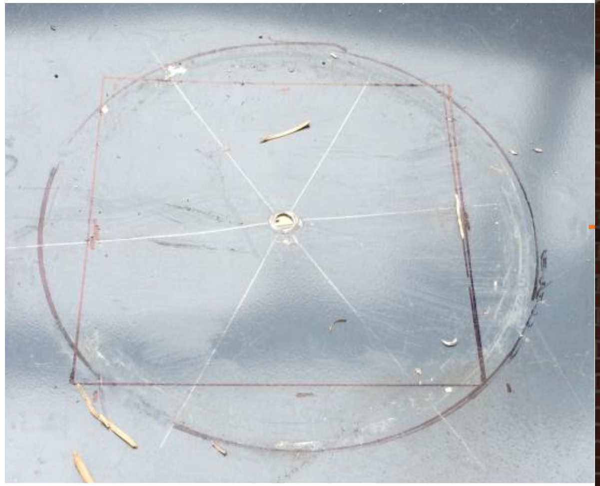

[11]

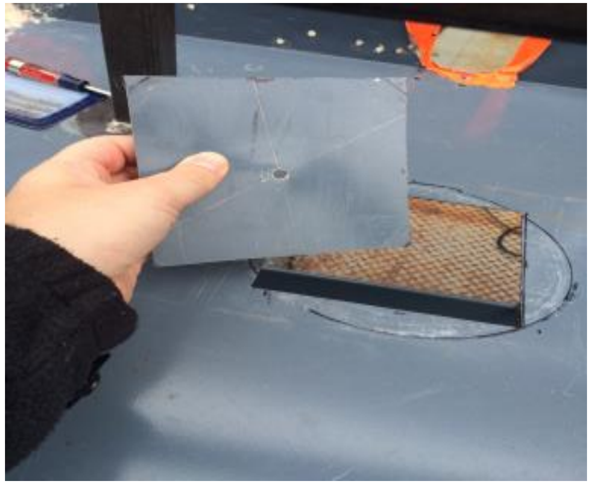
[12]


[13]

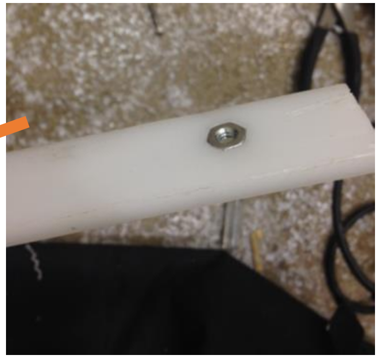
# Building: Replacing Wheels


# Building: Lowering Center of Gravity





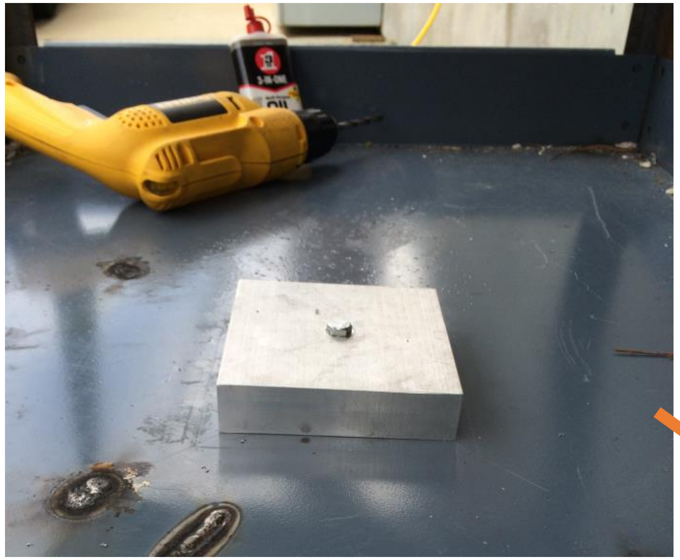
# Building: Installing Pulleys and Buffer Strips



Recessed buffer strip

Mounted pulleys

# Building: Mounting Poles

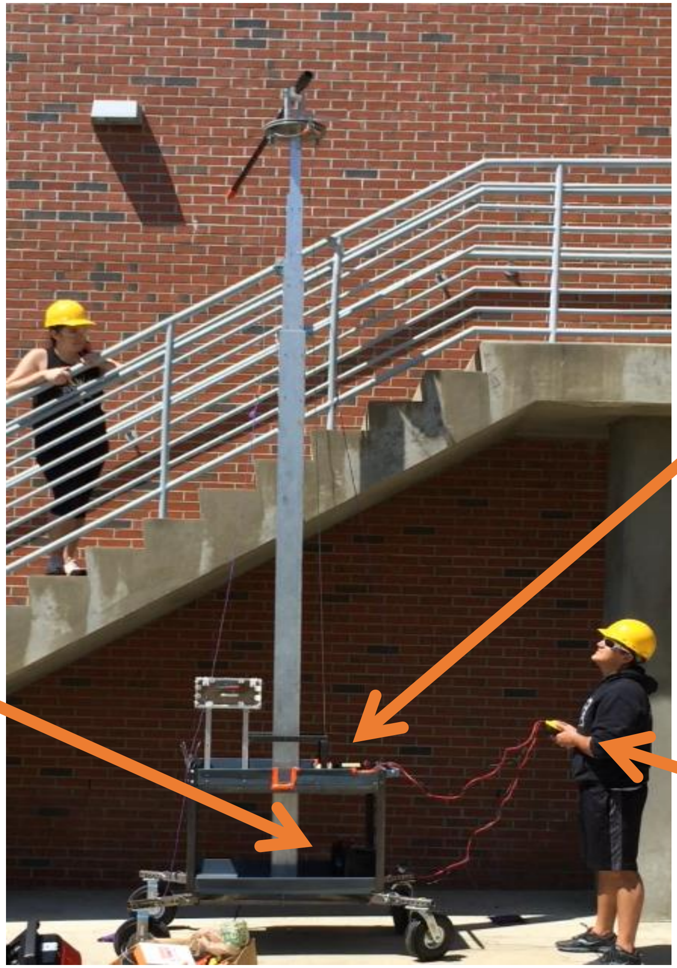


Alignment block

# Building: Motorizing Pulley System

[13]


Batter
y



[11]

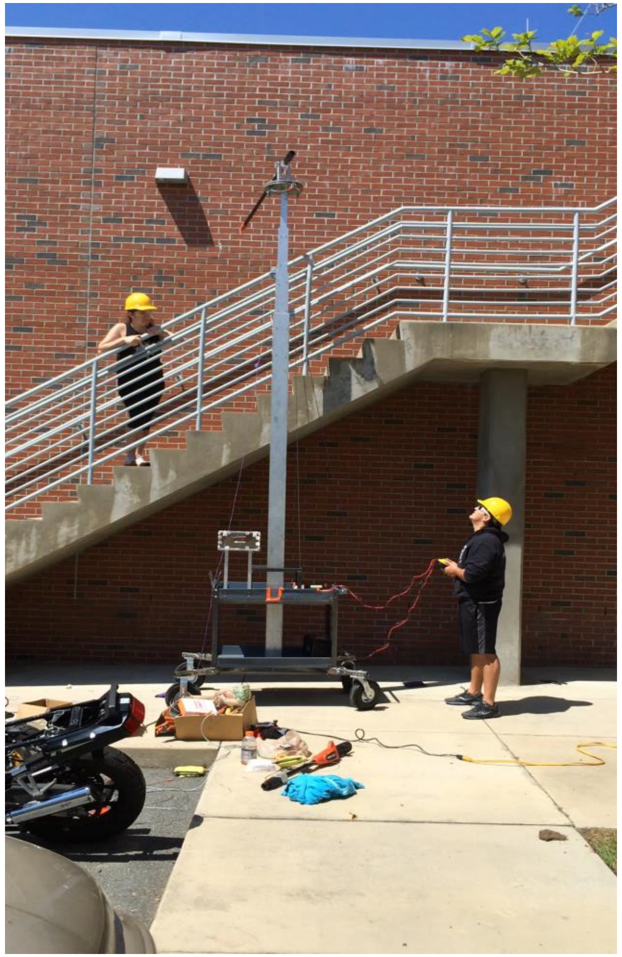
Motor

[11]

Operation
Controller

# Results: Testing

- Reached maximum height of 35min
- Minimal deflection
- Line speed test: 11.25ft/min



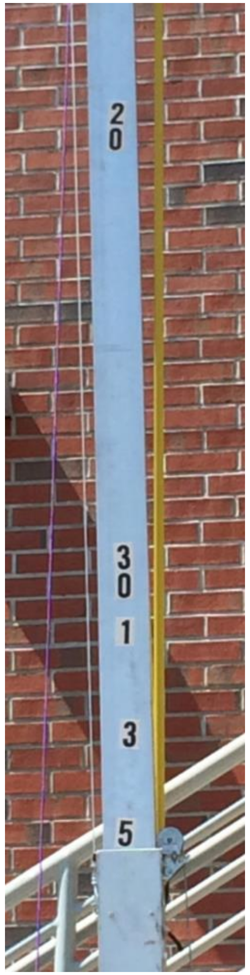
# Results: Time Analysis

- Assembly and disassembly only necessary for transportation and maintenance purposes
- Rise time (to 25 feet): 16 seconds
- Fall time (from 25 feet): 12 seconds

| Process | Old Mechanism (min:sec) | New Mechanism (min:sec) | Time Difference (min:sec) |
|---|---|---|---|
| Assembly | 3:10 | 0:00 | -3:10 |
| Disassembly | 1:40 | 0:00 | -1:40 |
| Rise to 25ft | 0:40 | 0:16 | -0:24 |
| Lower from 25ft | 0:40 | 0:12 | -0:28 |
| | | Total Saved Time | 5:42 |

# Safety Precautions

Hard hats worn at all times




| | |
|---|---|
| **SAFE** | **13ft - 30ft** |
| **CAUTION** | **31ft - 35ft** |
| **DANGER** | **> 35ft** |

# Business Case: Economic Analysis

- Manufacturing cost is approximately $1,500

- Inexpensive maintenance
  - Buffer strips
  - Battery
  - Nuts and bolts
  - Pulleys
  - Cabling

# Business Case: Economic Analysis

- Assumptions:
  - Harvesting occurs at 35ft for each tree
  - Battery only powers electric winch
  - Raising/lowering times remain consistent
  - Five palm fruit bunches per tree

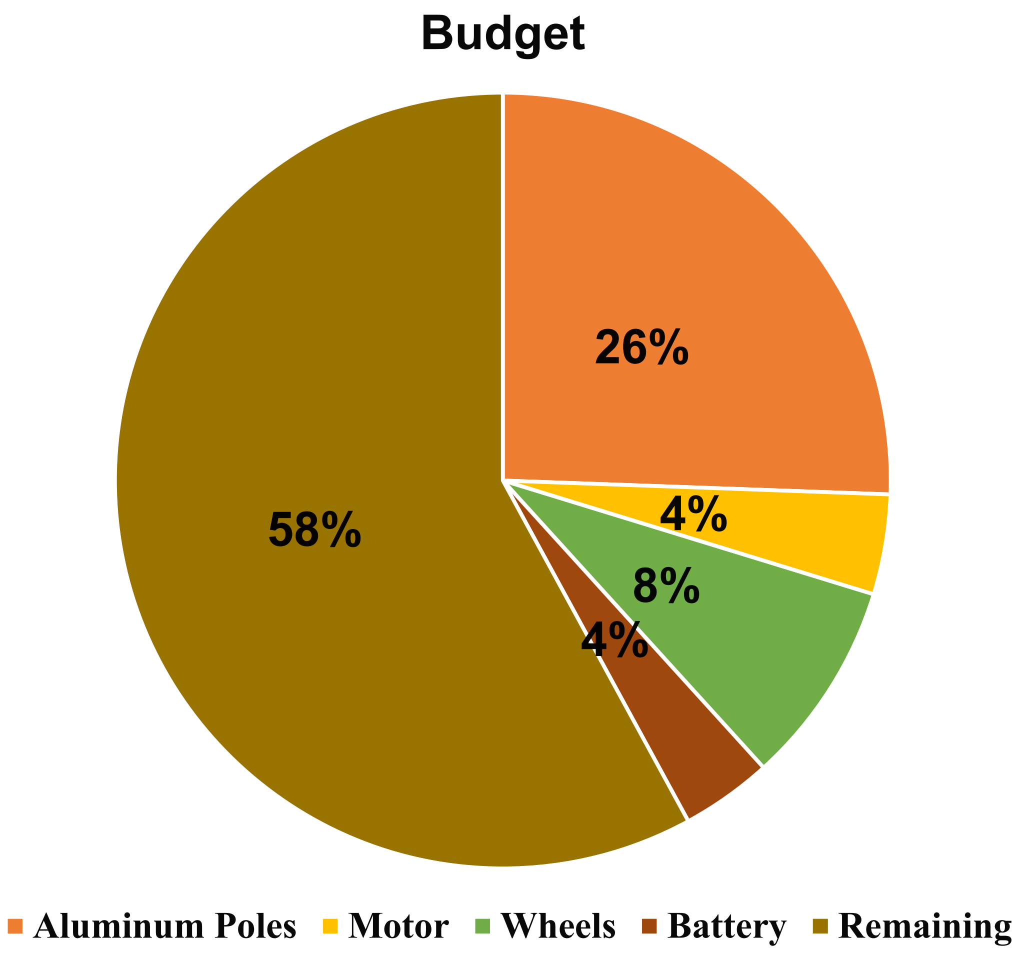
- Using motor/battery spec sheets and linear interpolation
  - Rated battery amp hour: 105Ah [14]
  - Battery discharge time: **3.9** hours
  - Can harvest approximately **361** trees
  - **Yields 22.3 tons of palm oil on one battery**

# Business Case: Environmental Impact

- Minimal contact made with oil palm trees
- No exhaust gases emitted
- Proper disposal of batteries
- All components are recyclable

# Budget

| Item | Company | Description | Cost |
|---|---|---|---|
| Wheels | Grainger | (4) Never Flat Wheel, 10-1/4 in, 350lb | $213.12 |
| Motor | Lowes | Trakker 1-HP 2,000-lb Universal Winch | $104.26 |
| Aluminum Pole | Discount Steel | 6063 AL TUBE<br>5 X 5 X ¼ X 120" | $225.60 |
| Aluminum Pole | Discount Steel | 6063 AL TUBE<br>4 X 4 X 1/8 X 120" | $85.77 |
| Aluminum Pole | Discount Steel | 6063 AL TUBE<br>3 X 3 X 1/8 X 120" | $61.21 |
| Aluminum Pole | Discount Steel | 6063 AL TUBE<br>3 X 3 X 1/8 X 120" | $41.66 |
| Shipping | Discount Steel | - | $225.00 |
| Battery | O'Reilly Auto Parts | 12 V Super Start Marine- Deep Cycle | $94.99 |
| | | | **Total** : $1,051.61 |



# Lessons Learned

- Begin procurement process earlier
- Test all current components before planning design stage
- Have pre-determined meetings with sponsors and advisors
- Better communication amongst team members

# Conclusion

- Improved previous palm harvester by:
  - Increased stability
  - Increased ductility
  - Increased the maximum height
  - Minimized required user effort
  - Eliminated assembly and disassembly times
  - Decreased rise and fall times

- Overall a safer, reliable, and efficient palm harvesting mechanism

# Future Recommendations

- Fruit-catching system
- Cutting alignment mechanism
- Operating camera
- Trailer hitching system
- Waterproofing

# References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# Questions

# Specific Calculations

Car Battery Capacity Calculations
*Assuming the pole extends to the max of 35 feet

| KT2000 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Line speed and Motor current (first layer) | Line Pull | Lbs | 0 | 500 | 1000 | 1500 | 2000 |
| | | Kgs | 0 | 227 | 454 | 680 | 907 |
| | Line speed | FPM | 13 | 10 | 7 | 5.5 | 4.5 |
| | | MPM | 3.96 | 3.05 | 2.13 | 1.68 | 1.37 |
| | Motor Current | Amps | 8 | 40 | 70 | 90 | 110 |
| Line pull & cable capacity | Layer of cable | | 1 | 2 | 3 | 4 | 5 |
| | Rated line pull per layer | Lbs | 2000 | 1745 | 1550 | 1394 | 1266 |
| | | Kgs | 907 | 792 | 703 | 632 | 574 |
| | Cable capacity per layer | Ft. | 6.69 | 8.17 | 9.66 | 11.15 | 12.63 |
| | | M | 2.0 | 2.49 | 2.94 | 3.4 | 3.85 |

| Rolling Load Capacities (first layer) | Slope* | 10% (4.5°) | 20%(9°) | 40%(18°) | 100%(45°) |
|---|---|---|---|---|---|
| | Lbs | 10500 | 6803 | 4308 | 2175 |
| | Kgs | 4763 | 3086 | 1954 | 987 |

$Wpc := 69.3lb$ Weight of the poles and cutting mechanism

$fpm := \frac{60s \cdot 3ft}{1min \cdot 16s} = 11.25 \cdot \frac{ft}{min}$ It took 16 seconds for the rope to move 3 ft

$I := \left[\frac{\left(fpm - 13\frac{ft}{min}\right) \cdot (40A - 8A)}{\left(10\frac{ft}{min} - 13\frac{ft}{min}\right)}\right] + 8A = 26.667\ A$ Amount of current required from the motor to pull 69.3 lb by using the above chart to interpolate

$Irate := 105A \cdot hr$ Amp hour rating of the car battery

$Bt := \frac{Irate}{I} = 3.938 \cdot hr$ Amount of time, in hrs, the battery will last based on the 69.3 lb

$Bt = 1.418 \times 10^{4}\ s$ Amount of time, in sec, the battery will last based on the 69.3 lb

$trise := 22.4s$ Amount of time it takes the mechanism to reach 35ft

$tfall := 16.8s$ Amount of time it takes the mechanism to go from 35 ft to full compressed 13 ft

$t := trise + tfall = 39.2\ s$ Total amount of time the mechanism takes to rise to and descend from 35 ft

$trees := \frac{Bt}{t} = 361.607$ The amount of time the battery will last divided by the total amount of time per tree the mechanism takes to rise to and descend from 35 feet, resulting in the amount of trees that can be harvested on one battery

$bpt := 5$ Average amount of bunches per tree

$fpb := 3000$ Average amount of fruit per bunch

$bunches := trees \cdot bpt = 1.808 \times 10^{3}$ Amount of palm fruit bunches harvested on the life of one car battery

$fruit := bunches \cdot fpb = 5.424 \times 10^{6}$ Amount of palm fruit harvested on the life of one car battery

$opf := 0.45$ Approximately 45% of each palm fruit is oil

$ppb := 55lb$ Weight per bunch

$p := 885\frac{kg}{m^3}$ Density of palm oil in si units

$p = 7.386 \cdot \frac{lb}{gal}$ Density of palm oil in US units

$oil := bunches \cdot opf \cdot ppb \cdot \left(\frac{1}{p}\right) = 6.059 \times 10^{3} \cdot gal$ Amount of oil produced on one car battery

$lboil := oil \cdot p = 22.374 \cdot ton$ Amount of oil produced in tons per car battery

# Specific Calculations

Drag Force Calculations: Old and New Telescoping Poles

Square Cross Section:

Height:

$h := 10ft$

Side measurement:

$s1 := 5in$

$s2 := 4in$

$s3 := 3in$

$s4 := 2in$

Density of Air:

$p := 1.2922 \frac{kg}{m^3}$

Average wind speed:

$v := 3.8 \frac{m}{s}$

Drag Coefficient:

$Cd := 1.05$

Surface Area:

$A1 := s1 \cdot h = 0.387 m^2$

$A2 := s2 \cdot h = 0.31 m^2$

$A3 := s3 \cdot h = 0.232 m^2$

$A4 := s4 \cdot h = 0.155 m^2$

Drag Force:

$Fd1 := 0.5 \cdot p \cdot v^2 \cdot Cd \cdot A1 = 3.792 N$

$Fd2 := 0.5 \cdot p \cdot v^2 \cdot Cd \cdot A2 = 3.034 N$

$Fd3 := 0.5 \cdot p \cdot v^2 \cdot Cd \cdot A3 = 2.275 N$

$Fd4 := 0.5 \cdot p \cdot v^2 \cdot Cd \cdot A4 = 1.517 N$

Circular Cross Section:

Drag Coefficient:

$Cd := 1$

Diameter:

$d1 := 6in$

$d2 := 5.75in$

$d3 := 5.5in$

$d4 := 5.25in$

Radius:

$r1 := \frac{d1}{2} = 0.076 m$

$r2 := \frac{d2}{2} = 0.073 m$

$r3 := \frac{d3}{2} = 0.07 m$

$r4 := \frac{d4}{2} = 0.067 m$

Surface Area:

$A1 := \pi \cdot r1 \cdot h = 0.73 m^2$

$A2 := \pi \cdot r2 \cdot h = 0.699 m^2$

$A3 := \pi \cdot r3 \cdot h = 0.669 m^2$

$A4 := \pi \cdot r4 \cdot h = 0.638 m^2$

Drag Forces:

$Fd1 := 0.5 \cdot p \cdot v^2 \cdot Cd \cdot A1 = 3.792 N$

$Fd2 := 0.5 \cdot p \cdot v^2 \cdot Cd \cdot A2 = 3.034 N$

$Fd3 := 0.5 \cdot p \cdot v^2 \cdot Cd \cdot A3 = 2.275 N$

$Fd4 := 0.5 \cdot p \cdot v^2 \cdot Cd \cdot A4 = 1.517 N$

# Specific Calculations

**Force to Initiate Movement of Cart**

Average height of Malaysian man $h := 5.4ft$

Average arm length for 5.4ft man $l\_arm := 2ft$

Horizontal distance from person to cart $d\_ptc := 1.5ft$

Angle of force (rad) $\theta := \left(acos\left(\frac{d\_ptc}{l\_arm}\right)\right) = 0.723$

$Wcut := 6.3lb + 15lb = 21.3 \cdot lb$

$Wcart := 35lb + 20lb = 55 \cdot lb$

$Wmotor := 13.2lb = 13.2 \cdot lb$

$Wbat := 59.2lb$

$Wpoles := 55lb + 22lb + 16lb + 10lb = 103 \cdot lb$

$Wwheels := 4.5lb \cdot 4 = 18 \cdot lb$

$Wtot := Wcut + Wcart + Wmotor + Wbat + Wpoles + Wwheels = 269.7 \cdot lb$

**Calculation of force to initiate movement:**

Since cart is not moving initially $ax := 0$

Coefficient of static friction of dirt road $\mu s := 0.35$

$\Sigma Fx := m \cdot ax$  $Ff := \mu s \cdot N$

$-Ff + F \cdot \sin(\theta) = 0$

$-\mu s \cdot N + F \cdot \sin(\theta) = 0$

$\Sigma Fy := 0$  $N - Wtot - F \cdot \cos(\theta) = 0$

$N - F \cdot \cos(\theta) = 1 \cdot Wtot$

$$F := \frac{Wtot}{\left(\frac{\sin(\theta)}{\mu s}\right) - \cos(\theta)} = 236.616 \cdot lb$$

$N := F \cdot \cos(\theta) + Wtot = 447.162 \cdot lb$

Normal force per wheel:

$N\_wheel := \frac{N}{4} = 111.79 \cdot lb$