

2020 Bearcat Baja Project Management and Steering

A Baccalaureate thesis submitted to the
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University of Cincinnati

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Bachelor of Science

in Mechanical Engineering Technology

by

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Abstract

Seniors in the Mechanical Engineering Technology Program and the Mechanical Engineering Program partake in Baja SAE events throughout the country. Baja SAE is a design competition in which students design, build, and test an all-terrain vehicle capable of speeds up to 40 miles per hour. Several events throughout the United States are hosted each year by SAE, which is the Society of Automotive Engineering. Students use this organization and events as their senior design project and utilize efficient designs and techniques in order create a competitive vehicle. This report explains the current issues the team has, the progress made this year, and the steering assembly details regarding design and fabrication.

Problem Definition and Research

Problem Statement

The University of Cincinnati Bearcat Baja team is designing an entire new baja to be eligible to compete in the competition this year. The new standards and regulations require the vehicle to have 4-wheel drive capabilities. My portion of the car is to work on the steering system and use more advanced methods than years' past.

Background

Baja SAE is a competition in which students design and build an all-terrain vehicle capable of performing multiple tasks. The baja itself is designed with reliability, maintainability, ergonomic intentions, and economic production capabilities (1). The competition involves teams from across the united states. Points are awarded to teams who place high in the varying events. These events include an acceleration challenge, hill climb/traction event, and an endurance event. Strict specifications are also required for each vehicle that the universities enter the competition. If the vehicle is not within the criteria, there is a possibility that it would not be allowed to compete in certain events.

Research

Scope of the Problem

The major issue for the steering is to determine the correct angles used in the Ackermann steering. Based off these angles, the tie rods and steering rack must be placed in a certain way. Steering has a direct impact on the car because it dictates when the car can move horizontally. If the steering calculations and choices are off, the car's wheels will not be able to turn, causing the car to crash. The other issue for the steering is the placement of the steering rack. The car, having to be 4-wheel drive for the 2020 year, adds an additional differential in the front portion of the car. The front differential is in the place of where the steering rack usually is placed. The challenge this year was to place the steering rack in a way that it does not meet the differential but can also maintain the correct distance between the steering rack and the wheels of the car.

Current State of the Art

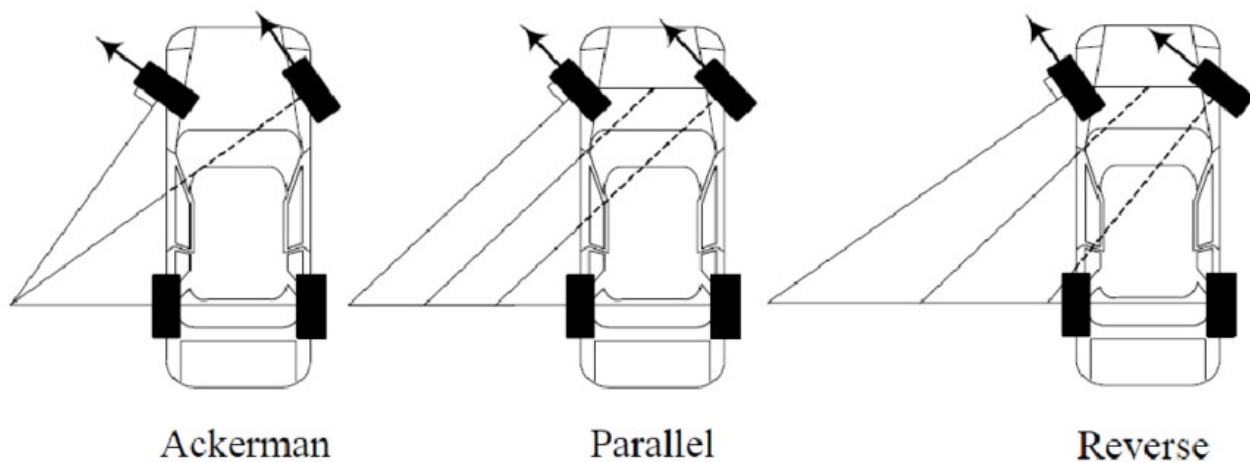


Figure 1 - Ackermann, Parallel, and Reverse Steering Geometry (2)

For low speed steering, the geometry for the Ackermann steering system is ideal. This is because the inner wheel would have a longer turning radius than the other wheel. The wheel would turn more slowly, but sharper. The parallel geometry would be the best for high speed steering. This would make both wheels turn at the same rate (2). If a quick reaction is required when needing to turn, the parallel system can make sure that both tires are turning in the same direction at the same time, preventing malfunctions that may occur while turning.

The current status of the steering system is that it can get the bare minimum job done. The steering column itself is in rough shape. The wheels can only turn so far due to how big the tires are. The previous baja team calculated the most affordable option of the steering rack ratio to be 6.4:1 (3). This is the lowest allowable ratio before the system cannot turn and function properly. This ratio was chosen because it was cheap, and it fit in the budget well. The past baja teams used a 12:1 ratio. The 6.4:1 ratio

makes the driver use more force in order to turn the vehicle (3). A ratio of at least 12:1 will improve the steering design by a great amount.

End User

The end user for the steering mechanism would be the future baja teams, whether they be at the University of Cincinnati or at another baja team at another university. Future teams could look at mine, as well as my teammates research to help them better develop their project. Another end user would be automotive manufacturers. Using the research and data we have and are gathering; they could implement improvement projects.

Conclusions and Summary of Research

Based off research, the type of steering that will be used when updating and repairing the baja will be the parallel style. This is the most balanced steering system and would prove to be highly effective while navigating rough terrain. The current steering mechanism is sub-par at best due to wear and tear as well as lack of maintenance. A steering rack mechanism with a minimum ratio of 12:1 will be used. This will let the driver use less effort when steering and allow them to use their energy to focus on the track in front of them. A combination of a 12:1 steering ratio and a parallel steering system will be the most efficient combination to maximize the baja's ability.

Customer Features

Steering Angle – The angle at which the wheels turn based on the input of the driver steering the car. The car was designed so that the driver gives as little effort as possible on the steering wheel, but the car's rotation was significant.

Durability – How long the steering wheel can last before breaking or needing a new component. The steering contained a variety of components, most of which were new. The steering rack used was taken from an old car that was used for spare parts. The steering rack is also the only component that may need replaced within a few years.

Comfort – Where the steering wheel is placed has a direct impact on the comfort of the driver. The steering wheel was placed to where the driver would not need to extend his/her arms to full length but would still be able to turn the car at ease.

Affordability – Having the low budgeted cost of \$750, the steering system was the most inexpensive component of the baja.

Maintenance – Maintaining the steering system requires proper storage and a proper cleaning after each use. There is a potential for the rusting of components if left outdoors in extreme conditions for an extended period.

Product Objectives

- 1. Steering Rack Ratio (25.7)**
 - a. Based off previous steering design, the most effective steering rack ratio will be calculated.
- 2. Height of the Steering Rack (20.5)**
 - a. Calculated based on ergonomics and frame design
- 3. Strength of Material (20.1)**
 - a. Tensile Strength of various materials to determine material to be used
 - b. Ultimate Strength of various materials to determine material to be used
- 4. Structural Layout (14.5)**
 - a. Determined based on frame design
- 5. Ease of Use (10.8)**
- 6. Dimension Parameters (8.4)**

Quality Function Deployment

Title: Steering Column: Hours of Quality
Author: Brad Bondal
Date: 10/19/2019
Notes:

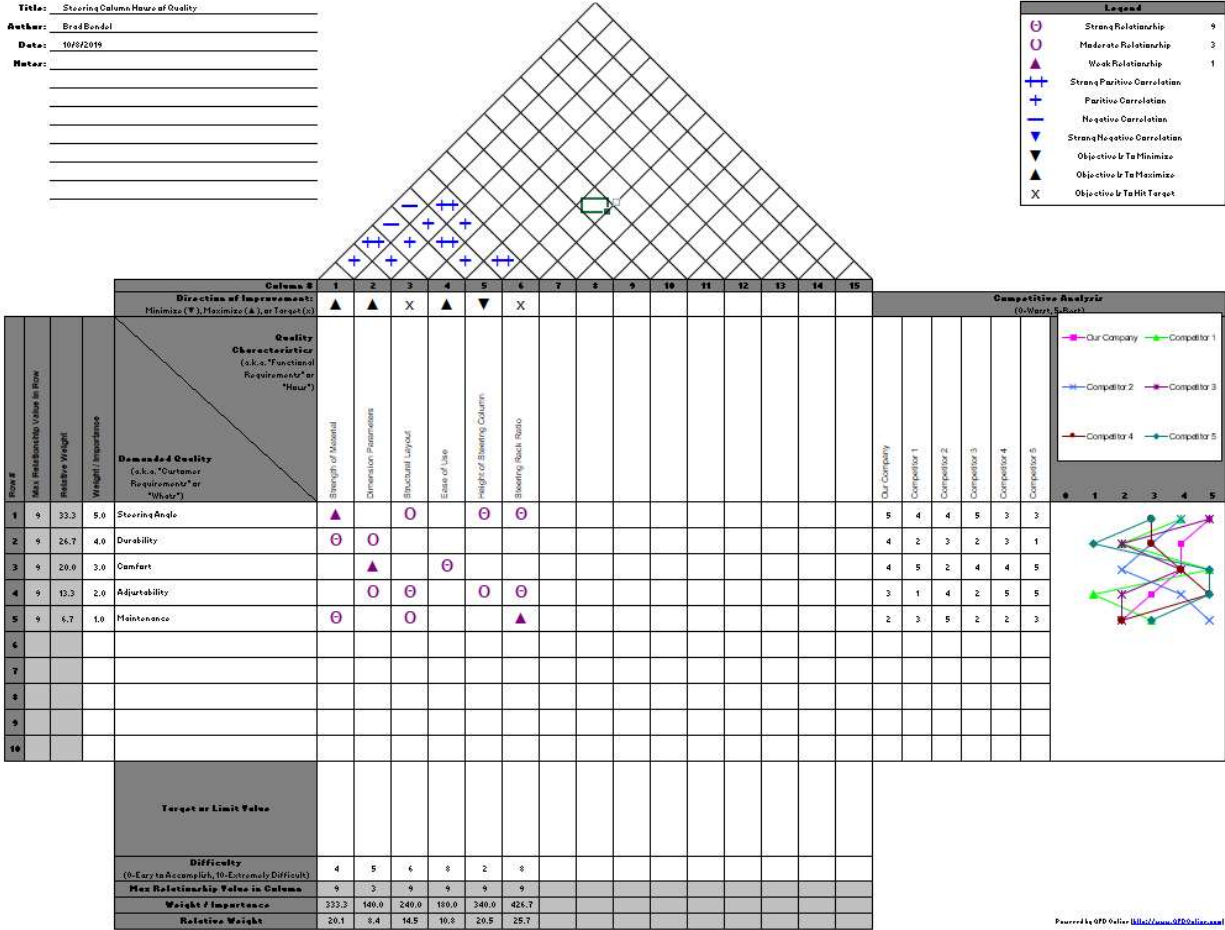


Figure 2 - Quality Function Deployment Diagram

Design

Ackermann Calculations

To calculate the Ackermann steering angle, the distance between the center of the rear wheels and the distance between the left/right side wheels are needed. The most important factor of Ackermann is that the imaginary perpendicular line from the front wheels must intersect before reaching the back wheels. Most of the heavy equipment (engine, transmission, gas tank, rear suspension) are in the rear of the car, so the center of gravity is towards the back of the car, rather than the front. From this, you can find the angle between the midline of the car, and the wheel. This is repeated for both the right and left side. I found that the outermost wheel is to have an angle of 30 degrees and the inside wheel is to have an angle of 50 degrees. Both angles help make the car not slip when turning and allows the car to turn on a shorter radius.

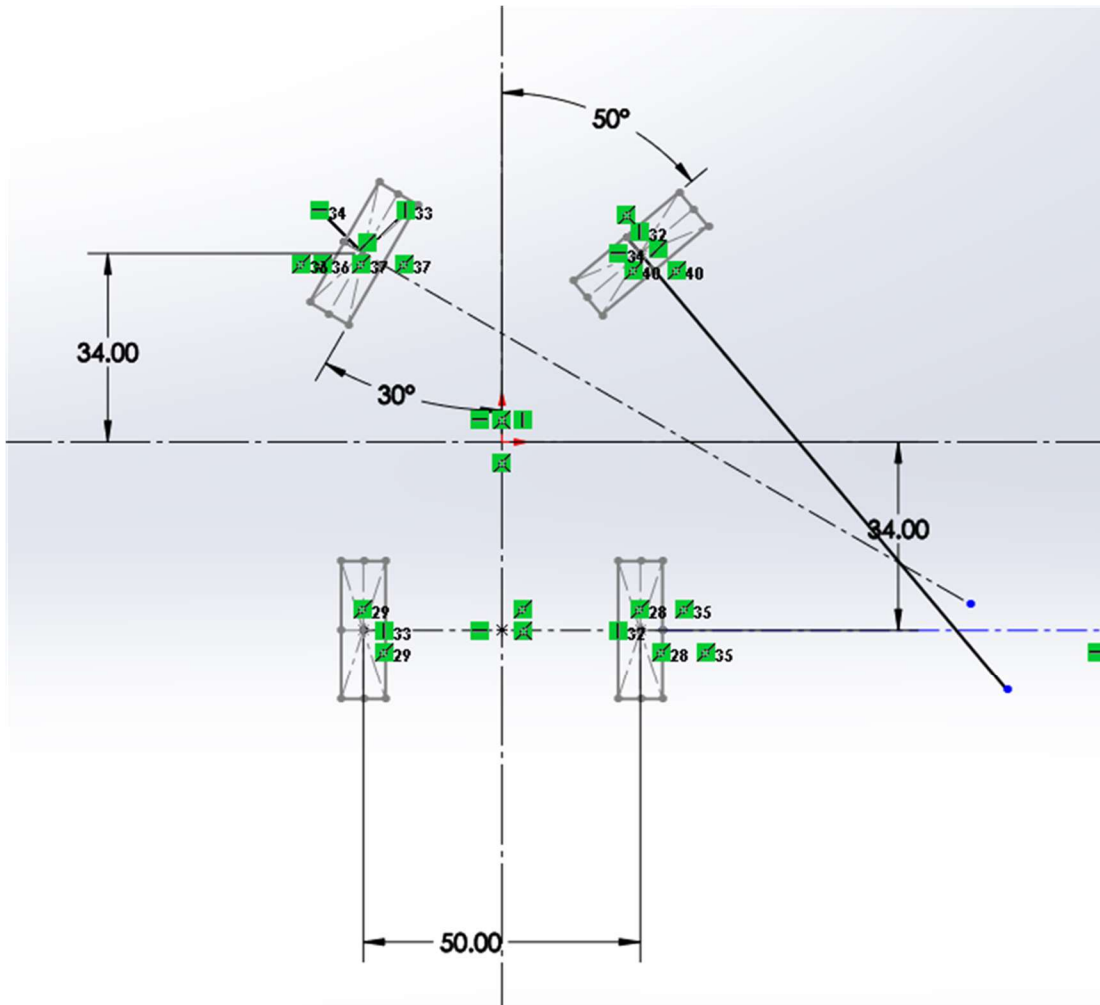


Figure 3 - Ackermann Steering Angle Calculation

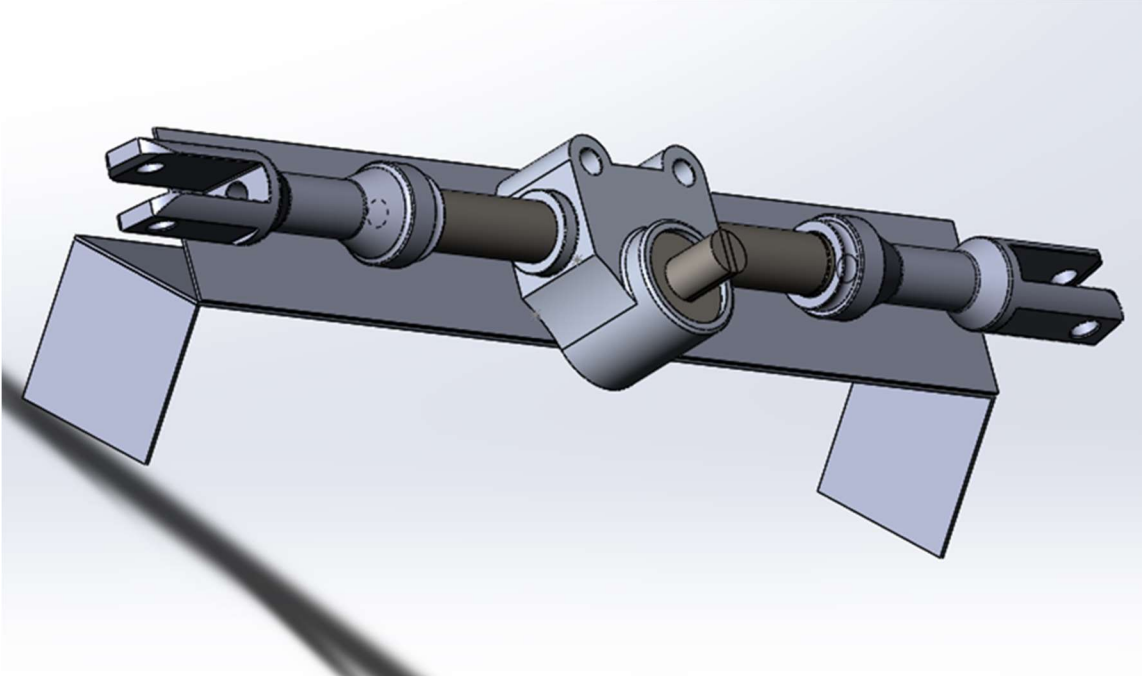


Figure 4 - Steering rack salvaged from retired car. It is mounted on top of risers, allowing the differential to be placed underneath.

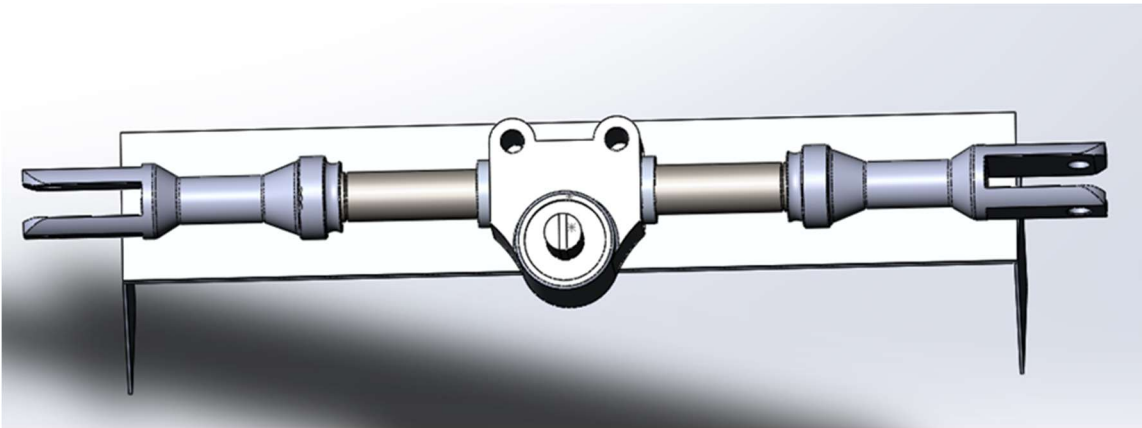


Figure 5 - Front View of steering rack.

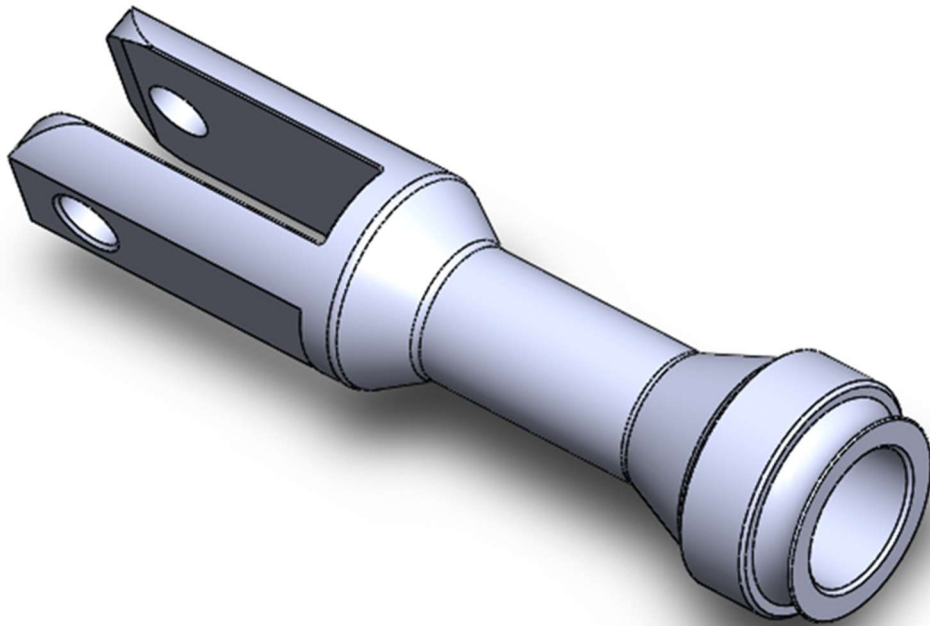


Figure 6 - Spacers that are placed on the ends of the steering rack, allowing the tie rods to connect from the rack to the wheels.

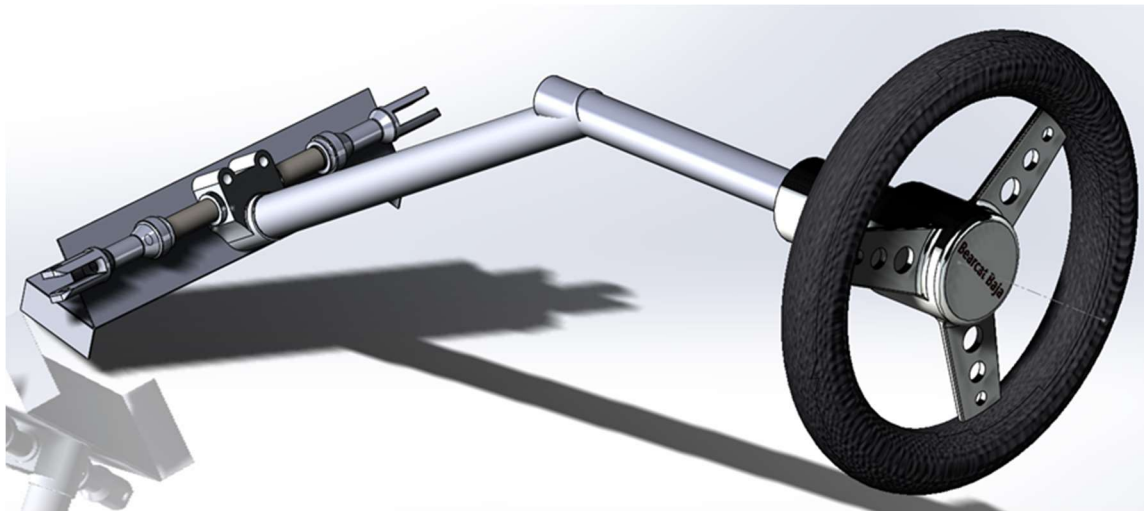


Figure 7 - Overall steering mechanism featuring steering rack, spacers, risers, steering wheel connections, and steering wheel.

Project Management

Budget

For funding in the 2019/2020 year, we had several companies and organizations willing to assist us with funding. From the previous Baja team, we had \$1,861 in additional funding to use for this year’s vehicle. Advics agreed to fund all the suspension of the car, allowing us to have an additional \$6,000 for funding. AK Steel supplied all the material for the frame, which was valued at \$1,500. We also received a donation from the College of Engineering, valued at \$8,000. This gave the team a net total of \$17,361 in funding for the 2019/2020 Baja team.

Sponsor	Area Of Sponsorship	Sponsorship Amount
Existing	Baja	\$ 1,861.00
Advics	Suspension	\$ 6,000.00
AK Steel	Frame	\$ 1,500.00
CEAS Donation	Baja	\$ 8,000.00
	Total	\$ 17,361.00

Figure 8 - Baja 2019/2020 Sponsorship

Based on previous expenditures of baja vehicles in years past, the allotted budget for the allotted budget for the 2020 year was found to be \$18,550. Each subsection of the Baja team was over-budgeted in case wrong parts were ordered or if something broke while testing or installing. Before the machine shops were closed, we had spent a grand total of \$13,300 for various sections of the vehicle.

Baja Section	Alloted Budget	Actually Spent
Suspension	\$ 6,000.00	\$ 4,200.00
Drivetrain	\$ 5,300.00	\$ 4,100.00
Braking	\$ 1,000.00	\$ 200.00
Ergonomics	\$ 1,500.00	\$ 1,500.00
Steering	\$ 750.00	\$ -
Misc.	\$ 4,000.00	\$ 3,300.00
Total	\$ 18,550.00	\$ 13,300.00

Figure 9 - Baja 2019/2020 planned and actual spending.

The remaining balance after considering sponsors and money spent was \$4,061. This is to be used to help funding for next year’s senior design team.

Total After Spending	\$ 4,061.00
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Figure 10 - Remaining balance in Baja account after 2019/2020 purchases.

Schedule

The figure below outlines the planned schedule for designing, building, and testing the 2020 Baja car. The bars in green is what was expected to be complete at the respective times

Proposed Schedule	September	October	November	December	January	February	March	April	May	June
Project Planning	Green	Green								
Research		Green								
Design			Green							
Modeling				Green						
Order Materials				Green	Green	Green				
Design Presentation					Green					
Manufacture					Green	Green	Green			
Testing							Green	Green	Green	
Tech Expo						Green	Green	Green	Green	
Final Presentation							Green	Green	Green	
Graduation									Green	Green
May SAE Event									Green	Green
June SAE Event										Green

Figure 11 - Proposed Schedule

The figure below represents the actual schedule. Designing took longer than expected because of the issue of having to design a 4-wheel drive vehicle. Parts were continuing to be ordered throughout the month of March. Due to COVID-19, all University of Cincinnati machine shops and buildings were closed. Tech Expo, Graduation, the May SAE event, and the June SAE were also cancelled. During this time, we were unable to complete the fabrication of the Baja. The bars in red represent what was unable to be completed.

Actual Schedule	September	October	November	December	January	February	March	April	May	June
Project Planning	Green	Green								
Research		Green								
Design			Green							
Modeling				Green						
Order Materials				Green	Green	Green				
Design Presentation					Green					
Manufacture					Green	Green	Green			
Testing										
Tech Expo							Red	Red	Red	Red
Final Presentation							Red	Green	Red	Red
Graduation							Red	Red	Red	Red
May SAE Event							Red	Red	Red	Red
June SAE Event							Red	Red	Red	Red

Figure 12 - Actual Schedule

Plan to Finish

The project was unable to be completed. The items needed in order to complete the steering are listed in the table below:

Item	Quantity
45 degree U-joint	2
Heim Joints	4
Steering Wheel	1
Spacer Material (Aluminum Tube)	1.5 ft. of material
Steering Arms (1020 Stainless Steel)	2.5 ft. of material
Quick Release Hub	1
Tie Rods	2

We currently have heim joints in storage for the steering, as well as the spacer material and steering arm material. The U-joints, steering wheel, quick-release hub, and tie rods need to be purchased in order to complete the steering wheel for next year's vehicle.

Sustainability and Material Usage

For the steering to be more sustainable and efficient in the future, a new steering rack is recommended. Because of the usage of a steering rack from an older car, newer and more efficient steering systems exist. Having a steering rack with a lower gear ratio will improve the turning radius on the steering, allowing for more sharp and clean turns. This will also reduce the amount of wheel slippage when turning the car on a rough terrain.

Acknowledgements

I would first like to thank my advisor, **Allen Arthur**, for guidance throughout the last year. I would also like to thank the rest of the Baja Team for being a supportive group and assisting me in the efforts on the entire project: **Donald Gustwiller, Noah Suran, Austin Kelleher, David Senter, Alec Holste, Moxit Patel, Hunter Lindeman, Nick Hafler, and Max Neal**. I would also like to thank **Cason Williams**, who has assisted the Baja team for the past few years. Finally, I would like to thank **my family** for the support throughout the entire process.

Special thanks go to our sponsors whose assistance made this entire project possible: Valvoline, Advics, AK Steel, College of Engineering and Applied Science, and the 1819 Innovation Hub.

Works Cited

1. **International, SAE**. SAE International. [Online] 10 8, 2019. <https://www.sae.org/attend/student-events/>.
2. **Colgrove, Dallin**. *Steering System for SAE Baja*. 2019.
3. **Rogers, James O**. *Bearcats Baja Team Management and Steering*. 2013.

Appendix A

Definitions and Acronyms

SAE – Society of Automotive Engineers

Differential – Transfers power from the driveshaft to the axels of the vehicle.

Transmission – gearbox of the vehicle; turns the engines power into something the car can use to go forward.

Heim Joints – rigid articulating joint used on the ends of various linkages to connect to each other

Slippage – Relative motion between a tire and the surface it is moving on.

COVID-19(Coronavirus) – Flu-like disease that caused the project to not to be completed.