2021 Baja Ergonomics and Project Management

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Zachary Fenger

April 2021

Thesis Advisor:

Professor Allen Arthur

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The Bearcat Baja team's objective is to design, build, and test a single seat off-road vehicle that is capable of extreme terrains. This report is specifically for the ergonomics and project management. Under ergonomics, this report focuses on the design, build, and test of an adjustable pedal assembly. Started the project by performing research including prior art, background, problem impact, state-of-the-art, quality function deployment, and product objectives. After the research phase, then 3 concepts were created and finalized down to one concept. After the concept phase, then the project went into the design phase where the design was finalized including materials, fit/function, and geometry. Following the design phase came the build phase. The build phase including all manufacturing of custom parts, purchasing off-shelf parts, and assembling all components. After the build phase came the testing phase where the design was validated through 4 tests.

I want to thank those that aided in the success of the MET 2021 class and helped set a good foundation for future success in my career. I would like to first thank all the MET professors including but not limited to Prof. Elgafy, Prof. Al-Ubaidi, Prof. Dong, and Prof. Tsung. I also wanted to thank Dean Allen Arthur for his time and work with the Bearcat Baja team and providing an excellent learning experience. I also wanted to thank Dean Gautam Pillay for his behind-the-scenes time and work to direct me towards my long-term career goals. Lastly, I wanted to thank the whole University of Cincinnati CEAS staff for the time and work to help make the 2021 MET program a success.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The Society of Automotive Engineers International (SAE International) hosts an annual competition for many Universities around the globe. The objective of the competition is to design and build an all-terrain vehicle that can withstand extreme off-road conditions. I will be project manager for the University of Cincinnati's Baja senior design 2021 team underneath Dean Allen Arthur. I will need to lead and manage the Baja team to finish designing and building upon the 2020 team's work. I will also be designing all ergonomic aspects of the vehicle. Upon completion we will be competing to win the SAE Baja 2021 competition(s).

RESEARCH

BACKGROUND AND SCOPE OF THE PROBLEM

Each year students from around the world design and build single seat all-terrain vehicles as part of the SAE BAJA competition. SAE describes the goal of the challenge on their website: "engineering students are tasked with designing and building a single-seat, all-terrain sporting vehicle that is to be a prototype for a reliable, maintainable, ergonomic, and economic production vehicle that serves a recreational user market." (1) The vehicles are designed under the premise that they are for a "customer" - a fictitious utility vehicle supplier that will produce 4,000 units annually. Pleasing a "customer", keeping costs low and designing with a known production quantity is part of the challenge of this competition.

SAE updates the rules and regulations of the competition yearly to prevent teams from submitting the same vehicle multiple years in a row. Historically the SAE specified the design of a two-wheel drive vehicle, but this year SAE is requiring a four-wheel drive vehicle. SAE also has historically changed their rules regarding components such as the frame and fuel tanks to improve safety. In 2018 teams needed to switch the fuel tanks and splash pan configurations from past years to meet SAE's new safety guidelines. (2) Along with SAE's required changes, each year teams have different points of emphasis that they consider when designing their vehicle with a goal to improve in specific areas compared to previous years. In 2018 the team from UC designed the frame prioritized the improvement of driver ergonomics, maintenance access and weight reduction from past years. Other components experienced less progression such as steering. In 2017 the UC team's goal for steering was for a design with effective and precise maneuverability that will meet SAE criteria. (3) This is an example of a goal that carries over from year to year. The competition rules and regulations change yearly but the same general challenge remains the same.

Impact of the Problem

The groups most impacted by this project are the end user and the “company” we are designing the vehicle for. The vehicle must be designed with a “customer” in mind that wants to produce 4,000 units annually. This impacts how our team will evaluate costs associated with the project. Since this design would then be sold by the “customer” to an end user, the comfort and performance need to be considered. As an off-road vehicle the safety of the end-user is the highest priority by both SAE and the design team.
Our team will also take our design to competition where the vehicle be put through a series of tests. Our team members will be operating the vehicle and will be impacted by the ergonomics, safety, and performance as well.

Magnitude of the Problem

The magnitude of the problem is the challenge to build an economical, safe, and durable vehicle. With 4,000 units expected annually, material and manufacturing costs must be kept to a minimum. Safety is also a significant concern because the extreme terrain, and accidents like rollovers might happen, so the driver must be protected. There are also the engineering challenges such as acceleration, handling, and performance on rugged and off-road terrain. (1)

How the Problem is Currently Being Addressed

The latest University of Cincinnati (UC) Baja design was done in 2020. The off-road capability, safety, and comfortability played a large role in the design of the 2020 UC Baja design. To address these 3 areas, the 2020 UC Baja team chose the parallel method of steering, 4-wheel drive drivetrain, and a frame to support the front differential while providing the end user with enough leg room.

The 2020 UC Baja design looked at how to address the off-road capability, safety, and comfortability through the following ways. The parallel method of steering was used in the 2020 UC Baja design. (4) The parallel method is well balanced and will prove to be highly effective in extreme terrain. 4-wheel drive was an added feature that the 2020 UC Baja team added to the design from previous years. (4) The 4-wheel drive feature will greatly improve traction and the friction force that the car will be able to provide on the driving surfaces thus allowing significantly better off-road capabilities. The 2020 UC Baja design included spacing and brackets to hold the additional differential in the front of the vehicle. (4) This design will allow the end user the proper safety and comfortability when driving with the 4-wheel drive feature. The design from 2020 will be a starting point for our team and we will build off what was started in 2020.

CURRENT STATE OF THE ART

The University of Cincinnati Bearcat Baja team currently has 4 designed vehicles and 3 partially built and partially functional vehicles built. The vehicles from the 2014, 2016, and 2019 Bearcat Baja teams are fully built and functional. I will be discussing the state of the art from these three years.

In 2014, the Bearcat Baja team fully designed and built their Baja vehicle with several factors to help the ergonomic design. The 2014 team added a spoiler in the front of the vehicle that served 3 main purposes: to improve aerodynamics, to reduce the amount of mud and water to splash up into the cabin, and to have additional space for sponsorships to be placed. (5) Though this design caused improvement, there were some flaws to it too: it reduced the drivers viewing area, gained the potential for water, mud, and debris to slide up and fling back onto the driver, and was visually unappealing.

In 2016, the Bearcat Baja team fully designed and built their Baja vehicle accounting for improving a few ergonomic aspects. The 2016 team eliminated the front spoiler, changed the seat to be a form fitting bucket style seat, and added a cushioned headrest. (5) Though they designed the vehicle with better ergonomics than 2014, there were some flaws to it too: the bucket chair is a hard surface with no cushion at all, the headrest has no neck support for side-to-side movement of the head, and the front open end gives a visually unappealing look.

In 2019, the Bearcat Baja team fully designed and built their Baja vehicle accounting for a few more ergonomic improvements. The 2019 team improved the ergonomics of the vehicle by increasing the visual appeal of the vehicle and the increasing the functionality of the vehicle. They added additional paneling to the front of the vehicle, changed the rims to an aggressive and more appealing rim, added designs to the paneling, and added a light bar for night driving. (5) There are a few cons of the ergonomic design of this vehicle: there is not much room for sponsors, the bucket seat has no padding, and there is no headrest.

END USER

The end user for the 2021 Bearcat Baja senior design is the drivers of the Baja vehicle. This will include the drivers using the Baja vehicle for the SAE Baja competition and the drivers that will be purchasing the Baja vehicle from the fictitious company for recreational use. Safety will be the biggest priority in our design while also designing the Baja vehicle to be reliable, ergonomic, durable, and have exceptional off-road capabilities.

The vehicle will be designed with a specific customer in mind. This customer is a fictitious company that plans on purchasing 4,000 units per year and will sell directly to their own customers. (1) The design of the vehicle must be able to facilitate this production quantity. People buying the vehicle from the fictitious company would be purchasing it for recreational use. These users would be mostly concerned with the overall performance of the vehicle. The speed, agility and comfort would all be areas prioritized by these users. Since the motor we will be using is not exceptionally powerful it is likely the people purchasing it from the fictitious company would be less experienced drivers looking for a less powerful and more user-friendly vehicle. The user buying a vehicle from the fictitious company could be anyone so the vehicle will need to accommodate as many people as possible.

CONCLUSIONS AND SUMMARY OF RESEARCH

Based upon the background research developed, the largest problems that need to be addressed regarding ergonomics is driver comfort, visual appeal, nighttime driving accessories, and mud/water intrusion into the cabin. The current technology does not address end users that will be driving the vehicle in nighttime conditions well enough. There are improvements that can be made to this year's Bearcat Baja team design to better address the end user's wants and needs with ergonomics.

QUALITY FUNCTION DEPLOYMENT

We sent out two surveys and received over 130 responses. The first survey was sent to people with general knowledge of off-road vehicles or SAE BAJA and asked the participant to rate potential features of an off-road vehicle. The second survey was sent to people that have knowledge specific to SAE BAJA and were asked to rate features of current BAJA cars. Based on the results of the surveys we determined features that potential customers feel are most important to an off-road vehicle. We then identified the metrics we can use to measure and quantify how well our vehicle meets the needs of customers.

Survey Samples:

Survey 1
Thank you for participating! We are designing and building an off-road vehicle as part of the SAE BAJA competition. The car we build will be driven in a competition with other teams from around the world. We are using this survey to help us decide what aspects of the car a user thinks should have the most attention. If you are not familiar with a BAJA car just imagine a four wheeled off-road vehicle with an enclosed driver compartment like a side by side or a pimped out, off-road golf cart.
For the following questions please rate their importance assuming you were looking to purchase an off-road vehicle (5 being highest importance, 1 being lowest importance)

- BASELINE - How familiar are you with SAE BAJA or other off-road vehicles as a concept?
- Safety
- Top Speed/Acceleration
- Hill Climbing
- Maneuverability
- Suspension and Traction
- Head room
- Leg room
- Cost
- Reliability
- Four Wheel Drive Capabilities
- Aesthetics
- Adjustable gas and brake pedals

- Multiple gears/Reverse
- Low maintenance
- Padded seat
- Display Gauges (fuel, speedometer, temperature)
- Lights (for night driving)
- Small turn radius
- Low effort to turn steering wheel
- Steering tightness
- Ride smoothness
- Wind/mud shield
- How did you find this survey?

Survey 2
Thank you for participating! We are designing and building an off-road vehicle as part of the SAE BAJA competition. The car we build will be driven in a competition with other teams from around the world. We are using this survey to help us decide what aspects of the car a user thinks should have the most attention.
- BASELINE - How familiar are you with SAE BAJA or other off-road vehicles as a concept? (1 being know nothing, 5 being know everything)

For the following question please rank your satisfaction with current off-road or BAJA vehicles with "1" being not at all satisfied and "5" being fully satisfied

- Safety
- Reliability
- Hill Climbing
- Ride Smoothness
- Maneuverability
- Cost
- Lights / ability to drive at night
- Turn Radius
- Steering Tightness
- How did you find this survey?

CUSTOMER FEATURES

- Meets Safety Requirements
- Maintains a High Level of Reliability
- Climbs Steep Grade
- Maintains a High Level of Reliability
- Maneuvers Easily
- Is Cost Efficient
- Illuminates Path
- Turns with Small Radius
- Steers Tightly
- Cushions Driver

ENGINEERING CHARACTERISTICS

- Frame Strength (kPa)
- Distance Driven (km)
- Angle of Inclination (degrees)
- Suspension Travel (cm)
- Suspension Spring Stiffness (N/m)
- Price (USD)
- Lumen Distance (Lumens)
- Turn Radius (m)
- Steering Wheel Play (mm)
- Cushion Firmness (N)

HOUSE OF QUALITY

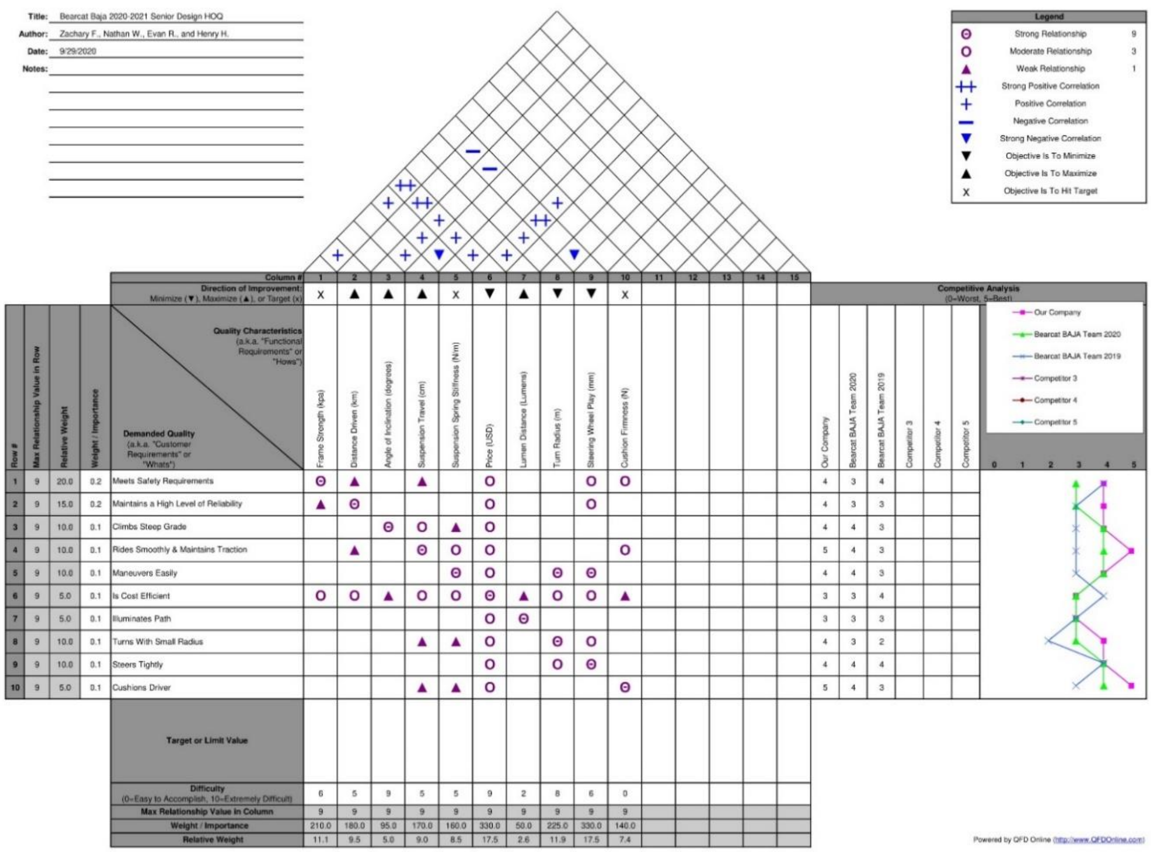


Figure 1. House of Quality

Product Objectives

-Meets Safety Requirements (20%)
- Meet and exceed rules from the SAE Baja 2020 and 2021 rule booklet.

-Maintains a High Level of Reliability (15%)
- Will focus on the quality of parts purchased and manufactured.

-Climbs Steep Grade (10%)
- Ensure a low center of gravity, have good traction, and have high suspension travel.

-Maneuvers Easily (10%)
- Small turn radius, tightness in steering system

-Is Cost Efficient (5%)
- Will make as many parts as possible using the resources at the Victory Parkway Campus.

-Illuminates Path (5%)
- Light bars will be installed to illuminate in front of the vehicle to help guide the operator and to make the vehicle visible to others.

-Turns with Small Radius (10%)
- Shorter wheelbase and higher degree of wheel rotation.

-Steers Tightly (10%)
- Will ensure bushings and tie rod ends are good quality and that the knuckles will be within a tight tolerance.

-Cushions Driver (5%)
- A cushion will be placed on the driver's seat to maximize comfort.

DESIGN

DESIGN ALTERNATIVES AND SELECTION

Concept 1:

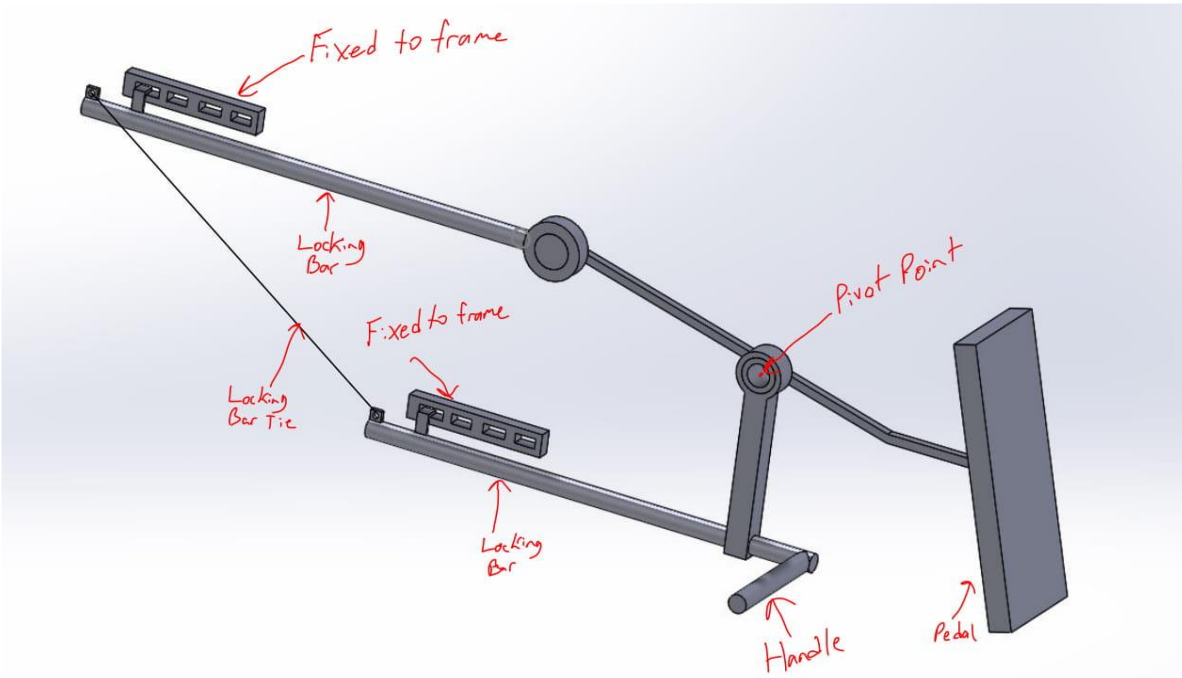


Figure 2. Concept 1

Concept 1 shows an adjustable pedal with suspended mounting. The user rotates the handle thus rotating the locking bar with the handle. This rotational movement then rotates the other locking bar via the locking bar tie. As the 2 locking bars rotate, the tang on each locking bar disengages with the opening of the fixed to frame parts. Once the locking bar tangs are disengaged, the user can pull the pedals closer or push the pedals further away. When the user lets go of the handle, a spring will lock the tangs back into the openings from the fixed to frame parts.

Concept 1 is about the same cost efficiency as concept 2 but is less cost efficient that concept 3. There are more components that could potentially fail compared to concept 3 so from a safety standpoint concept 3 is safer and more reliable.

Concept 2:

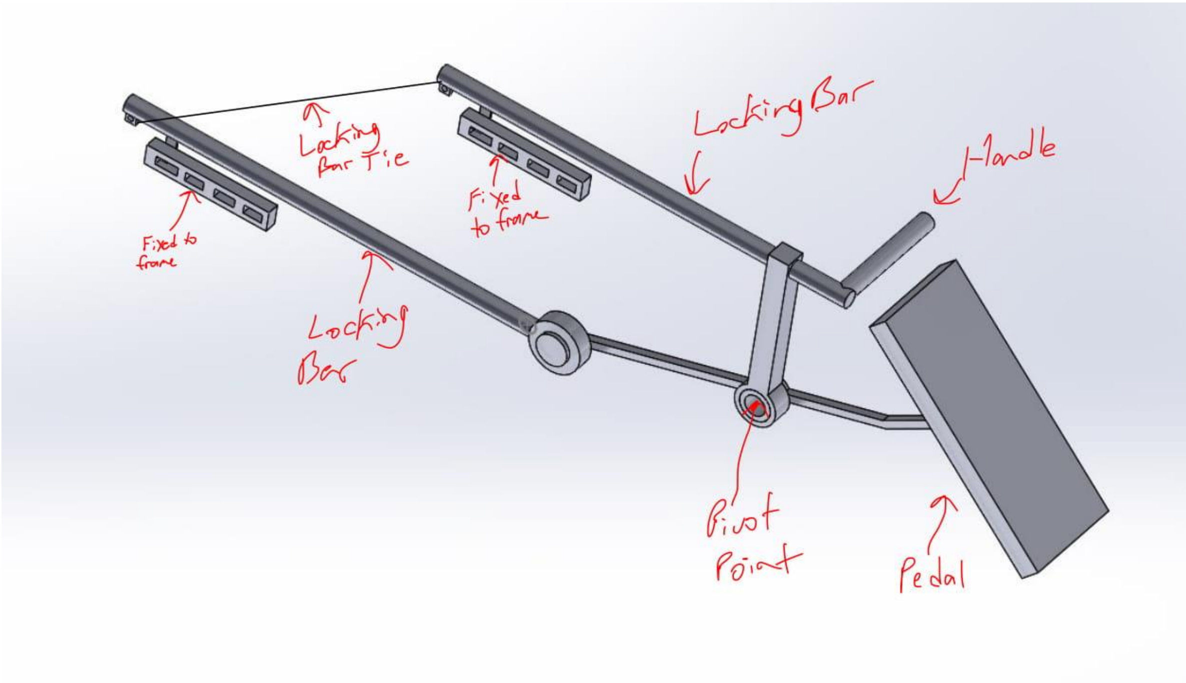


Figure 3. Concept 2

Concept 2 shows an adjustable pedal with floor mounting. The user rotates the handle thus rotating the locking bar with the handle. This rotational movement then rotates the other locking bar via the locking bar tie. As the 2 locking bars rotate, the tang on each locking bar disengages with the opening of the fixed to frame parts. Once the locking bar tangs are disengaged, the user can pull the pedals closer or push the pedals further away. When the user lets go of the handle, a spring will lock the tangs back into the openings from the fixed to frame parts.

Concept 2 is about the same cost efficiency as concept 1 but is less cost efficient that concept 3. There are more components that could potentially fail compared to concept 3 so from a safety standpoint concept 3 is safer and more reliable.

Concept 3:

Figure 4. Concept 3

Concept 3 shows an adjustable bucket seat. The user rotates the handle thus rotating the locking bar with the handle. This rotational movement then rotates the other locking bar via the locking bar tie. As the 2 locking bars rotate, the tang on each locking bar disengages with the opening of the fixed to frame parts. Once the locking bar tangs are disengaged, the user can pull the seat closer or push the seat further away. When the user lets go of the handle, a spring will lock the tangs back into the openings from the fixed to frame parts.

Concept 3 is more cost efficient than concept 1 and concept 2. There are less components that could potentially fail compared to concept 1 and concept 2 so from a safety standpoint concept 3 is safer and more reliable. The mechanism that controls concept 3 has been used for most vehicles thus it is a tried and proven design with little safety risk.

ENGINEERING CALCULATIONS

List of equations

$$\Sigma F_{\boldsymbol{x}} = \mathbf{0}$$

$$\Sigma M_{\boldsymbol{F1}} = \mathbf{0}$$

$$\boldsymbol{Max\ Braking\ Force} = \mathbf{2000}\ \boldsymbol{N}\ (\mathbf{450}\ \boldsymbol{lbf})$$

Loading Conditions

$$\boldsymbol{Max\ Braking\ Force} = \mathbf{2000}\ \boldsymbol{N}\ (\mathbf{450}\ \boldsymbol{lbf})\ \textbf{(FSAE Rule T7.1.8)}$$

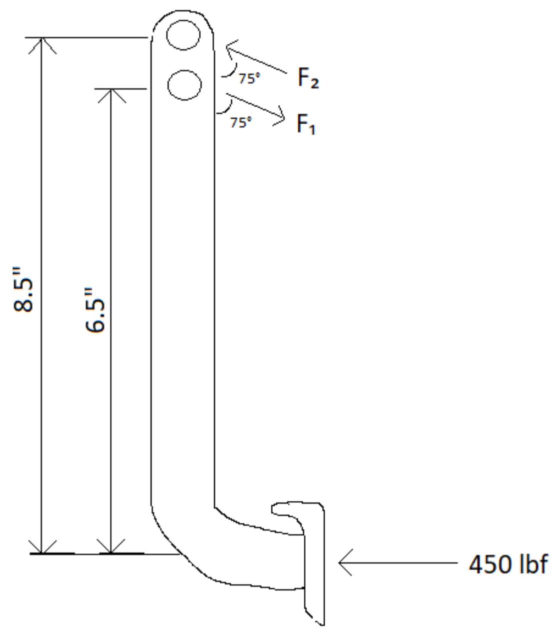


Figure 5. Brake Pedal FBD

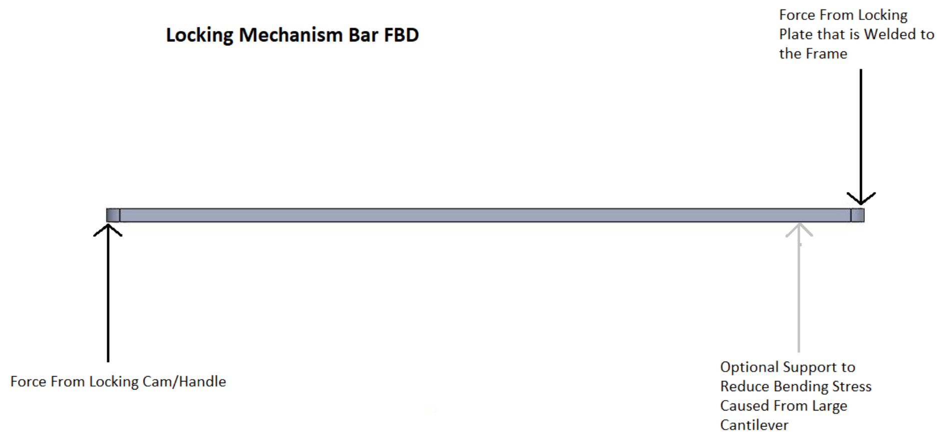


Figure 6. Locking Bar FBD

Force Calculations

$$\boldsymbol{Max\ Braking\ Force = 2000\ N\ (450\ lbf)}$$

$$\Sigma F_x = \mathbf{0} = -\mathbf{450}\ \boldsymbol{lbf} + \boldsymbol{F_1}\ \boldsymbol{sin}(\mathbf{75}) - \boldsymbol{F_2}\ \boldsymbol{sin}(\mathbf{75})$$

$$\Sigma F_y = \mathbf{0} = \boldsymbol{F_2}\ \boldsymbol{sin}(\mathbf{75}) - \boldsymbol{F_1}\ \boldsymbol{sin}(\mathbf{75})$$

$$\Sigma M_{F1} = \mathbf{0} = \boldsymbol{F_2} * \mathbf{2}\ \boldsymbol{sin}(\mathbf{75}) - \mathbf{450}\ \boldsymbol{lbf} * \mathbf{8.5}''\ \boldsymbol{sin}(\mathbf{75})$$

$$F_2 = \mathbf{1913}\ \boldsymbol{lbf}$$

$$F_1 = -\mathbf{1447}\ \boldsymbol{lbf}$$

$$\boldsymbol{Force\ Transmitted\ to\ Each\ Locking\ Bar} = \frac{\boldsymbol{F_1}}{\mathbf{2}} = \frac{\mathbf{1447}\ \boldsymbol{lbf}}{\mathbf{2}} = \mathbf{723}\ \boldsymbol{lbf}$$

Stress Calculations

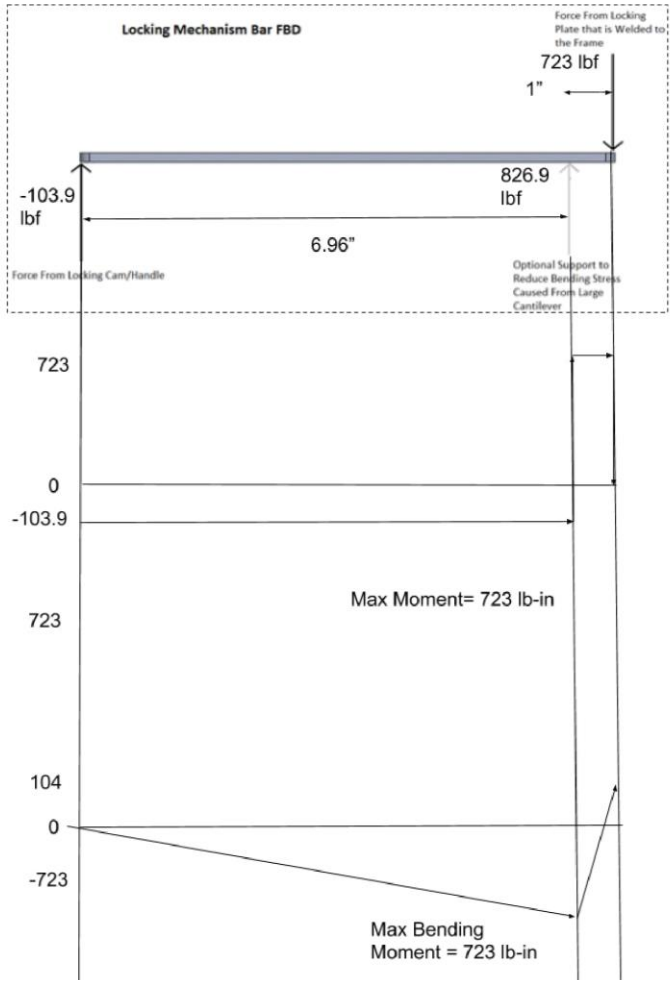


Figure 7. Locking Bar Bending Moment Diagram

$$\Sigma F_y = 0 = F_1 + F_2 - 723\ lbf$$

$$\Sigma M_{F1} = 0 = F_2(6.96") - 723\ lbf(7.96")$$

$$F_2 = 827\ lbf$$

$$F_1 = -104\ lbf$$

$$\sigma_{bending} = \frac{M_{max\ bend}}{I} = \frac{723\ lb-in}{0.021 in^4} = 3.4 \times 10^4\ psi$$

$$N = 2$$

$$Ultimate\ Strength = N \times \sigma_{bending} = 2 \times (3.4 \times 10^4\ psi) = 6.8 \times 10^4\ psi = 68\ ksi$$

$$Steel\ Alloy\ 1040\ Yield\ Strength = 71\ ksi$$

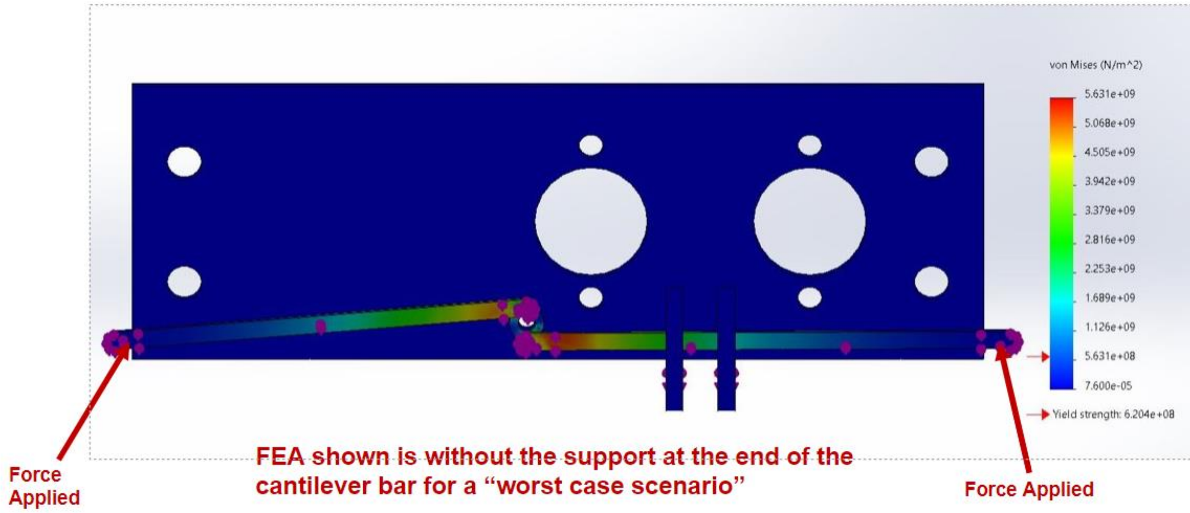


Figure 8. Locking Bar FEA

Factors of Safety

Chose a factor of safety of 2 because the application is for use with reliable materials where loading and environmental conditions are not severe. (6)

Material Selection

Material selected to be Steel Alloy 1040 Cold Rolled which has a tensile yield strength of 71 ksi. This material was chosen because it is sufficient for the max bending stress of 68 ksi.

MANUFACTURING DRAWINGS

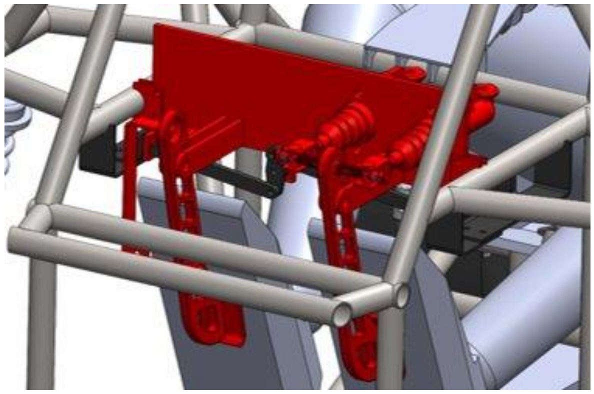


Figure 9. Adjustable Pedal Assembly on Frame

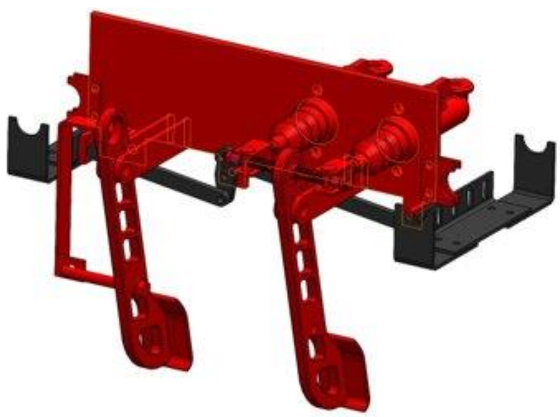


Figure 10. Adjustable Pedal Assembly Isolated

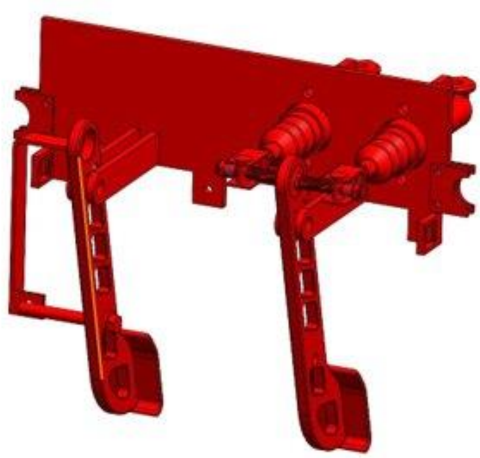


Figure 11. Pedal Plate Assembly Isolated

Figure 12. Locking Mechanism Isolated

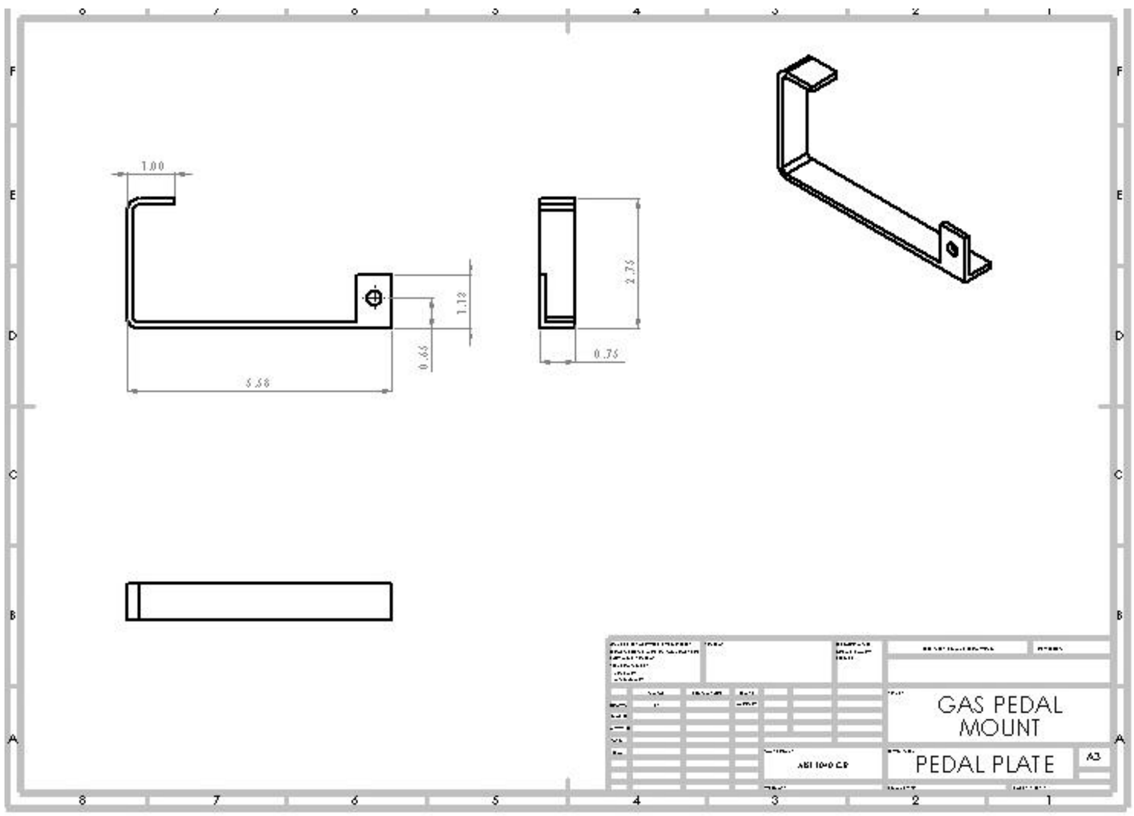


Figure 13. Throttle Cable Mount Drawing

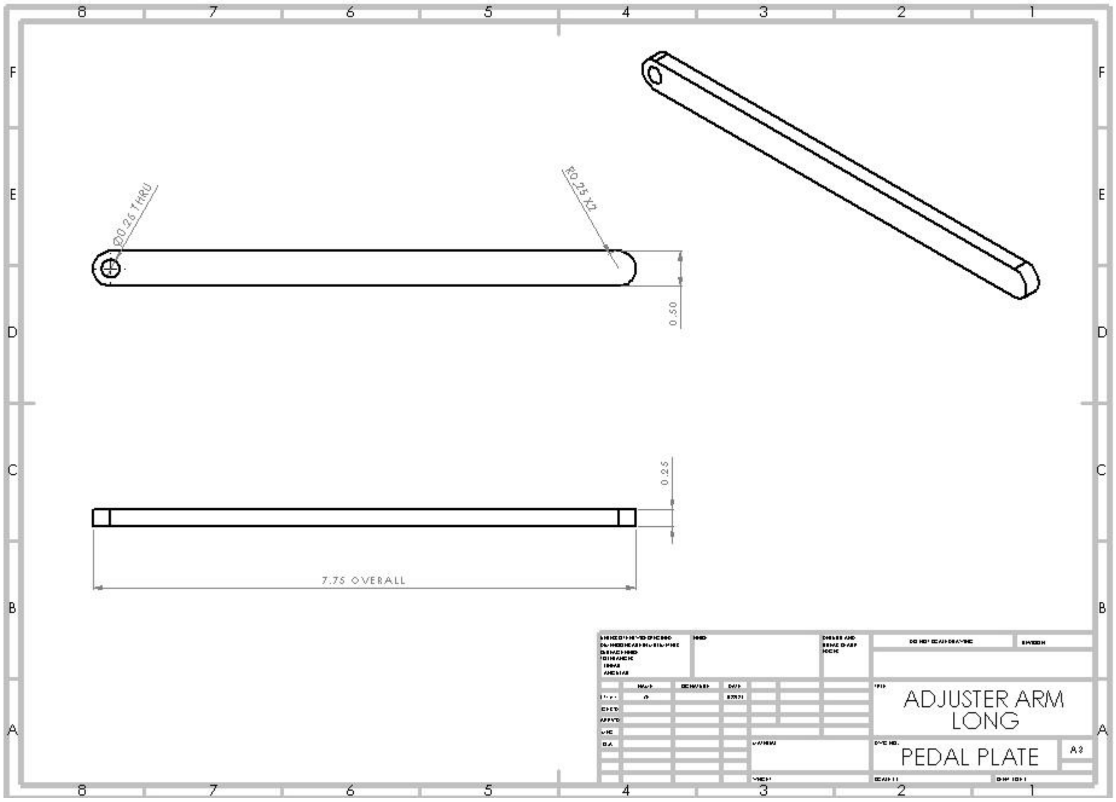


Figure 14. Long Adjuster Bar Drawing

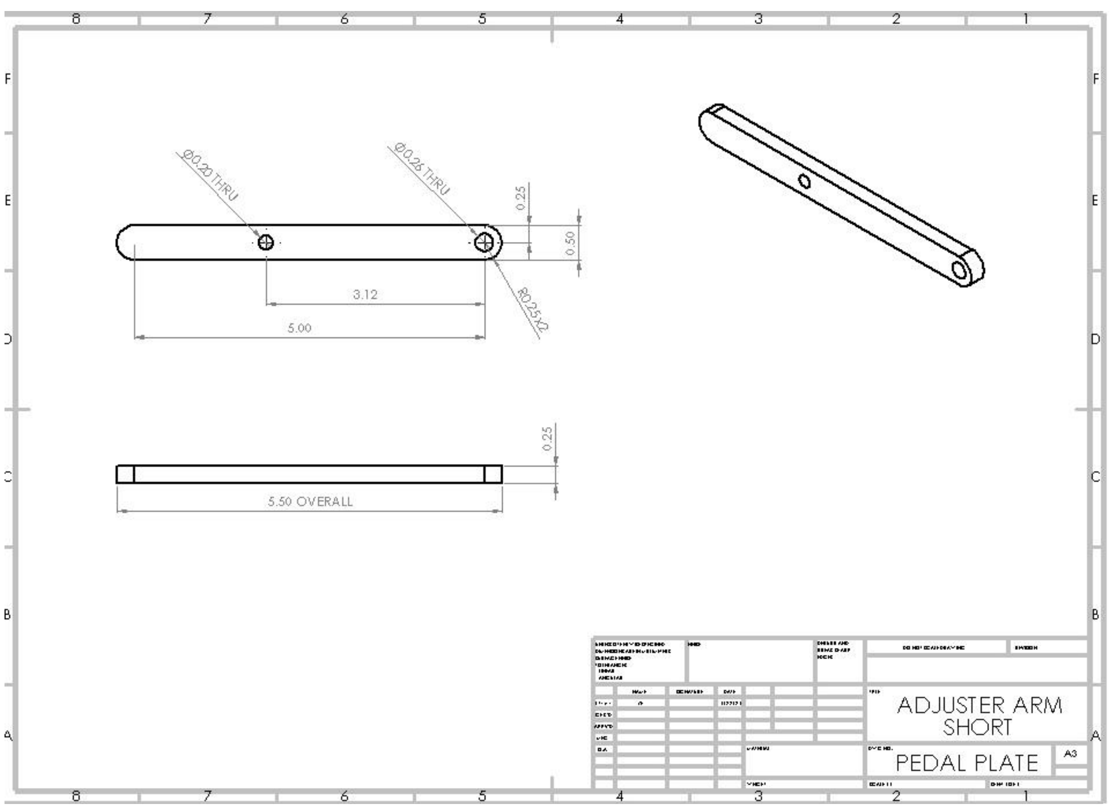


Figure 15. Short Adjuster Bar Drawing

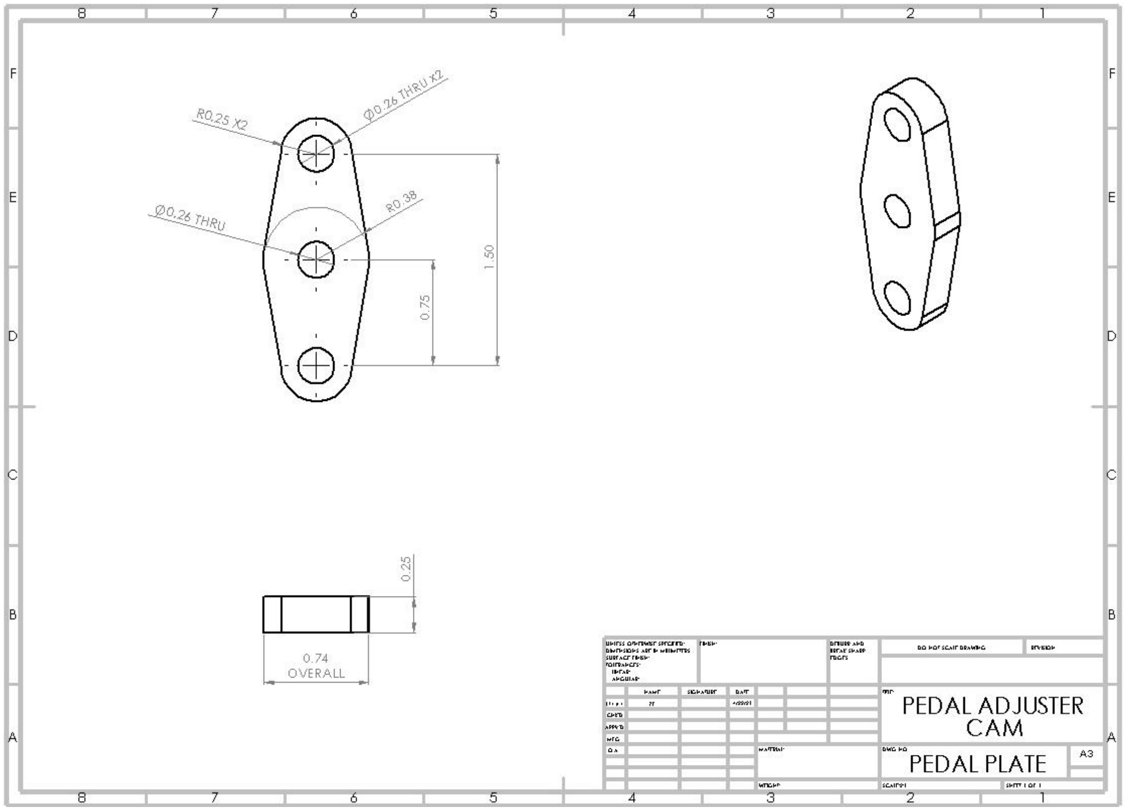


Figure 16. Pedal Adjuster CAM Drawing

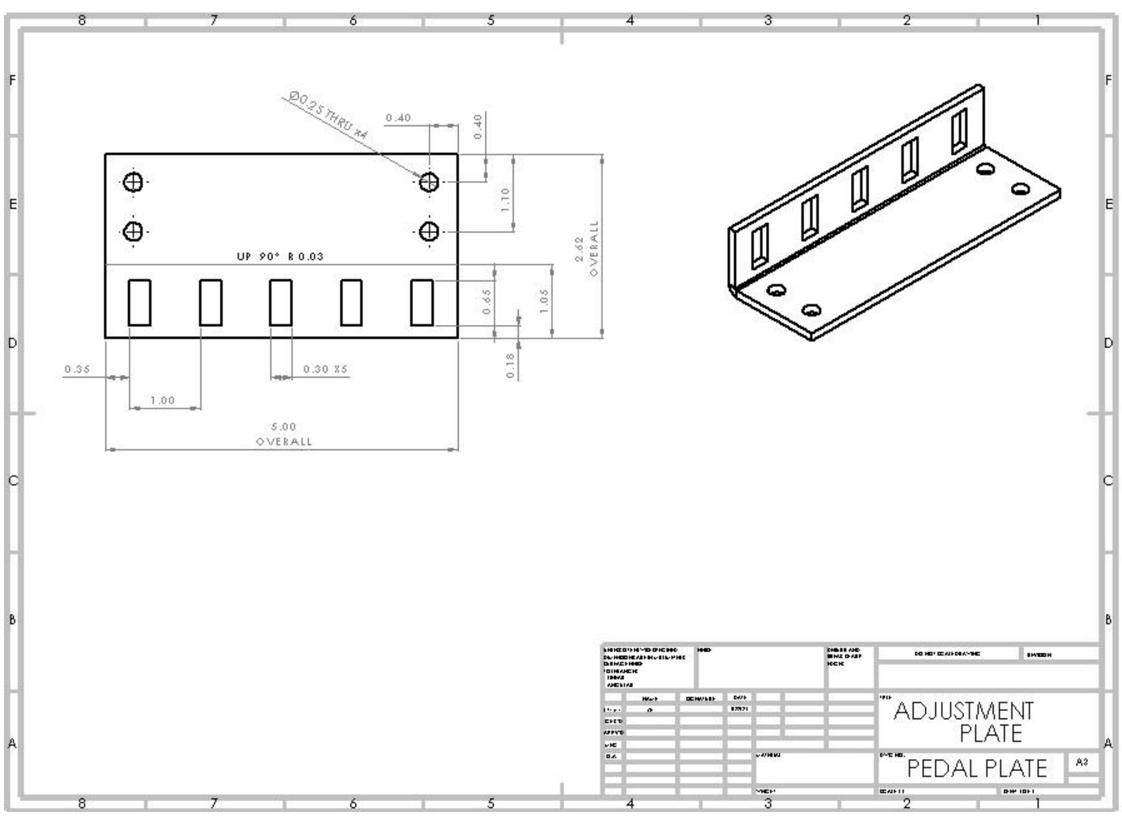


Figure 17. Adjustment Plate Drawing

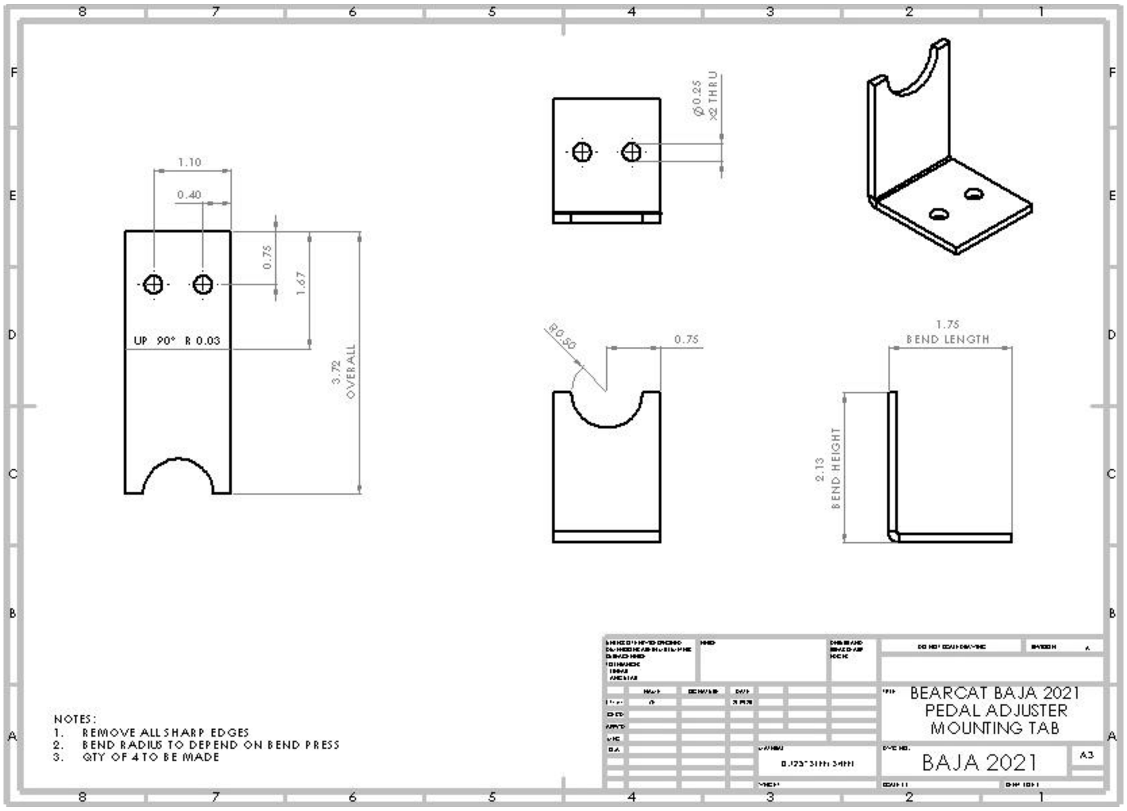


Figure 18. Adjuster Plate Mounting Tab Drawing

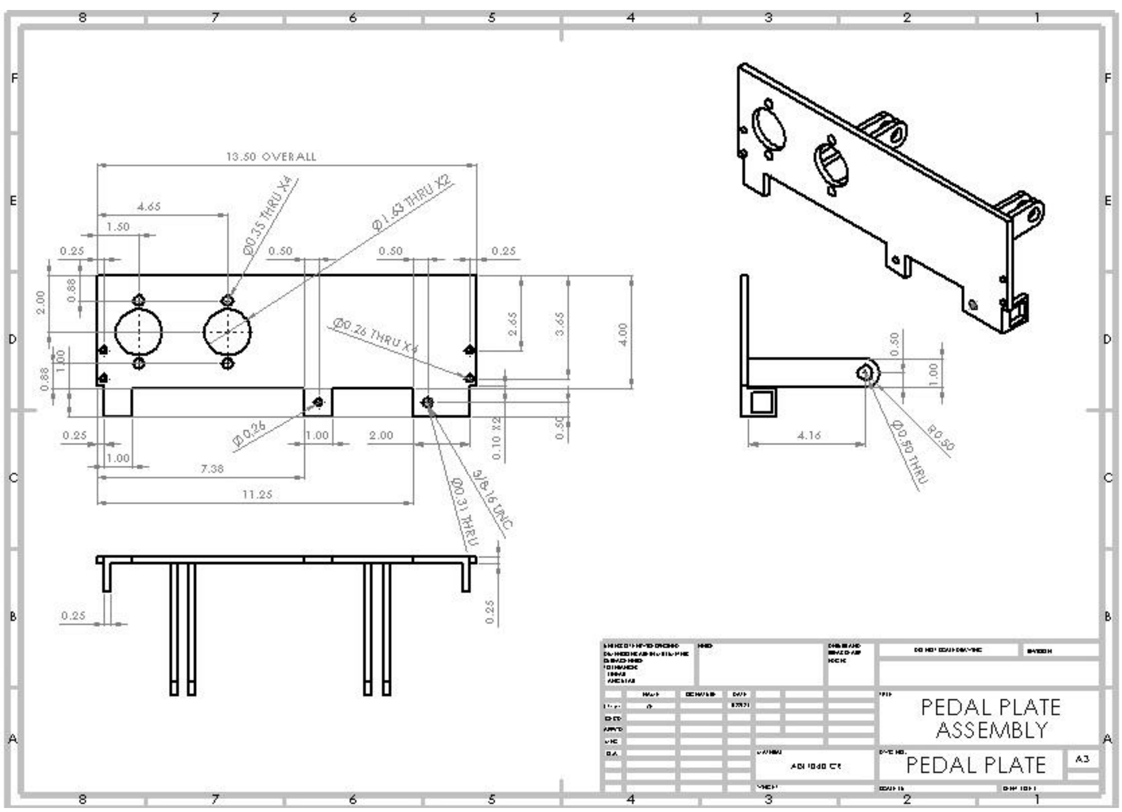


Figure 19. Pedal Plate Assembly Drawing

BILL OF MATERIAL

Adjustable Pedal Assembly BOM

System	Item	Qty. Req.	Unit Price	Total Price	Vendor	Part#	Link
Pedal Asm	Knob Spring Pin Plunger	1	$ 14.97	$ 14.97	McMaster Carr	84935A39	https://www.mcmaster.com/84935A39-84935A29/
Pedal Asm	M6x25 HHCS	10	$ 0.25	$ 2.50	Home Depot	N/a	www.homedepot.com
Pedal Asm	M6 Hex Nut	10	$ 0.15	$ 1.50	Home Depot	N/a	www.homedepot.com
Pedal Asm	M6 Washer	10	$ 0.17	$ 1.70	Home Depot	N/a	www.homedepot.com
Pedal Asm	M8x25 HHCS	10	$ 0.27	$ 2.70	Home Depot	N/a	www.homedepot.com
Pedal Asm	M8 Hex Nut	10	$ 0.17	$ 1.70	Home Depot	N/a	www.homedepot.com
Pedal Asm	M8 Washer	10	$ 0.19	$ 1.90	Home Depot	N/a	www.homedepot.com
Pedal Asm	15" Black Nylon Zip Ties Pk 100	1	$ 21.94	$ 21.94	Grainger	36J166	https://www.grainger.com/product/POWER-FIRST-Cable-Tie-36J166
Pedal Asm	Iron Handle Nut	1	$ 3.80	$ 3.80	McMaster Carr	91044A119	https://www.mcmaster.com/91044A119/
Pedal Asm	Universal 70" Throttle Cable	1	$ 12.27	$ 12.27	Amazon/FixRightPro	N/a	[illegible]
Pedal Asm	1/8" AISI HR 1020 Steel	1	$ 50.00	$ 50.00	Bearcat Baja	N/a	N/a
Pedal Asm	1/4" AISI CR 1040 Steel	1	$ 75.00	$ 75.00	Bearcat Baja	N/a	N/a
Pedal Asm	Polaris Brake Caliper	4	$ 64.99	$ 259.96	Bearcat Baja	N/a	N/a
Pedal Asm	Polaris Rear Brake Rotor	2	$ 49.99	$ 99.98	Bearcat Baja	N/a	N/a
Pedal Asm	Polaris Front Brake Rotor	2	$ 49.99	$ 99.98	Bearcat Baja	N/a	N/a
Pedal Asm	Brake Master Cylinder	2	$ 69.99	$ 139.98	Bearcat Baja	N/a	N/a
Pedal Asm	Flexible Brake Line- 1ft	10	$ 6.18	$ 61.80	Bearcat Baja	N/a	N/a
Pedal Asm	Metal Brake Line- 1ft	10	$ 5.99	$ 59.90	Bearcat Baja	N/a	N/a
Pedal Asm	Biasing Bar	1	$ 9.95	$ 9.95	Bearcat Baja	N/a	N/a
Pedal Asm	Brake Pedal	1	$ 34.99	$ 34.99	Bearcat Baja	N/a	N/a
Pedal Asm	Gas Pedal	1	$ 34.99	$ 34.99	Bearcat Baja	N/a	N/a
		Total Cost:		**$ 991.51**			
		Savings From Recycling:		**$ 926.53**			
		Actual Cost:		**$ 64.98**			

BUILD AND TEST

DISCUSSION OF THE MANUFACTURING PROCESSES UTILIZED

All custom components were cut using a plasma cutter and either ¼” steel or 1/8” steel. Once the steel was cut from the plasma cutter, the slag was taken off and edges smoothed using an angle grinder and followed up with a pneumatic sanding disc. All finished parts were then marked and put into position using 90° welding magnets. Once positioned, the parts were then welded using a MIG welder. After welding, the pedal plate was smoothed using an angle grinder and sanding disc. The locking plate was bolted to the locking mount. The locking mount was fully welded to the frame using a MIG welder.






TEST PROCEDURE AND CRITERIA

There were 4 tests performed for design validation. First, a functionality test was performed on the locking mechanism. Second, a functionality test was performed on the slide function. Third, a functionality test was performed on the brake system. Lastly, a structural test was performed on the brake pedal.

The fourth and final test, the brake structural test, was performed replicating the Formula SAE test requirements for the FSAE technical expo. The test consists of multiple panic brake operations by applying as much force to the brake pedal as possible. Once multiple panic brake operations were performed, then a visual inspection of the adjustable pedal assembly was performed to inspect for bent, fractured, or broken components within the adjustable pedal assembly.

Customer needs relevant to the adjustable pedal assembly were:

1. Safe
2. High reliability
3. Cost efficient
4. Comfortable for the driver

The product objectives relevant to the adjustable pedal assembly were:

1. Meet or exceed safety requirements from SAE Baja 2021 rule booklet
2. Focus on the quality of parts purchased and manufactured
3. Recycle as many parts as possible
4. Fit different sized drivers

Based on the quality function deployment (qfd) as summarized above, the first test corresponded with the qfd items 1, 2, and 4. The second test corresponded with the qfd items 2 and 4. The third test corresponded with the qfd items 1 and 2. The last test corresponded with the qfd items 1, 2, and 4.

TEST RESULTS AND FINDINGS

The first test to test the functionality of the locking mechanism passed with some additional findings. Overall, the test passed, and the locking feature worked. It was found that it requires 2 hands to properly align the locking mechanism with the locking plates and the closest position fits our shortest team member who is 5’4” while the last position allow for a more comfortable fit for most other team members with an average height of 6’0”. The first test showed that the locking mechanism could be improved through larger locking plate notches and a less strong spring pull locking pin.

The second test to test the functionality of the slide function passed with some additional findings. Overall, the test passed, and the sliding feature worked. It was found that as the assembly is slid back and forth, it tends to bind up if not kept aligned. The second test found that the slide function could be improved through an off shelf linear slide product such as drawer slides. This would keep the assembly aligned and easy to slide back and forth without binding.

The third test to test the functionality of the brake system passed. All brake lines and fittings were inspected for leaks and each wheel was independently spun and locked through the brake pedal. There were no findings during this test as everything operated as expected. This test showed that the brake system will be safe and reliable when being used for the SAE Baja competition.

The fourth test to test the structural integrity of the adjustable pedal assembly passed.

Multiple panic stop operations were performed while the vehicle was on the ground and all adjustable pedal assembly components remained the same without any form of deformation or fracturing. Like the third test, this test showed that the brake system will be safe and reliable when being used for the SAE Baja competition.

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Total Ergonomics Proposed Budget: $750
Total Ergonomics Actual Budget: $669.42

Table 1. Total Ergonomics Actual Budget

Baja 2021 Ergonomics Actual Budget

System	Item	Qty. Req.	Unit Price	Total Price	Vendor
Pedal Asm	Adjustable Pedal Assembly	1	$ 64.98	$ 64.98	N/a
Ergonomics	Fire Extinguisher	1	$ 17.44	$ 17.44	Kiddle
Ergonomics	Fire Extinguisher Mount	1	$ 9.00	$ 9.00	ULINE
Ergonomics	Cushion for Seat	1	$ 78.00	$ 78.00	Purple
Ergonomics	Powder Coating	1	$ 350.00	$ 350.00	Powderwerx
Ergonomics	LED Light Bar	1	$ 75.00	$ 75.00	Superbrightledlights
Ergonomics	LED Lights	1	$ 13.59	$ 13.59	Smraza Basics
Ergonomics	Vinyl Prints	1	$ 150.00	$ 150.00	Alwanwraps
		Total Cost:		**$ 758.01**	
		Savings From Recycling:		**$ 88.59**	
		Actual Cost:		**$ 669.42**	

Total Adjustable Pedal Assembly Proposed Budget: $100
Total Adjustable Pedal Assembly Actual Budget: $64.98

Table 2. Total Adjustable Pedal Assembly Actual Budget

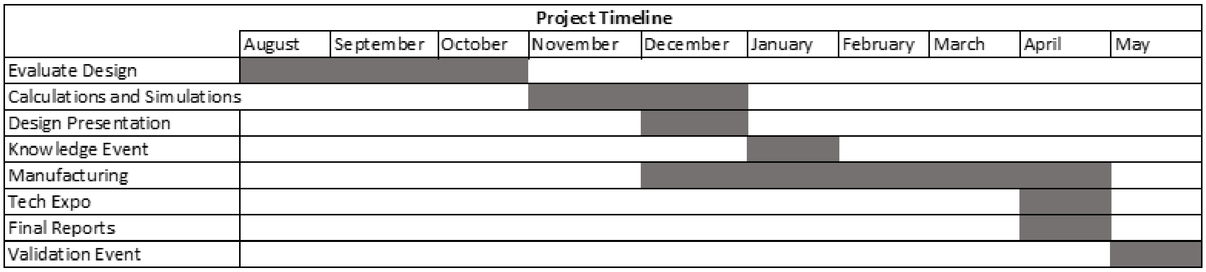
Baja 2021 Adjustable Pedal Assembly Actual Budget

System	Item	Qty. Req.	Unit Price	Total Price	Vendor	Part#	Link
Pedal Asm	Knob Spring Pin Plunger	1	$ 14.97	$ 14.97	McMaster Carr	84935A39	https://www.mcmaster.com/84935A39-84935A29/
Pedal Asm	M6x25 HHCS	10	$ 0.25	$ 2.50	Home Depot	N/a	www.homedepot.com
Pedal Asm	M6 Hex Nut	10	$ 0.15	$ 1.50	Home Depot	N/a	www.homedepot.com
Pedal Asm	M6 Washer	10	$ 0.17	$ 1.70	Home Depot	N/a	www.homedepot.com
Pedal Asm	M8x25 HHCS	10	$ 0.27	$ 2.70	Home Depot	N/a	www.homedepot.com
Pedal Asm	M8 Hex Nut	10	$ 0.17	$ 1.70	Home Depot	N/a	www.homedepot.com
Pedal Asm	M8 Washer	10	$ 0.19	$ 1.90	Home Depot	N/a	www.homedepot.com
Pedal Asm	15" Black Nylon Zip Ties Pk 100	1	$ 21.94	$ 21.94	Grainger	36J166	https://www.grainger.com/product/POWER-FIRST-Cable-Tie-36J166
Pedal Asm	Iron Handle Nut	1	$ 3.80	$ 3.80	McMaster Carr	91044A119	https://www.mcmaster.com/91044A119/
Pedal Asm	Universal 70" Throttle Cable	1	$ 12.27	$ 12.27	Amazon/FixRightPro	N/a	[illegible]
Pedal Asm	1/8" AISI HR 1020 Steel	1	$ 50.00	$ 50.00	Bearcat Baja	N/a	N/a
Pedal Asm	1/4" AISI CR 1040 Steel	1	$ 75.00	$ 75.00	Bearcat Baja	N/a	N/a
Pedal Asm	Polaris Brake Caliper	4	$ 64.99	$ 259.96	Bearcat Baja	N/a	N/a
Pedal Asm	Polaris Rear Brake Rotor	2	$ 49.99	$ 99.98	Bearcat Baja	N/a	N/a
Pedal Asm	Polaris Front Brake Rotor	2	$ 49.99	$ 99.98	Bearcat Baja	N/a	N/a
Pedal Asm	Brake Master Cylinder	2	$ 69.99	$ 139.98	Bearcat Baja	N/a	N/a
Pedal Asm	Flexible Brake Line- 1ft	10	$ 6.18	$ 61.80	Bearcat Baja	N/a	N/a
Pedal Asm	Metal Brake Line- 1ft	10	$ 5.99	$ 59.90	Bearcat Baja	N/a	N/a
Pedal Asm	Biasing Bar	1	$ 9.95	$ 9.95	Bearcat Baja	N/a	N/a
Pedal Asm	Brake Pedal	1	$ 34.99	$ 34.99	Bearcat Baja	N/a	N/a
Pedal Asm	Gas Pedal	1	$ 34.99	$ 34.99	Bearcat Baja	N/a	N/a
		Total Cost:		**$ 991.51**			
		Savings From Recycling:		**$ 926.53**			
		Actual Cost:		**$ 64.98**			

SCHEDULE, PROPOSED /ACTUAL

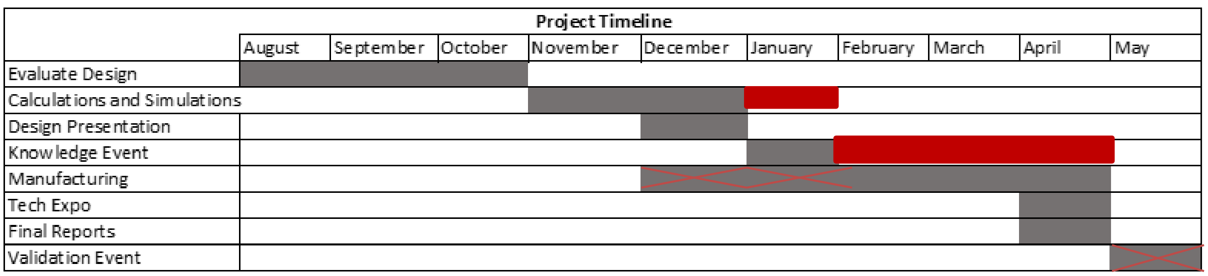
Proposed Schedule:

Table 3. Proposed Schedule



Actual Schedule:

Table 4. Actual Schedule



The actual schedule differed slightly from the proposed schedule in the calculations/simulations, knowledge event, manufacturing, and the validation event. The calculations and simulations had some design changes that took place in January that was not reflected in the proposed schedule. Due to Covid-19 restrictions enforced by the University of Cincinnati, there was a period in December and January that we were unable to access the Victory Parkway lab to perform manufacturing on the Baja vehicle. Also due to Covid-19 travel restrictions enforced by the University of Cincinnati, Bearcat Baja was unable to attend the in-person validation event scheduled for May 2021.

SUSTAINABILITY AND MATERIAL USAGE

All material was recycled from existing ¼" and 1/8" steel. For future projects, I would suggest using as much recycled material and parts as possible to reduce the cost. Bearcat Baja has a bin full of spare brake components that includes expensive parts such as master cylinders, master cylinder reservoirs, brake lines, brake pedals, brake line fittings, brake calipers, and brake rotors. These spare parts can be used to replace components on the 2021 adjustable pedal assembly when needed.

CONCLUSIONS

The problem definition is to design and build an off-road vehicle that will survive the severe punishment of rough terrain and in some competitions, water. The 2021 Bearcat Baja vehicle succeeded to reduce weight compared to the 2019 Bearcat Baja vehicle. The results from the quality function deployment provided four product objectives that are relevant to the ergonomics and adjustable pedal assembly: meet and exceed safety requirements from SAE Baja 2021 rule booklet, focus on quality of parts purchased and manufactured, use recycled parts and materials where possible, fit different sized drivers. All four of these product objectives were met or exceeded expectations. There were four tests performed to validate the design: locking mechanism functionality test, slide functionality test, brake system functionality test, structural test. The test results showed that everything was functional and safe however, there is an opportunity to improve the design using off-shelf linear slides and increasing the locking plate notch sizes. This change will only improve the user friendliness of the design but will not impact the safety of the design. The adjustable pedal assembly project was completed under budget and on-time.

WORKS CITED

1. **SAE International.** Baja SAE Lousiville. *SAE International.* [Online] August 1, 2020. https://www.sae.org/attend/student-events/baja-sae-louisville.
2. **Gardner, Vincent.** *2018 University of Cincinnati SAE Baja.* Cincinnati : University of CIncinnati College of Engineering and Applied Science, 2018.
3. **Wessels, Eric.** *2017 Bearcats Baja SAE – Steering System.* Cincinnati : University of CIncinnati College of Engineering and Applied Science, 2017.
4. **Bendel, Bradley M.** *2020 Bearcat Project Management and Steering.* Cincinnati : University of Cincinnati College of Engineering and Applied Science, 2020.
5. **Biteman, Brooks.** *Baja SAE Frame Design.* Cincinnati : University of Cincinnati College of Engineering and Applied Science, 2013.
6. **Forrest, Jonathon.** *2016 Baja SAE Series Frame Design.* Cincinnati : University of Cincinnati College of Engineering and Applied Science, 2016.
7. **Kelleher, Austin.** *Bearcat Baja Frame/Ergonomics.* Cincinnati : University of Cincinnati-College of Engineering and Applied Science, 2020.
8. **Biteman, Brooks.** *Baja SAE Frame Design.* Cincinnati : University of Cincinnati College of Engineering and Applied Science, 2013.
9. **Forrest, Jonathon.** *2016 Baja SAE® Series Frame Design.* Cincinnati : University of CIncinnati College of Engineering and Applied Science, 2016.

APPENDIX A