# Basic Utility Vehicle Team

# Front Suspension and Steering

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
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In partial fulfillment of the
Requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

By

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Thesis Advisor:

**Professor Moise Cummings**

# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

## ACKNOWLEDGMENT

In completing this project of our basic utility vehicle (BUV), the MET senior design team wanted to thank those that made this project possible and helped us to pave our way to the end goal. First off, we would like to thank Lorenzo Cook from Pull-n-Pay for allowing us to come to the jackyard to pick out a Chevy S10 and donated to us to use as our chassis for our vehicle. This helped us start our project on a good foot and save money so we could put it elsewhere in the project.

We also would like to thank our advisor professor Cummings. He was a big help in answering questions when we needed advice and helping us get back on track when we were having problems starting up the manufacturing phase with our chassis.

Finally, we would like to thank David Conrad for being there to help us and provide advice and guidance on parts of the project we had questions on or need a little push in the right direction.

ABSTRACT

In third world countries, it is often very hard for people do get some of the luxuries we do not really realize. BUV is out to make it possible by trying to put in place basic utility vehicles that can help with simple problems that they struggle with by making these vehicles super cheap, simplistic, and easy to fix and durable. Every year BUV puts out a challenge that will help solve or alleviate one big problem out there for them. This year, the challenge was to be able to suck up, transport fresh water from a pond, and carry to villages as an example. With the set of rules that are in place, to be durable so that it can sustain a many trips that they will take without it breaking down and needing repair. The mechanical engineering program here at UC puts together a team to fulfill all of the requirements while building this vehicle so that they can compete and see how efficient their vehicle is. With requirements like less than $6,500 budget, 1250 lbs. max vehicle weight without cargo and max weight of 3000lb at max. These constraints and requirements make teams get creative of how they can make vehicles to accomplish the challenge. Overall, this project is to help understand how to make products that can efficiently enrich the lives of people in third world countries so they can go about doing more difficult and strenuous tasks a lot easier and more efficient.

# INTRODUCTION

## *PROBLEM STATEMENT*

The project is to design a Basic Utility Vehicle. A basic utility vehicle is vehicle designed to help bring aid to people and communities in third world countries without access to necessities such as water. The design of this vehicle needs to be as simplistic as possible while abiding by the specifications laid out by the Institution of Affordable Transportation. Some of these specifications are low cost, agile performance; 1750 lb pay load and a 20 MPH max speed.

Each member has a main section of the vehicle each team member is responsible to lead as listed below. Throughout the year we will collaborate and assist each member of our group in each other's' designated responsibilities to complete this project by April 20 2018. The front suspension and steering unit are the area I am working on,

## *TEAM MEMBER ROLES AND OBLIGATIONS*

For this project, each member took on a section of the vehicle that each person was responsible to do:

Marty Kowall – Chassis

Brad Sackett – Brake system

Chris Saranita – Front Suspension and Steering

El – Irrigation System

Cole Rardon – Drive train

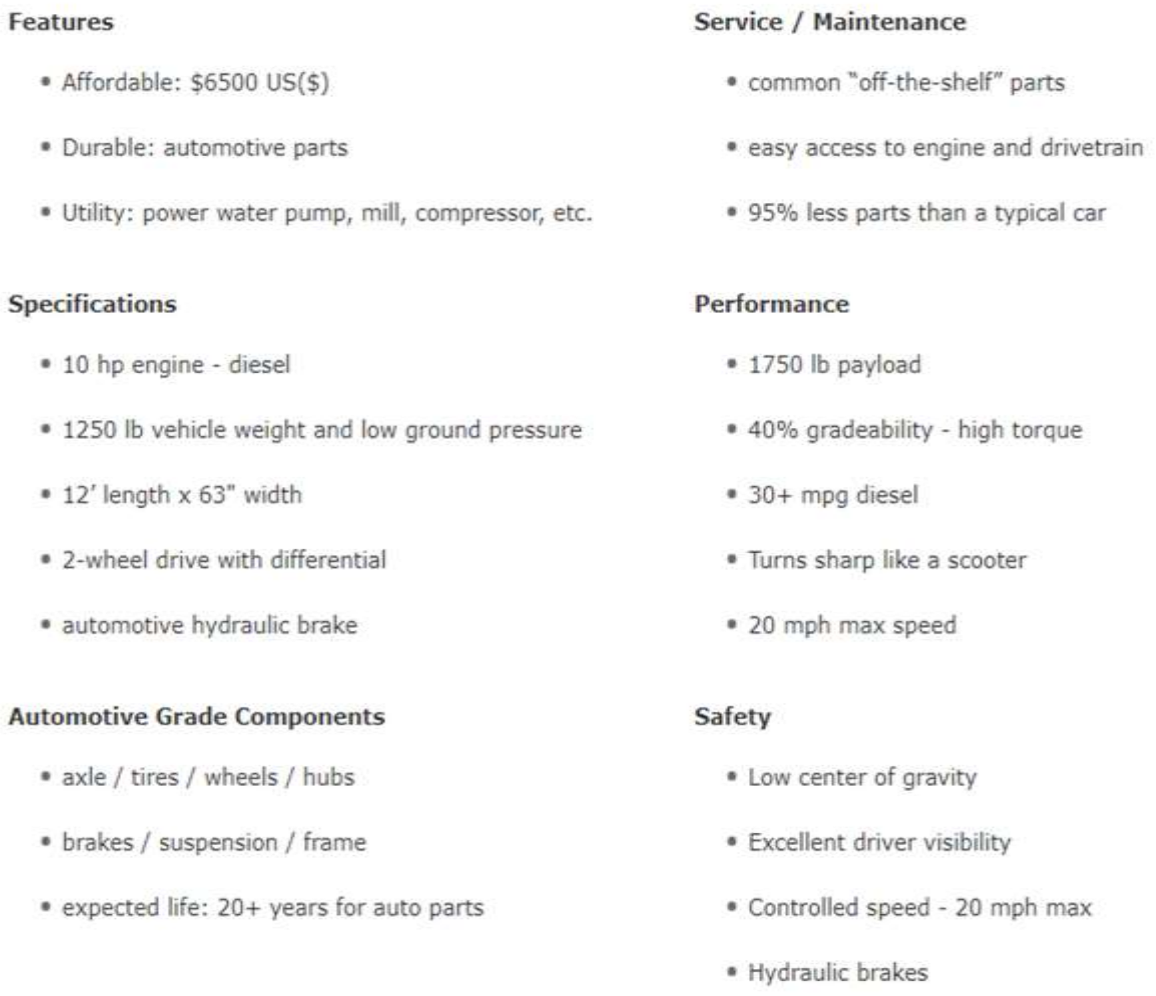
## BACKGROUND (BUV)

Will Austin founded the Institute of Affordable Transportation in the year 2000 after he realized the quality of life was dependent on cheap transportation. A year later, the first annual BUV design competition was held. Every year people try to improve upon the winning design. The idea is to design the cheapest, lightweight and durable vehicle for transporting water and aid for impoverished countries. The IAT sets out specific specifications that need to followed. These specifications include speed, weight payload and more.

The success of a BUV depends on the weight of the vehicle, and the vehicles ability to hold and transport large sums of water. Because of this, the strongest, most lightweight material that will be used to build the chassis and components of this vehicle.

### *CUSTOMER FEATURES AND SPECIFICATIONS*

Below is the list of requirements that needed to be included in the BUV design for the competition. For my section, the key requirements are to make sure the vehicle is able to turn very sharply and assure it is very maneuverable. In addition, when looking for the load stressed on the vehicle, the max weight it can be with full load is 3000lbs.



**Features**

- Affordable: $6500 US($)
- Durable: automotive parts
- Utility: power water pump, mill, compressor, etc.

**Service / Maintenance**

- common "off-the-shelf" parts
- easy access to engine and drivetrain
- 95% less parts than a typical car

**Specifications**

- 10 hp engine - diesel
- 1250 lb vehicle weight and low ground pressure
- 12' length x 63" width
- 2-wheel drive with differential
- automotive hydraulic brake

**Performance**

- 1750 lb payload
- 40% gradeability - high torque
- 30+ mpg diesel
- Turns sharp like a scooter
- 20 mph max speed

**Automotive Grade Components**

- axle / tires / wheels / hubs
- brakes / suspension / frame
- expected life: 20+ years for auto parts

**Safety**

- Low center of gravity
- Excellent driver visibility
- Controlled speed - 20 mph max
- Hydraulic brakes

**Figure 1- Customer features and specs**

## *END USER*

When constructing this basic utility vehicle, the end user kept in mind are people from third world countries. The end user will likely require a vehicle that can maneuver around tough environments, is easy to use and simplistic in repairs, can transport water efficiently. Making sure that the vehicle is very simplistic and overall durable are big keys to this vehicle. Making the vehicles too complex can really make it harder for the end user to operate and maximize the use out of the vehicle. In addition, keeping it simplistic makes it easier to repair if it does brake down since people in third world countries to do not have the kind of resources and mechanical knowledge to fix complex systems. The Durability is important because this vehicle will most likely have to go over rough terrain and other unfished roads or pathways. With the limited resources, it Is ideal to make the strength of the vehicle as best as possible so that it does not break down often and can efficiently perform the tasks many times before signs of mechanical failure. Allowing the vehicle to be mobile in all surfaces and environments will help ensure that the end user can get the most out of the vehicle. Finally, allowing the vehicle to carry as much water as it can so that it can so that it can take less trips and to maximize the potentially water carried from the vehicle each time without too much stress on the vehicle and its frame.

## *QUALITY FUNCTION DEPLOYMENT(QFD)*

The QFD we worked on was able to establish the three big areas of concern and importance when designing and implementing our sections. The three areas were

1. Cost – being able to effectively and efficiently spend money to make it cheap but also very effective and durable for its function
2. Miles per gallon (MPG) on vehicle – trying to eliminate the need for the car to be filled up to and run on a lot more gasoline.
3. Weight vehicle can carry – being able to utilize the back area and make the car lightweight so that it can carry more and burn less gas

# RESEARCH

## *STATE OF THE ART / PAST DESIGNS*

In researching initially was looking into the concept of both 3-wheel and 4-wheel designs. Bearing that we were able to construct the chassis for a 3-wheel vehicle, I looked into these vehicles that exhibited this type of suspension which were motorcycles and past BUV vehicles. The vehicle needs to be able to go on any kinds of terrain grades or hills, as there are no paved roads to drive on.

If you look at figure 1 below, you will see the Baylor University's BUV they built last year. This vehicle uses a very simple Uni-strut with an elevated steering system. The steering system has a simplistic horizontal bar running across to allow to grip for the handle bar .This vehicles helped me decide on looking into the popular and simplistic uni-strut design that has been used in years past.

**Figure 2: Baylor BUV team**

The vehicle in figure 2 is a Honda CRF450R motocross motorcycle. These motorcycles have to ride through dirt and uneven dirt paths as well as make sometimes high jumps and be able to land them. These are some of the types of elements that the BUV is exposed to. In order from them to land these jumps on heavy vehicles, they have to have a good suspension system and it seems like the telescoping fork was the standard for bike to be able to distribute the load.

**Figure 3:Honda CRF450R**

## *SUSPENSION DESIGN CONCEPTS*

### Concept 1: Telescoping Fork

**Figure 4: Telescoping fork design**

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The Telescoping fork design mostly seen in motorcycle front suspension designs. This design had a lot of support on front suspension due to allowing the pressure to disperse through the two sides of front suspension. The springs on the piping on each side of the suspension system would help dampen the blow of the force and provide less stress. The big drawbacks from this system are that it could potentially provide a decreased range of steering due to being bulker and that it had many parts that could make it more costly and harder to repair.

### Concept 2: Hossack suspension

The hossack suspension system is another suspension type seen in motorcycles or off road motor bikes. This suspension system provides great frame support as the frame is cut in triangular tubing as to maximize the amount of support that is utilized by dispersing the stress in many areas. The spring attached at the top helps to increase damping of force above. The downside to this design is that it is a lot harder to repair due to the small triangular designs cut out in the frame. In addition, due to the complexity of the frame, it would be a lot more expensive to make for the end user in mind

**Figure 5: Hossack Suspension design on motorcycle**

## *DESIGN SELECTION*

**Table 1: suspension design decision-making matrix**

| | | Hossack | | Fork Design | |
|---|---|---|---|---|---|
| Factors | Importance weight (%) | Rating | Weighted Rating | Rating | Weighted Rating |
| Cost | 15% | 4 | 0.6 | 3 | 0.45 |
| Material Used | 5% | 3 | 0.15 | 4 | 0.2 |
| Easy to Fix | 10% | 2 | 0.2 | 4 | 0.4 |
| Durable | 20% | 4 | 0.8 | 5 | 1 |
| Weight | 25% | 2 | 0.5 | 3 | 0.75 |
| stability | 25% | 3 | 0.75 | 4 | 1 |
| | | | | | |
| total | 100% | | 3 | | 3.8 |
| | | | | | |
| Poor | 1 | | | | |
| Average | 2 | | | | |
| above average | 3 | | | | |
| good | 4 | | | | |
| Exceeds | 5 | | | | |

When comparing these designs, three of our most important factors are taken into account from our QFD. These factors were weight, stability, and durability. They weighed the heaviest into the decision. What I found was that the Telescoping fork design was the best design we could realistically fabricate that would be able to support the vehicle in the best. It eliminated the problems of having to worry support issues for the suspension system that were problems for past years.

## *STEERING RESEARCH/DESIGN CONCEPTS*

The steering devices used to vehicles over the years have been classified as either one of two different typed: the handlebars on bike and ATVS or the steering wheels used in cars.

### Concept 1: handlebars

The handle bar design is a lot more prominent in vehicles that are a lot smaller and use less space than other vehicles like cars. The handle bar uses up a lot less space than the steering wheel and in effect is able to use a lot less material than a steering wheel.

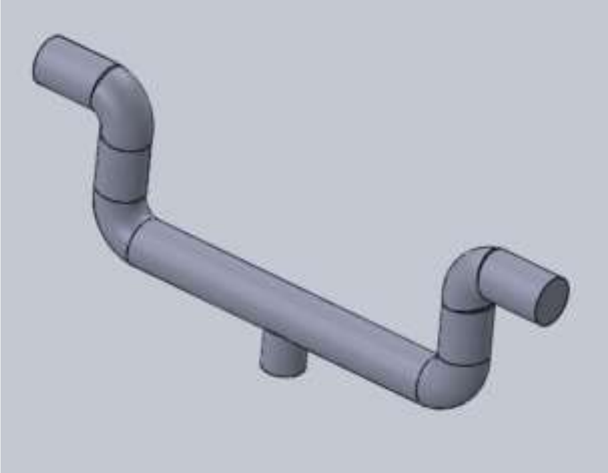


**Figure 6 : Handlebar Design**

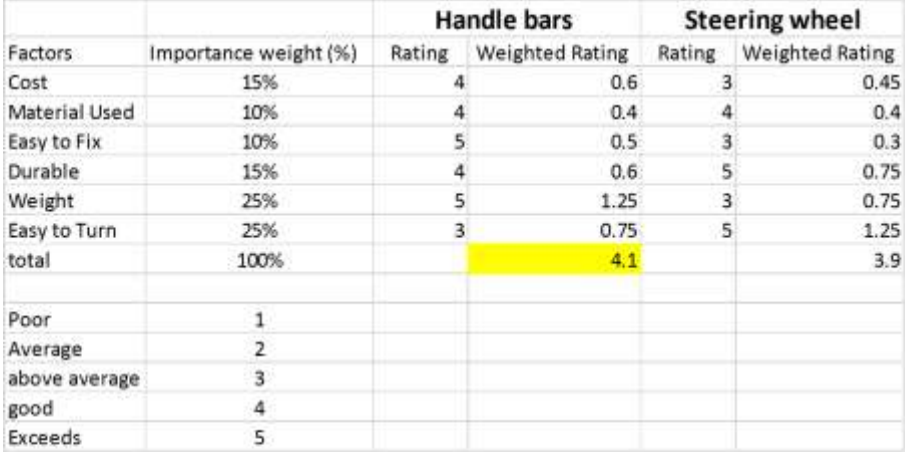
**Concept 2: steering wheel**

The steering wheel provides a lot less effort in steering either left or right because it uses a circular motion to turn instead of pushing left or right. In addition, steering wheel have better grip than handlebars and can be useful in the driver being able to stay in control. However, the steering wheel takes up more room, can be more complex to build and can be very heavy to lift.

**Figure 7: Picture of Car Steering Wheel**

With the chart below, the indication is that the handlebars are cost effective and more likely to yield less material need to make it than the steering wheel. In addition, the weight is a big factor in this and the handlebars can be very lightweight in comparison to a steering wheel

**Table 2: Steering System Decision-Making Matrix**



| | | Handle bars | | Steering wheel | |
|---|---|---|---|---|---|
| Factors | Importance weight (%) | Rating | Weighted Rating | Rating | Weighted Rating |
| Cost | 15% | 4 | 0.6 | 3 | 0.45 |
| Material Used | 10% | 4 | 0.4 | 4 | 0.4 |
| Easy to Fix | 10% | 5 | 0.5 | 3 | 0.3 |
| Durable | 15% | 4 | 0.6 | 5 | 0.75 |
| Weight | 25% | 5 | 1.25 | 3 | 0.75 |
| Easy to Turn | 25% | 3 | 0.75 | 5 | 1.25 |
| total | 100% | | 4.1 | | 3.9 |
| | | | | | |
| Poor | 1 | | | | |
| Average | 2 | | | | |
| above average | 3 | | | | |
| good | 4 | | | | |
| Exceeds | 5 | | | | |

## DESIGN AND MANUFACTURING

### *MODIFICATION OF ORIGINAL DESIGN*

As our final concept started to come together, we realized there was a flaw with the telescoping fork. The design was very bulky and with the cage at the front of our chassis, it was likely to have, the sides of the telescoping fork would hit or interfere with them with how far they would come out from the wheel. In addition, after starting to tally up the parts and cutting parts I would need I also realized I would need another mount on the other ides of the wheel to allow it to mount on both sides of the wheel, which would be more cost and time to fabricate another one. Overall, the design was not as effective or conducive to the main characteristics we want with being cost effective and simplistic.

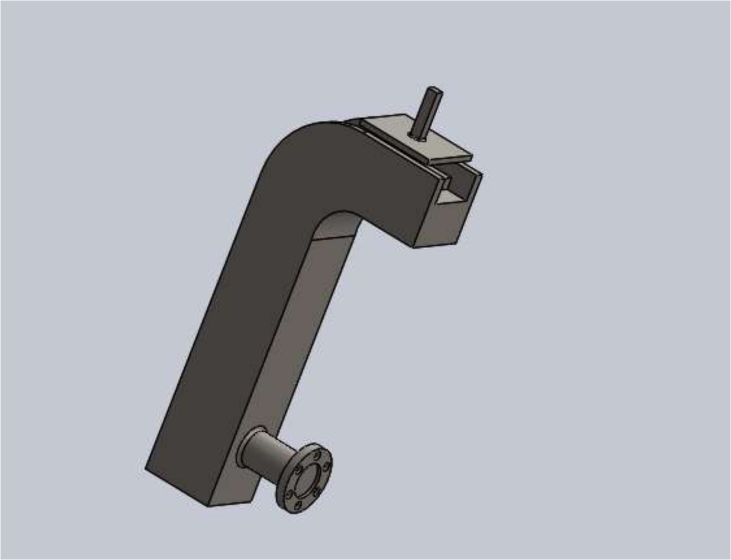
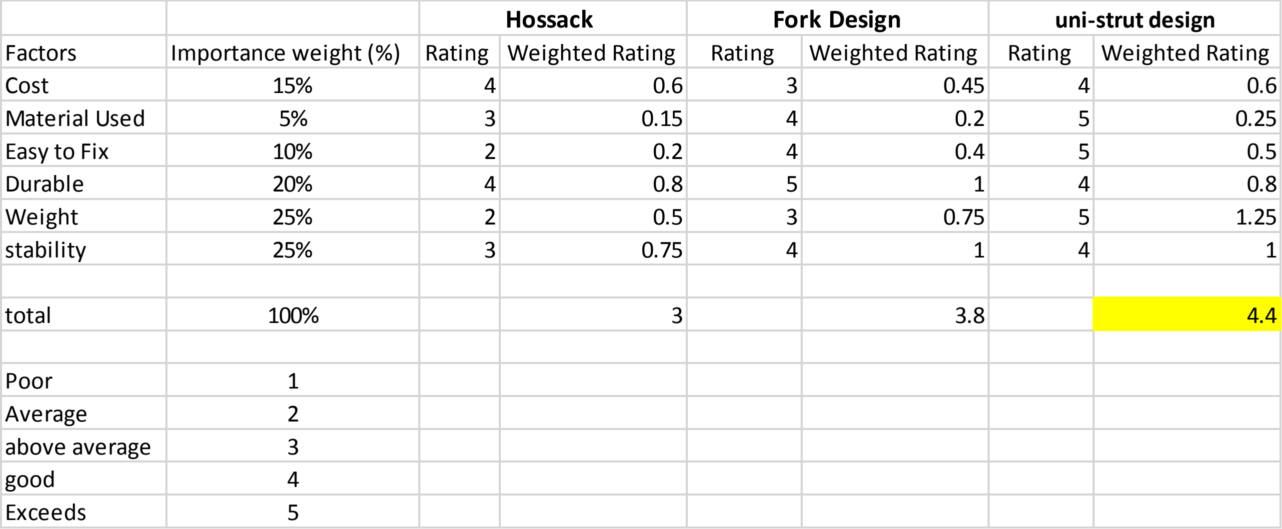


**Figure 8: Uni-strut design**

After some more research, I came across the uni-strut design. This design is very simplistic and uses a lot less material than the telescoping fork. It is a well-known and liked design across BUV and has good advantages for its unique design. It is a similar design used from the previous year BUV team. The design is a lot closer to the wheel and allows it to turn sharper and have a lot bigger turning radius. Also for having, the one wheel hub from past years was great design to be able to incorporate the one connection to wheel instead of two. As can be indicated from below, the uni-strut compared to the fork and hossack was able to do better or the same in most categories including being able to be easier to fix and use less materials.

**Table 3 : new suspension decision-making matrix**



| | | Hossack | | Fork Design | | uni-strut design | |
|---|---|---|---|---|---|---|---|
| Factors | Importance weight (%) | Rating | Weighted Rating | Rating | Weighted Rating | Rating | Weighted Rating |
| Cost | 15% | 4 | 0.6 | 3 | 0.45 | 4 | 0.6 |
| Material Used | 5% | 3 | 0.15 | 4 | 0.2 | 5 | 0.25 |
| Easy to Fix | 10% | 2 | 0.2 | 4 | 0.4 | 5 | 0.5 |
| Durable | 20% | 4 | 0.8 | 5 | 1 | 4 | 0.8 |
| Weight | 25% | 2 | 0.5 | 3 | 0.75 | 5 | 1.25 |
| stability | 25% | 3 | 0.75 | 4 | 1 | 4 | 1 |
| | | | | | | | |
| total | 100% | | 3 | | 3.8 | | 4.4 |
| | | | | | | | |
| Poor | 1 | | | | | | |
| Average | 2 | | | | | | |
| above average | 3 | | | | | | |
| good | 4 | | | | | | |
| Exceeds | 5 | | | | | | |

## MATERIAL SELECTION AND LOADING CONDITIONS

After selecting the uni-strut design as the suspension system we were going to use I had to find a good and stable steel to take the force from the vehicle. For what I have seen in the past, and has a lot of strength and durability was the structural c-channel. For material selection for the C-channel, I looked at both aluminum and steel. I found that the most cost effective and versatile to use for the purposes of machining or fabricating the material to fit what we needed the suspension to be ASTM-36.Past teams have also recommended this when looking at C-channel material. It will allow for a lot strength and flexibility with mounting.

## LOADING CONDITIONS

When looking at the requirements, our vehicle cannot exceed over 3,000lbs including the vehicle weight and max cargo. With this in mind, decided to use a 2.5 design factor on the max load that could possibly occur. In my calculations, this came out to 7500 lbs. of force that could be exerted from the weight of the vehicle to the suspension system. The reason I have the design factor at 2.5 is because the use of 2 was not enough in years past and adding a little more safety into the design factor, another 1500lbs, can help make sure that it will be able to sustain.

## *MODEL SIMULATIONS (STRESS ANALYSIS)*

For the stress analysis of the part, I put a force of 7500lb on the top of the uni-strut and on the sides to simulate the force that would occur if the force on the suspension system were 2.5 times the max weight. The part is fixed at the top plate, which will attach to the frame and the wheel hub attached to the wheel. As a result, the stress test on the angle of the c-channel took a good amount of stress but not close to breaking point due to the material having around a breaking point of 36,000 psi. The other area that may be a concern if the weight was a lot more would be the top of the c-channel as it takes a lot of the force for the system. The wheel hub we had from last year’s team and with the solid pipe we are able to run through it will be able to withstand the force of the 2.5 design factor.

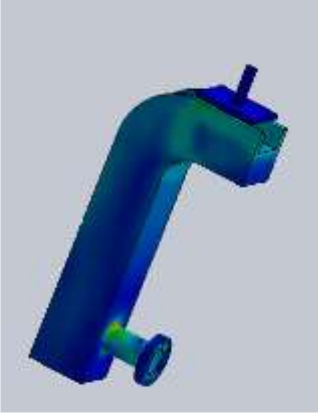


**Figure 9: Suspension Stress Analysis Test**

### MODIFICATIONS TO STEERING DESIGN

With the handlebar, I ran into a small problem when trying to implement it. I realized with the cage being in the front housing the engine and transmission, the driver would need to hunch over and hang onto the handlebars because it would not have length. To combat this problem, the steering wheel was elongated and in reach of the driver at all times so that they could be seated in a comfortable position and be able to turn the vehicle without any problem. Also, another reason I lengthened the steering wheel is due to increasing the torque so that it was easier for the driver to turn without excreting to much force. By looking at the equation Torque=Force*Distance ,I was able to see that the farther out the point of force used from the fulcrum, the less force that is needed to achieve the same movement or torque.

**Figure 10: Elongated Handlebar Design**

### *FABRICATION AND ASSEMBLY*

For the fabrication of the steering wheel, we used long 4 diameter tube that we were able to weld to the side of a hollow square tube. Originally, the tubes were going to weld on to the back of a plate on the square tube but with the tubes coming in at an angle, it was harder to weld the front on securely to it. We used the leftover angle iron from chassis to add some extra support to the bottom of both pipes. Onto the handlebar portion, we placed a small thin plate to be welded between the two 4 diameter pipes and the sideways 4 diameter pipe that we sued for the handlebars to complete the steering system.

**Figure 11: Steering System with Suspension System**

For the suspension system, we were able to use two 6-inch wide 1-inch thick plates to be able to weld and mount them to the c-channel steel. We drilled into the plate that connects to the chassis so that we could stick the axis bearing inside. The bearing was able to connect to the plates and c-channel by welding some leftover pipe between them. The suspension was able to connect to the steering by way of pressure pushing in a smaller square pipe with 1 inch width and height and welding them together so it connects to the bearing inside the plate and can now steer the suspension system. The years before were able to keep the front wheel tire and mount for us to use so we were able to use that and add a steel pipe to connect and attach it to the wheel .

**Figure 12: close ups of steering and suspension with full model assembly**

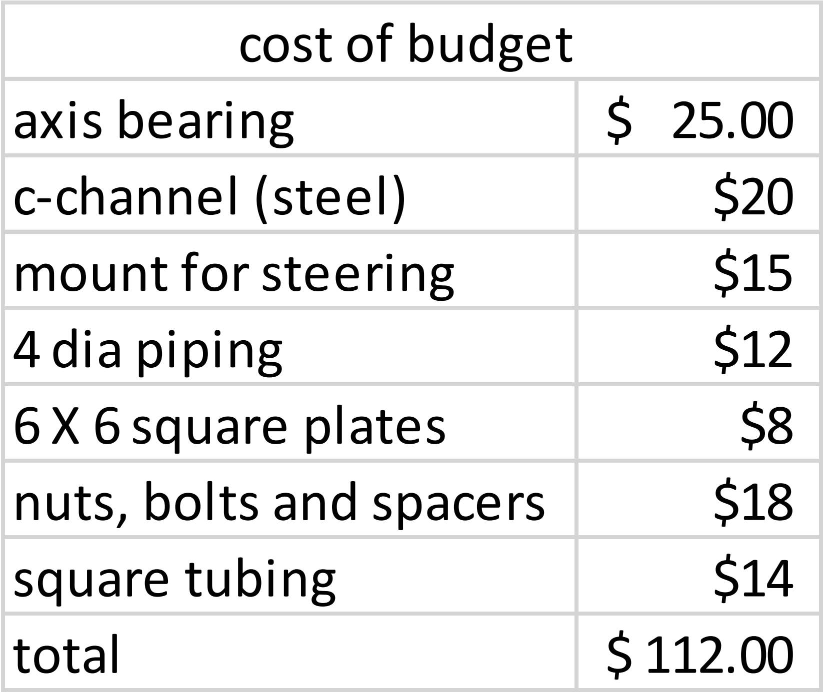
## PROJECT MANAGEMENT

### *BUDGET, PROPOSED/ACTUAL*

Proposed (left) and actual (right):

**Table 4: Proposed and Actual Broken Down Budget**

| BUV Section | Estimated Cost | | BUV Section | Estimated Cost |
|---|---|---|---|---|
| Chassis | $1,060.00 | | Chassis | $310.00 |
| Braking system | $360.00 | | Braking system | $130.00 |
| Irrigation | $160.00 | | Irrigation | $300.00 |
| Steering/Suspension | $460.00 | | Steering/Suspension | $112.00 |
| Drive Train | $560.00 | | Drive Train | $210.00 |
| | | | | |
| | | | | |
| Total Cost | $2,600.00 | | Total Cost | $1,062.00 |



| cost of budget | |
|---|---|
| axis bearing | $ 25.00 |
| c-channel (steel) | $20 |
| mount for steering | $15 |
| 4 dia piping | $12 |
| 6 X 6 square plates | $8 |
| nuts, bolts and spacers | $18 |
| square tubing | $14 |
| total | $ 112.00 |

**Table 5: Steering and Suspension Individual BOM**

For the budget, it was a lot less than I predicted it would be. I originally budgeted for the telescoping fork that had more materials to it and the need for two wheel mounts so it would have cost a lot more. In addition, what I did not factor into the budget at first was that we already had a front tire we could use and a mount to connect it to the wheel, which resulted in being super helpful in reducing the cost to an already simplified suspension system. The angle iron we used was the extra material chassis bought in case we needed it so used some of it for the steering with no extra cost on the budget,

### *SCHEDULE, PROPOSED /ACTUAL*

Proposed (left) and actual (right):

| Task | Start date | | Task | Start date |
|---|---|---|---|---|
| Design concept | October 2nd 2017 | | Design concept | October 2nd 2017 |
| Detailed outlook of each role | November 2nd 2017 | | Detailed outlook of each role | November 2nd 2017 |
| Bill of materials | November 11th 2017 | | Bill of materials | November 11th 2017 |
| Detailed design | November 16th 2017 | | Detailed design | November 16th 2017 |
| Completed design in CAD | December 30th 2017 | | Completed design in CAD | December 30th 2017 |
| Layout scheduling for manufacturing | January 1st 2018 | | Layout scheduling for manufacturing | January 1st 2018 |
| Presentation Proposal | January 26nd 2018 | | Presentation Proposal | January 26nd 2018 |
| Order parts | January 31th 2018 | | Order parts | March 7th 2018 |
| Design modifications/manufacturing | February 1st 26th 2018 | | Design modifications/manufacturing | March 8th 2018 |
| Start Testing | March 1st 2018 | | Start Testing | March 1st 2018 |
| Spring break | March 12th -18th 2018 | | Spring break | March 12th -18th 2018 |
| Testing modifications | April 1st 2018 | | Testing modifications | April 18st 2018 |
| Final test | April 15th 2018 | | Final test | April 15th 2018 |
| Competition / Final Presentation | April 20nd 2018 | | Competition / Final Presentation | April 20nd 2018 |

**Table 6: Proposed and Actual Project Schedule**

In terms of the scheduling of the project, we ran into an obstacle of finding a chassis early on at the start of the spring semester, which took us all some time away from our sections to try to figure out a way to get one donated or one cheap in the area. Once we had found one I was able to take some time to redesign what new system I wanted after realizing it would cause problems and have my parts ordered by beginning of March. Since the suspension, system was a little easier for this new design and having a plan in place to I was able to get it roughly done by the tech expo. From there I made sure it was working correctly and hoped we could test it out for the week or so before the competition

### *TESTING AND COMPETITION*

For the testing we were unable to take it out onto anything and do any sort of test on sharp includes or rocky areas due to not having the drivetrain and throttle fully hooked up. We did get to test the steering and see what kind of steering angle we had. We were able to let the steering go 360 degrees and be able to test to make sure that turning the wheel sideways would act as an emergency break and it was able to keep it in place when turn.

If I were to do the test, I would have liked to test the suspension system on different types of roads that may be rocky or dirt to see exactly how the suspension system and turning radius work. In addition, I would like to see how the suspension works on these roads in incremental payloads until it is at max capacity to see if there is any wear or stress over time wearing on the suspension. The last thing I would test on the suspension is if it could survive the 3 ft drop test and see if it is able to rebound without having too much force to fracture it. For testing the steering, I would want to see how it maneuvers in rough terrain around rocks and hills. In addition, I wanted to set up cones and see how sharp the turns can actually be without hitting the cones at different speeds to see the true turning angle when in motion.

The competition this year was in Batavia, Ohio on April 20-21st. the practice day before the competition is on the 20th and the actual competition is on the 21st. the competition is where local and regional BUV vehicles go to compete to see who has the most durable and efficient design. The theme for this year's competition was irrigation and durability. The objective and course consisted of teams filling up their car with 150 gallons of water and carrying it around three laps on a 2.2-mile course. After that, they must go back to the pond and refill their irrigation systems. This goes on repeat for about 7 hours or until there is one team remaining. The team left standing and still pumping water and driving by the end will be the winner. For our team we unfortunately could not make it or participate in the event. 3 days before our event the drive shaft started shaking when we tried to move after taking it out for test drive and we were not able to figure out what was causing the problem. We did not have the time to deconstruct it to find the root of them problem. Also, we were having last minute troubles with our irrigation system and not being able to put the final touches on it before the competition day.

## CONCLUSION

This project has been a great experience to be a part of and learn about vehicles and their systems. Doing the steering and suspension section of the vehicle was very tough and implementing different ideas and designs after some of them did not pan out well when put together was a challenge. I do wish we could have finished the vehicle on time so we could have test out what all our hard work had accomplished and for me to see if the suspension and steering system would be able to hold up in the competition setting. Although I was never able to test its performance, I feel that the uni-strut is going in the right direction in terms of finding the most simplistic and efficient suspension system out there and I think most teams should consider it in their designs even if it is not the first choice. It is a very versatile system and can likely be equip or fused with other suspension ideas to maximize the efficiency. If I had to make recommendations to the next BUV team, it would be to work on drawing out a plan and figuring out how all your pieces will go together soon. Also, make sure you know exactly what parts you want to order and research them enough so you can get the best deals and get the best material you can. Lastly, I recommend starting on ordering your parts before winter break so that you have them for the start of next semester and can realize if problems will arise early on, you can catch them.

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# APPENDIX A – COMPETITION SPEC SHEET

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|---|---|
| Engine | Use up to 11 horsepower unmodified engine. An auxiliary fuel tank may be added. |
| Exhaust | Stock muffler, which may be relocated, with additional heat shields as needed. |
| Gauges | An engine temperature indicator located in view of the driver. |
| Fuel | Retail pump fuel and oil with provisions to prevent spilling fuel on a hot engine. |
| Transmission | It is builder's choice, to meet event conditions, but should have reverse** and should have at least two forward speeds** not counting any variable drive features. |
| Power Takeoff | The ability to power auxiliary equipment** at approximately 1000 rpm. A V-belt drive is anticipated for auxiliary equipment. |
| Electrical | A 12 volt 35 amp or larger automotive alternator and an automotive battery are required**. |
| Cargo Bed | The bed must hold two, but may hold three 55 gallon standard steel drums**. The drums must be located on their sides with the small hole at the top. The drums must be located as low as possible in the bed. The drums must not be stacked in any manner. The front of the cargo bed must have a 16 inch minimum high bulkhead between the driver and the cargo. The other sides of the bed must be a minimum of 8 inches high. Drums should be easily removable for cargo**. |
| Roll Bar | A minimum height of 36 inches above the surface the driver will sit upon. The roll bar must be completely padded above the seat height. It must have a cross member that covers the ends of the vertical structures, and adequate bracing to prevent the vehicle from rolling over. |
| Driver Safety | A helmet is required for each person aboard the vehicle. Seat belts are at the option of the team and the team advisor. |

| | |
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| Safety Items | To participate in the event, you must have the following safety items:<br>1. An engine shutoff device marked with a nine-inch red streamer located within reach of the driver.<br>2. A ***dead man*** throttle with the spring located directly on the throttle linkage of the engine and not on the throttle control devices of vehicle.<br>3. Guarding from all moving parts and Padding of all sharp or dangerous areas.<br>4. Automotive horn, a fire extinguisher with a rating of 5 B-C or higher, and a high visibility safety flag above the vehicle. |
| Brake System | A redundant brake system****** that will prevent total brake failure if a brake line is severed anywhere on the vehicle. The brakes must be located at the wheels and not on the drive-line. A front wheel brake is not required on three wheeled vehicles. The parking brake is not considered the redundancy that is required. Hydraulic drives may use reverse for brakes. |
| Parking Brake | A parking brake capable of overcoming the engine power. It may be on the drive-line. |
| Tires | Agricultural tread, or aggressive tire chains are required. Chains must be carried by the vehicle if removed from the tires. |
| Towing | Each vehicle must have a 20 foot looped-end tow strap. There must be an attachment point at the front of the vehicle for towing. The trailer ball will be the rear attachment point for towing. |
| Trailer Hitch | A 1-7/8 inch trailer ball must be mounted at a height of 15 inches above the ground when the vehicle is unloaded. |
| Weatherproof | The vehicle should have protection from the weather elements to provide better reliability and greater durability. |
| Speed | Maximum of 20 MPH. |

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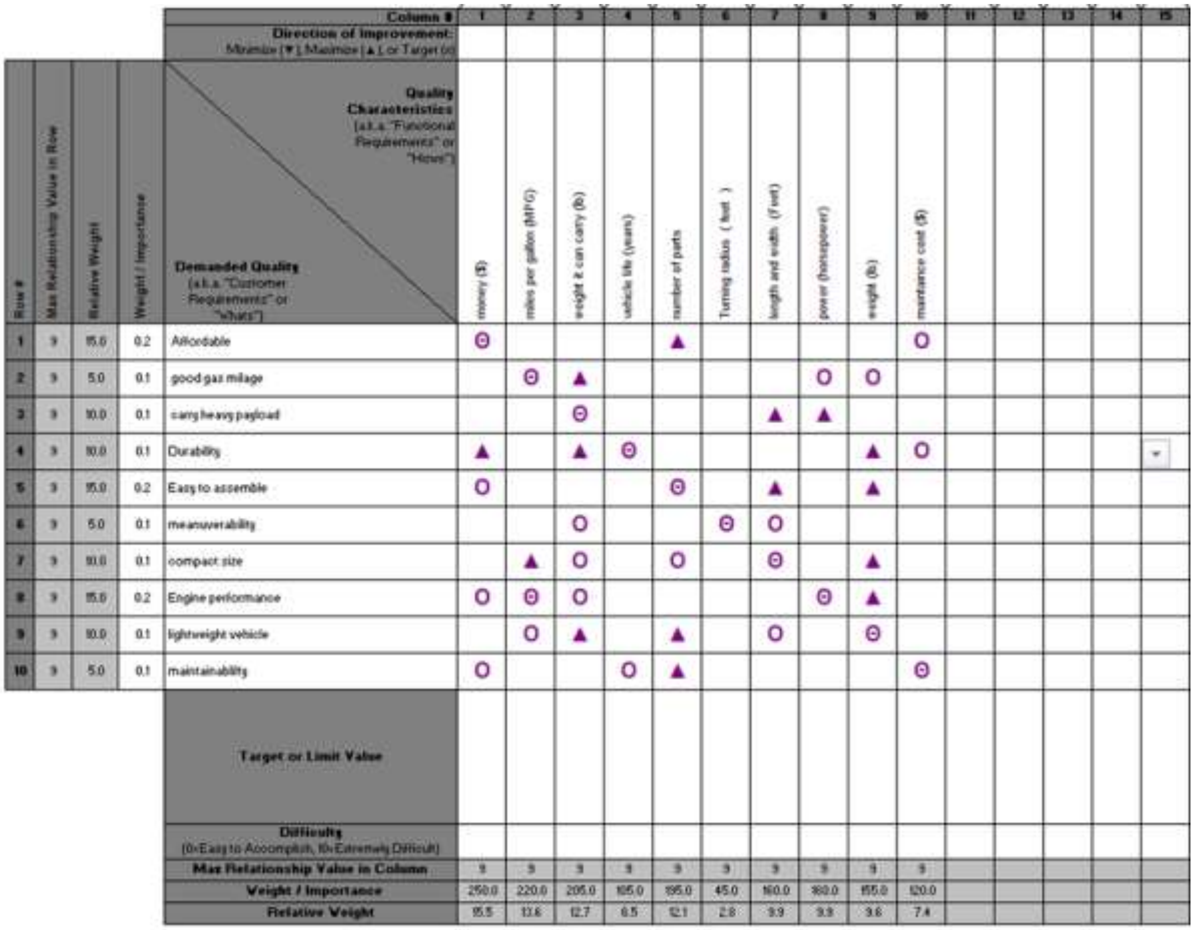
|---|---|
| Load | Maximum of 165 gallons of water, weighting roughly 1376 pounds. |
| Water Pump | Ability to fill 55-gallon drums from within 15 feet of a pond. All pumping equipment and hoses must be carried on the vehicle during the event. Pump driven form PTO device only. |
| Name Plate | The school name and team number displayed in 4-inch font on all sides of the vehicle. |

# APPENDIX B - QFD



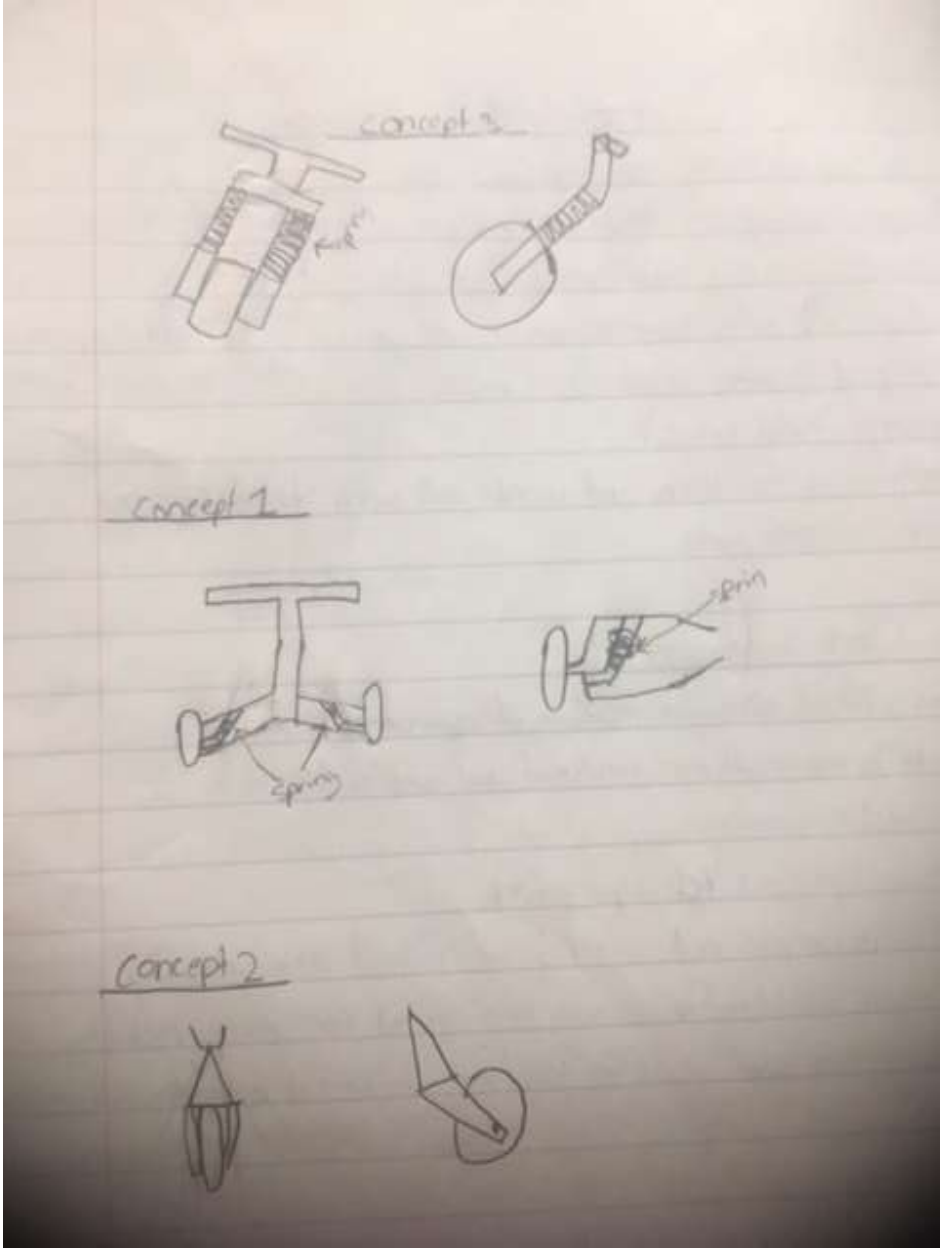
| | | | | **Column #** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Direction of Improvement:** Minimize (▼), Maximize (▲), or Target (x) | | | | | | | | | | | | | | | |
| Row # | Max Relationship Value in Row | Relative Weight | Weight / Importance | **Quality Characteristics** (a.k.a. "Functional Requirements" or "Hows")<br>**Demanded Quality** (a.k.a. "Customer Requirements" or "Whats") | money ($) | miles per gallon (MPG) | weight it can carry (lb) | vehicle life (years) | number of parts | Turning radius ( feet ) | length and width (Feet) | power (horsepower) | weight (lb) | mantaince cost ($) | | | | | |
| 1 | 9 | 15.0 | 0.2 | Affordable | Θ | | | | ▲ | | | | | O | | | | | |
| 2 | 9 | 5.0 | 0.1 | good gas milage | | Θ | ▲ | | | | | O | O | | | | | | |
| 3 | 9 | 10.0 | 0.1 | carry heavy payload | | | Θ | | | | ▲ | ▲ | | | | | | | |
| 4 | 9 | 10.0 | 0.1 | Durability | ▲ | | ▲ | Θ | | | | | ▲ | O | | | | | |
| 5 | 9 | 15.0 | 0.2 | Easy to assemble | O | | | | Θ | | ▲ | | ▲ | | | | | | |
| 6 | 9 | 5.0 | 0.1 | meanuverability | | | O | | | Θ | O | | | | | | | | |
| 7 | 9 | 10.0 | 0.1 | compact size | | ▲ | O | | O | | Θ | | ▲ | | | | | | |
| 8 | 9 | 15.0 | 0.2 | Engine performance | O | Θ | O | | | | | Θ | ▲ | | | | | | |
| 9 | 9 | 10.0 | 0.1 | lightweight vehicle | | O | ▲ | | ▲ | | O | | Θ | | | | | | |
| 10 | 9 | 5.0 | 0.1 | maintainability | O | | | O | ▲ | | | | | Θ | | | | | |
| | | | | **Target or Limit Value** | | | | | | | | | | | | | | | |
| | | | | **Difficulty** (0=Easy to Accomplish, 10=Extremely Difficult) | | | | | | | | | | | | | | | |
| | | | | **Max Relationship Value in Column** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | | | | |
| | | | | **Weight / Importance** | 250.0 | 220.0 | 205.0 | 105.0 | 195.0 | 45.0 | 160.0 | 160.0 | 155.0 | 120.0 | | | | | |
| | | | | **Relative Weight** | 15.5 | 13.6 | 12.7 | 6.5 | 12.1 | 2.8 | 9.9 | 9.9 | 9.6 | 7.4 | | | | | |

# APPENDIX C – DESIGN RESEARCH

**function**: Baylor's BUV team from last year had a very simplistic uni-strut design and had an elongated and T-shape steering system

**function:** These motorcycles have to ride through dirt and uneven dirt paths as well as make sometimes high jumps and be able to land them. These are some of the types of elements that the BUV is exposed to. In order from them to land these jumps on heavy vehicles, they have to have a good suspension system and it seems like the telescoping fork was the standard for bike to be able to distribute the load.

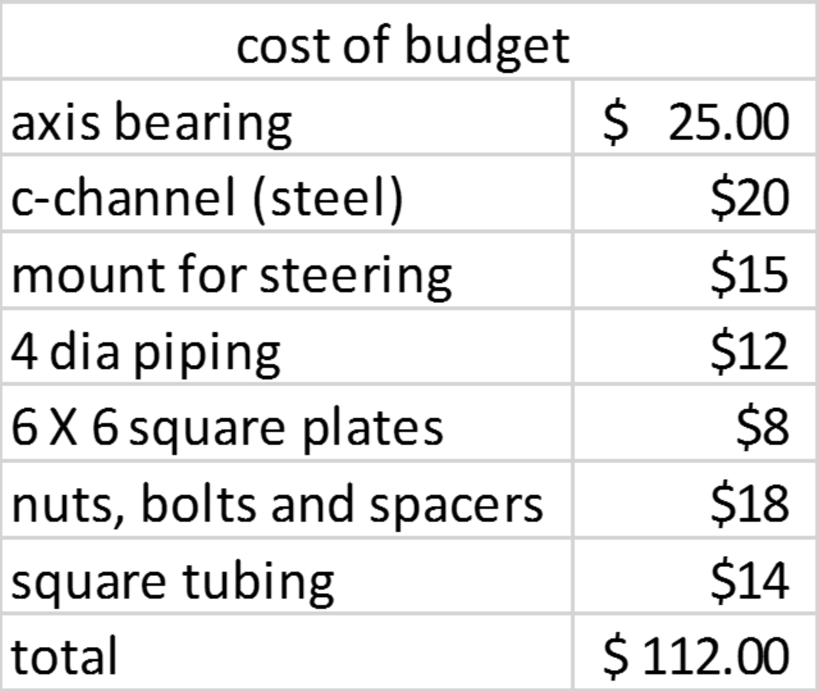
# APPENDIX D – EARLY SUSPENSION AND DESIGN DRAWINGS



These pictures indicate early design drawings with one being a two wheel design and the other being one wheel . the top design is more of the telescoping fork design with springs and tubes on the side. The bottom design is more like the hossack design that deals with having the frame form triangles to have great strength and durability but super complicated to make and repair

# APPENDIX E – SCHEDULE AND BUDGET

| BUV Section | Estimated Cost |  | BUV Section | Estimated Cost |
|---|---|---|---|---|
| **Chassis** | $1,060.00 |  | Chassis | $310.00 |
| **Braking system** | $360.00 |  | Braking system | $130.00 |
| **Irrigation** | $160.00 |  | Irrigation | $300.00 |
| **Steering/Suspension** | $460.00 |  | Steering/Suspension | $112.00 |
| **Drive Train** | $560.00 |  | Drive Train | $210.00 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Total Cost** | $2,600.00 |  | Total Cost | $1,062.00 |



| cost of budget |  |
|---|---|
| axis bearing | $ 25.00 |
| c-channel (steel) | $20 |
| mount for steering | $15 |
| 4 dia piping | $12 |
| 6 X 6 square plates | $8 |
| nuts, bolts and spacers | $18 |
| square tubing | $14 |
| total | $ 112.00 |

| Task | Start date | | Task | Start date |
|---|---|---|---|---|
| Design concept | October 2nd 2017 | | Design concept | October 2nd 2017 |
| Detailed outlook of each role | November 2nd 2017 | | Detailed outlook of each role | November 2nd 2017 |
| Bill of materials | November 11th 2017 | | Bill of materials | November 11th 2017 |
| Detailed design | November 16th 2017 | | Detailed design | November 16th 2017 |
| Completed design in CAD | December 30th 2017 | | Completed design in CAD | December 30th 2017 |
| Layout scheduling for manufacturing | January 1st 2018 | | Layout scheduling for manufacturing | January 1st 2018 |
| Presentation Proposal | January 26nd 2018 | | Presentation Proposal | January 26nd 2018 |
| Order parts | January 31th 2018 | | Order parts | March 7th 2018 |
| Design modifications/manufacturing | February 1st 26th 2018 | | Design modifications/manufacturing | March 8th 2018 |
| Start Testing | March 1st 2018 | | Start Testing | March 1st 2018 |
| Spring break | March 12th -18th 2018 | | Spring break | March 12th -18th 2018 |
| Testing modifications | April 1st 2018 | | Testing modifications | April 18st 2018 |
| Final test | April 15th 2018 | | Final test | April 15th 2018 |
| Competition / Final Presentation | April 20nd 2018 | | Competition / Final Presentation | April 20nd 2018 |