Human Powered Vehicle Team
Movin' Human Final Presentation

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UVU MECHANICAL ENGINEERING
UTAH VALLEY UNIVERSITY

Presentation Overview

- Project Overview
- Research
- Design Requirements
- Concept Generation
- Concept Selection
- Innovation
- Structural Analysis
- Cost Analysis
- Lessons Learned
- References

Project Overview

- The first Human Powered Vehicle from Utah Valley University, the Convertible Reverse Trike Bike (C-RTB)

- Single tube framing with an electric-powered rear wheel hub motor.

- Adjusting front arms/forks to allow front two wheels to be close like a bike or wide like a trike.

Research

- Three main sources of information
    - Fezzari Bicycles
    - Past competitors
    - Provo Bicycle Collective

- Main takeaways
    - Utilize 3D printing
    - Justify the design
    - Be creative

Past Competitor of
ASME HPVC [1]

Design Requirements

- Obtained from HPVC 2022 Rules

- Required benchmarks to be successful
  - Metrics and values make them measurable

Competition Requirements		
Metric	**Value**	**Units**
Turn Radius	Minimum 8	m
Stopping distance going 25 km/hr	Maximum 6	m
Can travel in a straight line moving 5 to 8 km/hr	Minimum 30	m
Front Brakes	Minimum 1	per wheel
Roll Cage with vertical force strength	Minimum 2670	N
Roll Cage with horizontal force strength	Minimum 1330	N
Safety harness	4 or 5	Secure Points
Class 1,2, or 3 Ebikes	Maximum assist 28	mph
Battery system	Maximum 48	Volts

Optional Design Objectives

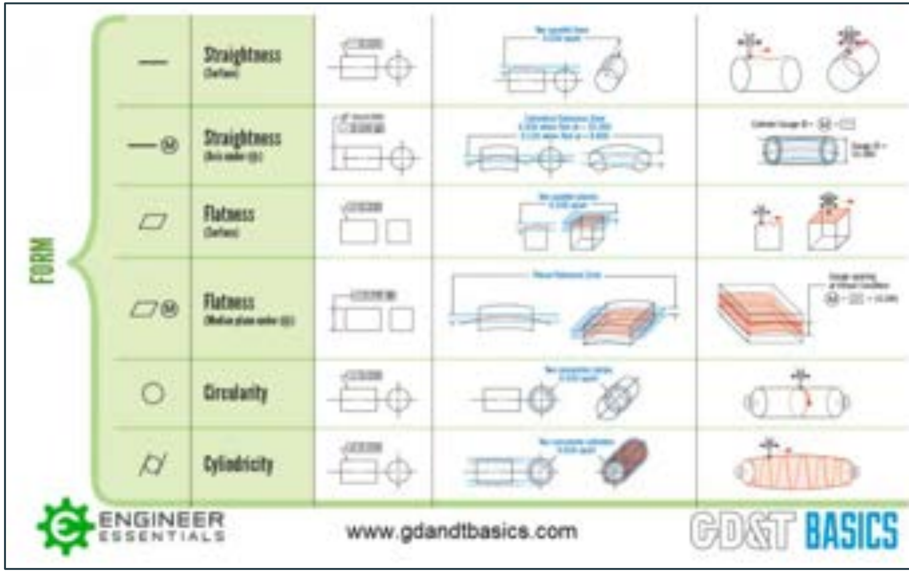
- Additional benchmarks gathered from interviews.
    - Makes product more consumer friendly

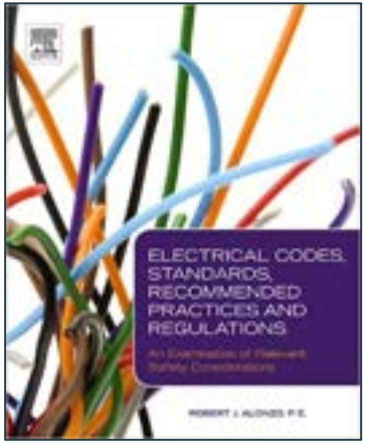
- Four main questions during interviews
    - “What are some musts in a bike?”
    - “What are some frustrations you’ve had?”
    - “Are there any wanted features?”
    - “Have you tried other bike-like vehicles?”

Consumer Needs		
Metric	**Value**	**Units**
Adjustable sizing for rider	60 to 77	in
Ride comfort	>1	hour
Suspension travel	0.1	m
Time between services	>6	months
Max Speed	>15.5	mph
Dry weight	<100	lbs
Length	<7	ft
Battery life	>30	miles

Codes and Standards

- ASME Y14.3, 14.5, 14.24
- ASTM A519 Grade 1026
- Utah's Department of Transportation (UDOT)
- National Electric Code (NEC)
- NFPA 485 (Lithium battery handling)





Concept Generation – External Search

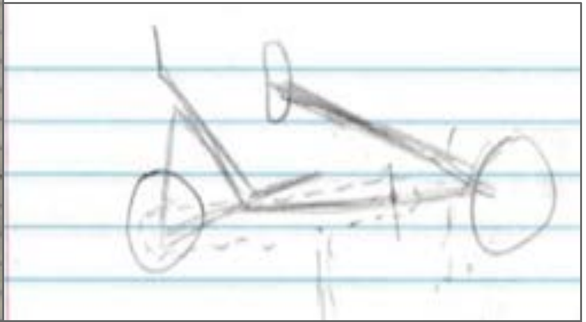
Cardboard Bicycle

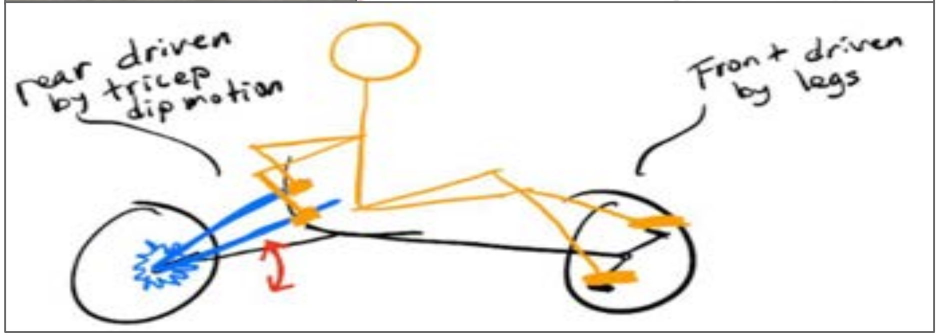
Compact Bicycle

Yamaha Niken [2]

Concept Generation Internal Search

- 100+ hand-drawn sketches
- Be creative, use inspirations
- Varied levels of detail





Concept Selection: Drivetrain

- Criteria were created from concerns in manufacturing and customization
- Rated on a scale from 1 to 5 with 5 being the high
- Highest score would be implemented in the design
- Subsystems were weighted and listed from most important to least important

Drivetrains				
Criteria	Dual (Hub motor)	CVT	Shaft Driven	Single
Dependability	4	3	5	3
Availability	4	2	1	3
Complexity	2	2	2	3
Life cycle	4	2	4	3
Ease of implementation	3	2	1	3
# Gear options	2	5	1	3
Size of gears	3	4	1	3
Total	22	20	15	21
Average	3.1	2.9	2.1	3

Concept Selection: Structure

- Had the most criteria
- Based on specific sketches
- Wheelchair and “Luge” were low scoring

Structural				
Criteria	Wheelchair	Reverse Trike	Quad "Bike"	"Luge"
Human power input	1	3	2	2
Steering performance	4	3	2	1
Braking performance	1	4	5	3
Roll cage mounting	4	4	5	2
Stability	4	5	5	3
Cost	2	2	1	2
Component availability	1	3	2	2
Seating comfort	4	4	3	3
Suspension comfort	1	3	3	2
Aerodynamic flexibility	2	4	4	4
Total	24	35	32	24
Average	2.4	3.5	3.2	2.4

Concept Selection: Steering

- Left the most open due to uncertainty
- Winner of this scoring matrix was Rack and Pinion
    - Rack and pinion not achievable with our selected innovation concept and steering complexity

Steering				
Criteria	Rack and Pinion	Handle Bars	Levers	Electric Steering
Steering ratios	4	3	3	5
Ease of implementation	2	3	2	2
Availability	3	3	2	1
Familiarity to driver	4	3	2	4
Total	13	12	9	12
Average	3.3	3.0	2.3	3.0

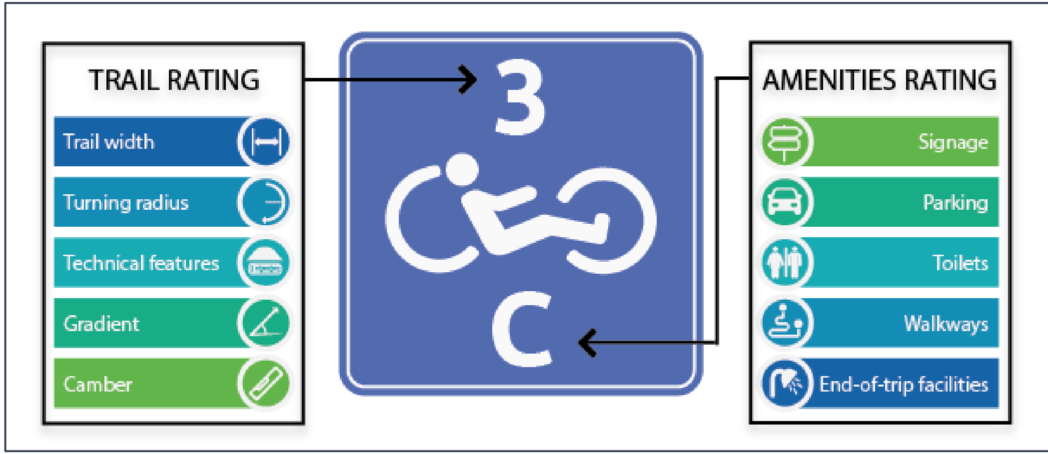
Concept Selection: Suspension

- Leaf springs could've been custom with elastomer damping
- Several average scores (3)
- Winner was Pneumatic
    - Did not account for fat tires

Suspension					
Criteria	Leafspring (custom)	Coil	Pneumatic	Seat	Suspension Spokes
Availability	2	3	3	3	2
Ease of implementation	1	3	3	3	3
Travel length	2	3	3	1	2
Life cycle	4	3	3	2	2
Prevention of vibrations	3	3	3	1	4
Cost	2	3	4	4	1
Comfort to rider	2	3	3	2	2
Total	14	18	19	14	14
Average	2.3	3.0	3.2	2.3	2.3

Innovation

- Our innovation's purpose is to help break down accessibility barriers for biking trails.
- We were led to two different options that, in theory would allow more stability on different terrain.
- Both options were modeled, prototyped, and evaluated.



Common Adaptive Trail Rating (ATR) [3]

Innovation Final Ideas

Option 1 - “Chopper”

- Swinging arms controlled by a chain connected to a 1:1 gear
- Movement is front to side
- All parts could be purchased



Option 2 - “Hopper”

- Unique design
- Vertical movement
- Would be custom CNC’d

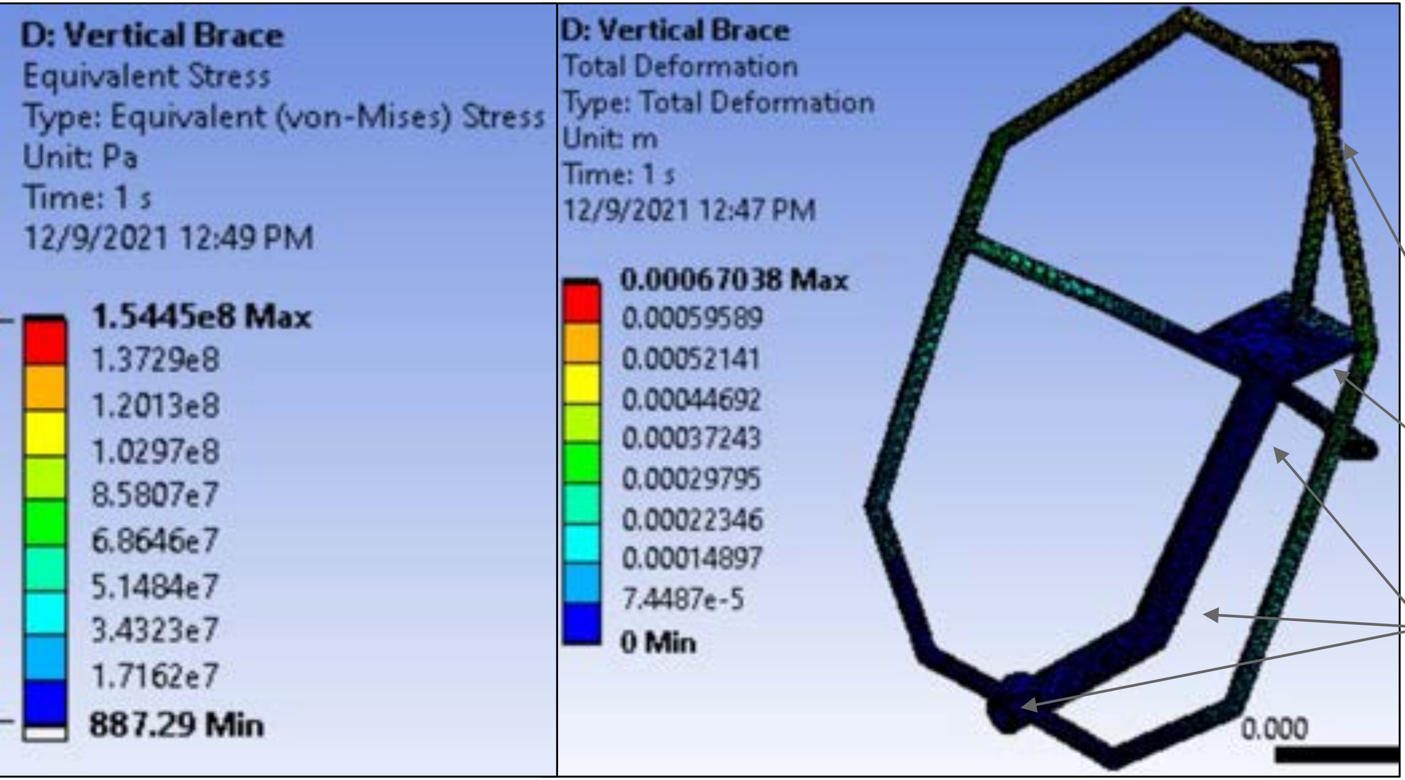

Innovation continued...

Benefits of choosing this innovation design include:

- Easier assembly and repair ability.
- Manufacturability and machine setup time.
- Raw materials easily obtainable.
- Replacement parts are widely available.

Proof of Concept

Structural Analysis
– Rollover Protection System



ASTM A519 Grade 1026 (AISI 1026) yield strength 415 MPa

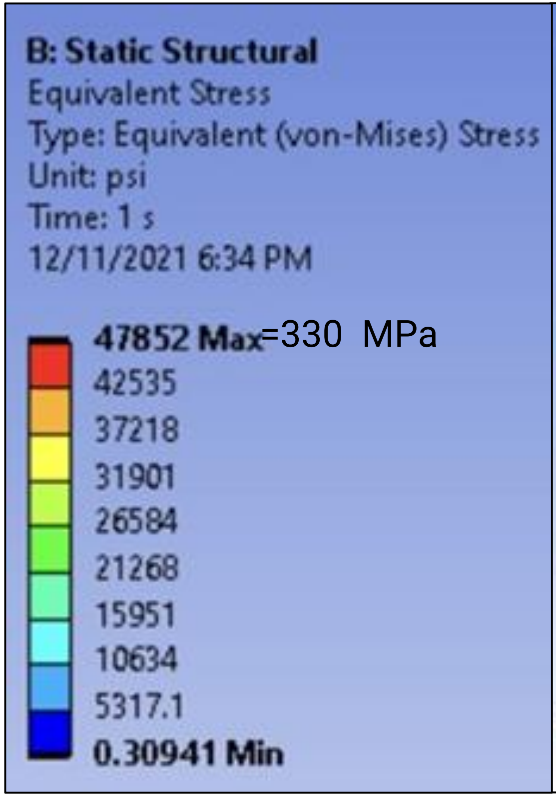
Factor of Safety = 2.75

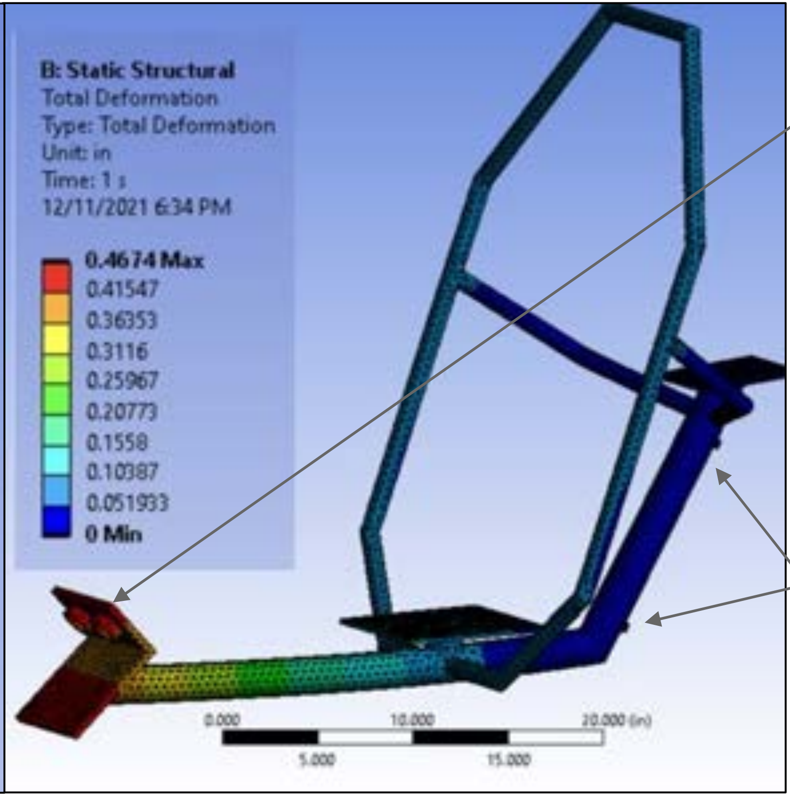
Vertical load - top of RPS (pictured)

Horizontal load - side of RPS

Fixed supports - Rear fork connection points and front of frame

Structural Analysis
– Frame





3,716.5 N Load - front forks connection point -very extreme case

ASTM A519 Grade 1026 (AISI 1026)

yield strength 415 MPa

Factor of Safety = 1.3

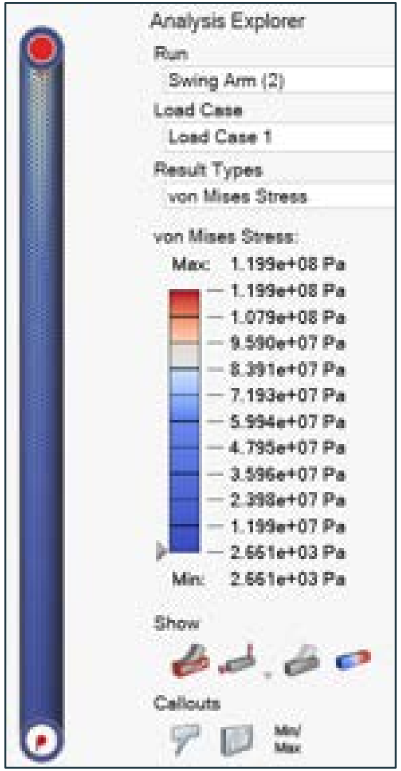
Fixed supports - Rear fork connection points

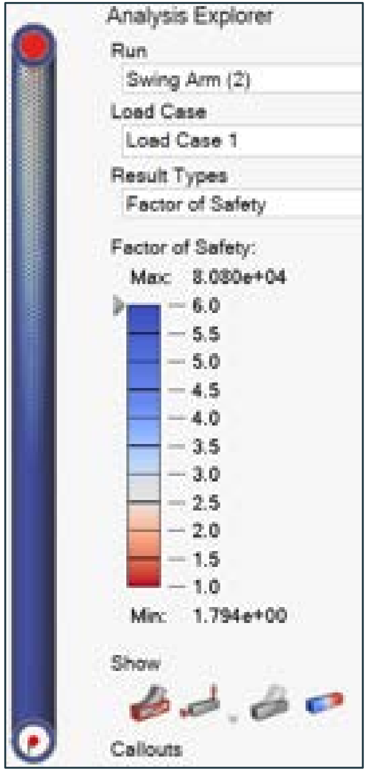
Structural Analysis
– Swinging lever arms

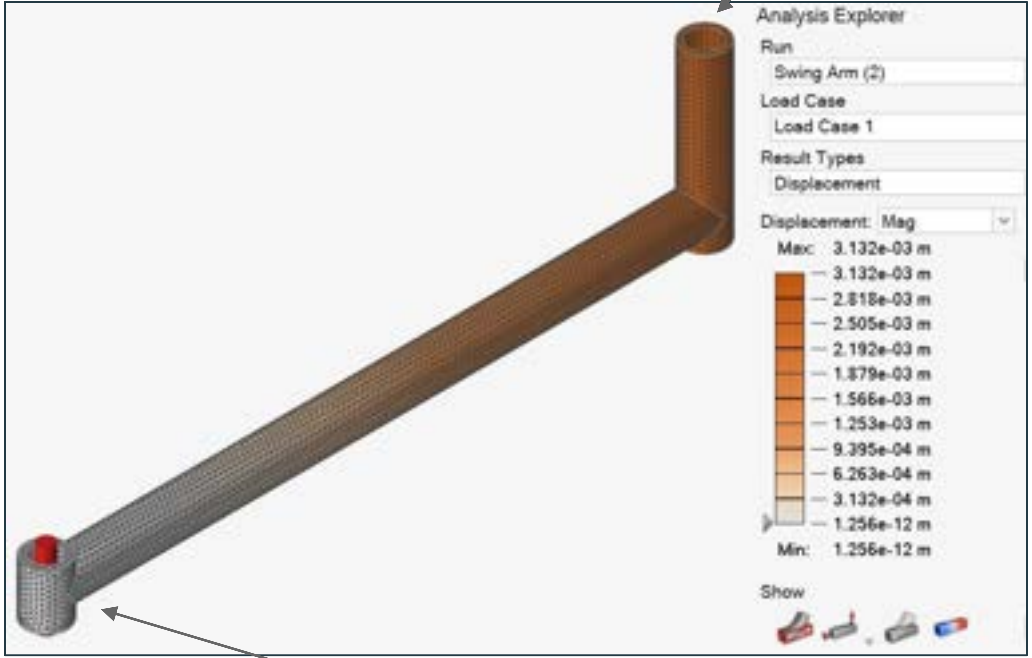
ASTM A519 Grade 1026
(AISI 1026)

yield strength 415 MPa

650 N load







Fixed support

Factor of Safety = 3.4

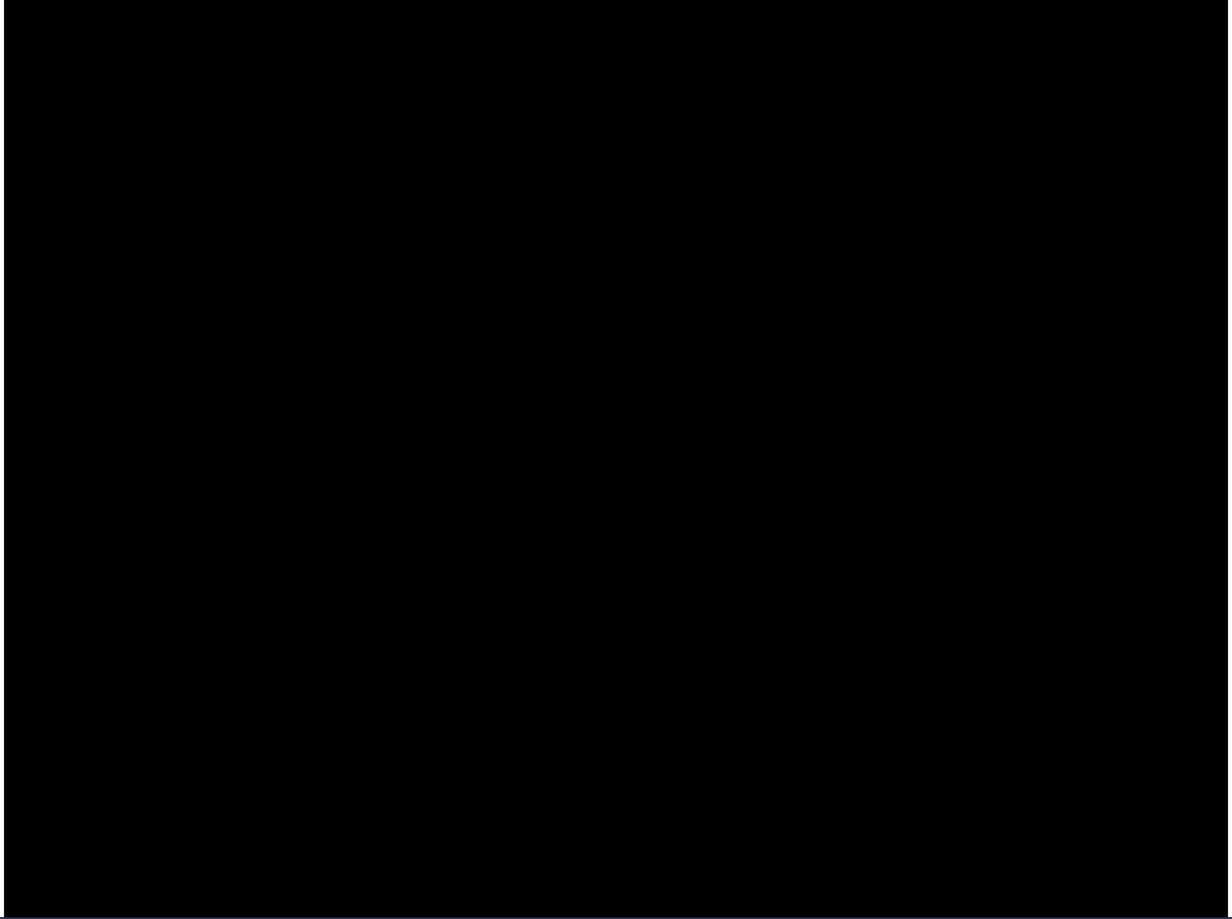
Cost Analysis

- Total budget was $5000.00
  - GEL Grant
  - Mechanical Engineering Department
- Budgeting goals
  - $3500 initial build cost
  - Remainder reserved for replacement parts or redesign.

Material Category	Cost
Raw Material - Frame	$393.78
Raw Material - RPS	$250.60
Raw Material - Swing Arm	$290.25
Raw Material - Handlebars	$41.02
Raw Material - Gearbox	$284.53
GearBox Components	$365.16
Fat Bike kit	$463.93
Hub Motor Kit	$941.34
Brake Components	$131
Steering Components	$282.98
Safety Harness	$59.99
TOTAL	**$3504.58**

Prototyping

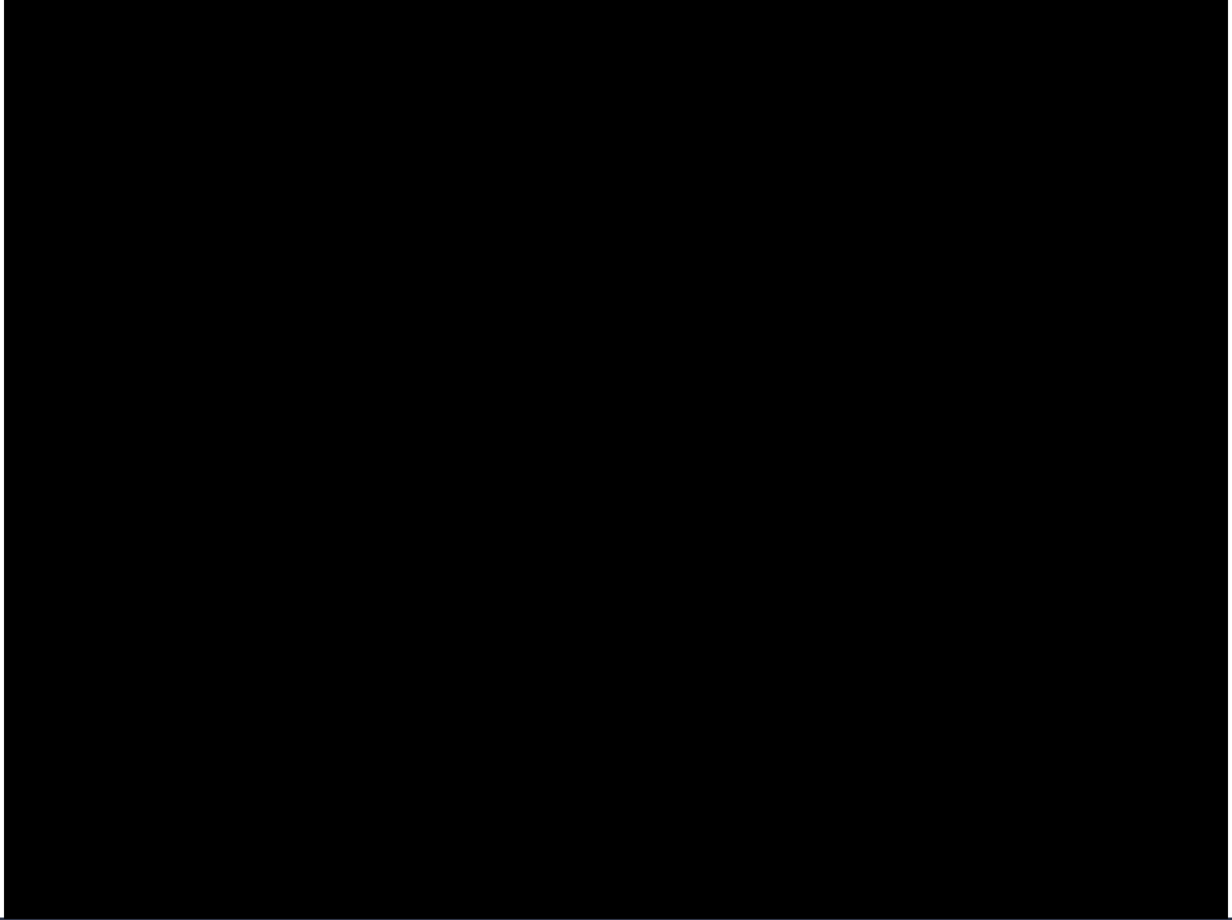
- Handlebar placement
- Upgrade to hydraulic brakes
- Configuration of arms
    - Pin system



Straight Line Testing

Brake Distance Testing

Complete stop from 25 km/h in 6 m



Turn Radius Testing

180 degrees in 8m

Final Design

Comparison

- Reflect back on design requirements
- The C-RTB meets all critical competition design requirements.
- Some optional design objectives were also completed.

Original Design Requirement	Actual Design Specifications
Minimum turn radius of 8 m	Turn radius of 3 m
Maximum stopping distance of 6 m	Stopped within 5.5 m
Stability test over 30 m	Passed test
Minimum 1 brake per front wheel	1 brake on each front wheel
Roll cage withstands 2670 N vertically	Passes test
Roll cage withstands 1330 N horizontally	Passes test
Safety harness has minimum of 4 contacts	Safety harness has 4 contact points
Ebike classification of 1, 2, or 3	Class 3 Ebike
Maximum battery voltage of 48 V	Voltage under 48 V
Adjustable for riders 60 in to 77 in	Non-adjustable frame
Ride comfortably for 1 hour	Ride comfortably for more than 1 hour
Minimum 0.1 m suspension travel	Fat tires provide sufficient suspension
Minimum 6 months between services	Unknown at this time
Maximum speed of at least 15 mph	Achieves speed of 15.5 mph
Weight not exceeding 100 lbs	Vehicle weighs 150 lbs (71 kg)
Maximum length of 7 ft	Vehicle length of 8.5 ft (2.6m)
Minimum battery life of 30 miles	Unknown at this time

Lessons Learned

- Teamwork and scheduling is effective
- Prototyping catches several design mishaps
- Off the shelf components must be considered carefully
- Perform analysis on any stress-bearing objects
- Stress concentrations need to be considered

References

[1] "University of Wisconsin-Milwaukee," Bicycle and Motorcycle Engineering Research Laboratory. [Online]. Available: https://sites.uwm.edu/bike-motorcycle-lab [Accessed: 12-Dec-2021].

[2] "2019 Yamaha Niken Sport Touring Motorcycle - Photo Gallery, video, Specs, features, offers, inventory and more," Yamaha Motorsports. [Online]. Available: https://www.yamahamotorsports.com/sport-touring/models/niken. [Accessed: 12-Dec-2021].

[3] "Adaptive Trail ratings," BREAK THE BOUNDARY, 18-Oct-2018. [Online]. Available: https://breaktheboundary.com/adaptive-trails/. [Accessed: 02-Mar-2022].

Questions?

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