BASIC UTILITY VEHICLE (BUV)

FRONT SUSPENSION AND STEERING DESIGN

A Baccalaureate thesis submitted to the

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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: Moise Cummings

ACKNOLEDGEMENT

The 2017 Mechanical Engineering Technology (MET) Basic Utility Vehicle (BUV) senior design team would like to extend their profound appreciations to the following individuals for their kindness in making this project successful. We cannot express the amount of impact your wonderful elemental contributions and donations have brought this project to reality due to lack of space here.

First and foremost, to Professor Moise Cummings, for your unique advice and guidance through the entire project. You really made a great impact coaching each and every member of the team the necessary requirements in putting both the structural of the vehicle and the final report together.

To “U pull and pay”, for donating the Chevrolet S10 paving way for the chassis of the vehicle to kick start the basis of the structural of the vehicle.

And last but not the least, to Professor. David Conrad, for your technical advisement throughout the designing and building the entire vehicle and also for hosting the Institute for Affordable Transportation Competition (IAT) in Batavia, Ohio.

ABSTRACT

In most impoverish countries, transportation is a challenged especially in the hinterlands where accessibility (roads) cannot be found. Going about the daily routines or activities such as going to school, the hospital, transportation of agriculture goods, fetching of water to and fro can be tedious due to lack of paved roads and low amount of financial resources in these countries. Pupils have to walk miles to school, women in labor and the sick barely make to hospitals which sometimes even lead to school drop outs and maternal deaths and other simple preventable deaths.

To curb these challenges, this project through the Institute for Affordable Transportation (IAT) will introduce a design, build and test a Basic Utility Vehicle (BUV) that will meet standardized requirements to be operated in this countries. The University of Cincinnati's College of Engineering and Applied Science's Mechanical Engineering Technology selects students who compete in the annual National Student Design Competition which is supported by the Institute for Affordable Transportation (IAT).

The BUV would be powered by a 10 horsepower gasoline engine and weighs less than a thousand pounds. It will be 135" long and 43" wide. The vehicle will be able to sustain a 500lbs loading force and tow little more than a 900lbs. It should be simple to maintain and portable to be transported in a form of kit. Simplicity will not compromise functionality. This project will improve the livelihood of the people in these impoverished countries by providing them with affordable but durable vehicle to facilitate community transformation and transportation.

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INTRODUCTION

PROBLEM STATEMENT

The Institute for Affordable Transportation (IAT) located in Indianapolis, Indiana, is a non-profit organization devoted to developing high-quality, low-cost transportation to provide mobility, freedom and economic hope to people in rural areas of developing countries. The vehicle is designed to transport people, water, and other materials. To develop a durable, low cost vehicle that can be built and maintained in a third world country. The vehicle should be suitable for farming and operating in areas without roads. The design should be in kit form and should be able to assemble with ease. Regulations for the competition are given on the specification sheet provided by the Institute for Affordable Transportation (IAT). The vehicle is to be ready for the competition on April 22nd, 2017. In order to achieve this project goals, workload was shared among team members and I Dickson Opoku was assigned to design the front suspension and the steering. Professor David Conrad technically advised the team through welding, fabrication and building of the Basic Utility Vehicle (BUV).

TEAM MEMBERS AND OBLIGATIONS

Bethany Nickson – Frame and Chassis

Dickson Opoku – Front Suspension and Steering

Chris Steward – Drive Train

Deaman Strefas – Irrigation System

Guanchun Ye – Brake system

RESEARCH AND BACKGROUND

PAST BUV DESIGNS

In order to come out with a more competitive design for the 2017 Basic Utility Vehicle (BUV), the team used past designs proposed by the Institute for Affordable Transportation (IAT), Utility Task Vehicles (UTV) and Recreational Off-Highway Vehicles (ROV) as a yardstick. The traditional norm of the Basic Utility Vehicle (BUV) is the three wheeled design, two wheels at the rear and one in front.

There are many reasons why the Institute for Affordable Transportation (IAT) enshrined the three wheeled vehicle: cost reduction, low maintenance, and cut down component parts thereby reducing the total weight of the vehicle allowing for reasonable moment of inertia thereby allowing for greater speed and overall increasing the lifespan and efficiency of the vehicle. A more critical look was made to vehicles which were successful or performed exceptionally in the previous competitions.

In Figure 1 is Alfred State College's 2016 Basic Utility Vehicle (BUV). Alfred States College won the 2016 National Basic Utility Vehicle (BUV) Competition. Most significant here, is the front suspension and steering design. The unit-strut suspension was chosen as a final design by the team.

Figure 1: Alfred State College 2016 BUV

The Basic Utility Vehicle (BUV) can accommodate different styles of front suspension and steering designs. However, most designs are in the 'Y-Shape' which engineers argue: it gives great agility for steering. Most of the steering are made from low carbon seamless steel of $^{3}/_{2}^{''}$ (OD) pipes providing greater gripping force on the handle bars. Figure 2 is the BUV Ghana. This steering design is popular for most (IAT) Basic Utility Vehicles (BUVs) in Ghana and across most countries where the Institute for Affordable Transportation (IAT) has a base or workshop for the BUV design and manufacture.

Figure 2: BUV Ghana

The John Deer Gator™ XUV Crossover is one of the popular Utility Transportation Vehicles (UTV) with great off-road performance. The design of the front suspension and the steering is quite different from that of the Basic Utility Vehicle (BUV) which also falls in the same family of vehicles. It has two wheels in front. The suspension kit is equipped with a shock and moog spring to absorb any impacts from a hard surface (tarred road) and may be quite expensive and not useful for the Basic Utility Vehicle (BUV) since it will be mainly used on an untarred roads in remote communities. Also, bear in mind that the Basic Utility Vehicle (BUV) requires a three wheel (tricycle) and may not be conducive considering this type of design for the front suspension and steering of the BUV. Figure 3 is the Gator™ XUV Crossover.

Figure 3: The Gator™ XUV Crossover

DESIGN CONCEPTS/ ALTERNATIVES

Concept 1: Earle's Fork Suspension

The Earle's fork is mostly used on most motorcycles and few times were used on some Basic Utility Vehicles (BUV). The Earle's fork has a lot of great advantages: good damping, precise turning/steering and dynamic compensation. However, it is mostly not a suitable choice for the Basic Utility (BUV). The suspension comes with a shock which is an expensive part and may be difficult to be replaced in case is worn out in those remote communities where the (BUV) will be operated. Figure 4 below is concept 1, Earle's fork.

Figure 4: Earle's Fork Suspension

Concept 2: Unit-Strut Spring and Shock

The Unit-Strut spring and shock is one of the most desirable designs for the BUV. It greater damping and steering clearance makes it a choice when considering suspensions and steering designs for BUVs. However, its complexity may not make it a good choice for the BUV, a lot of parts are needed to build this type of design and may be too expensive to put this on the BUV.

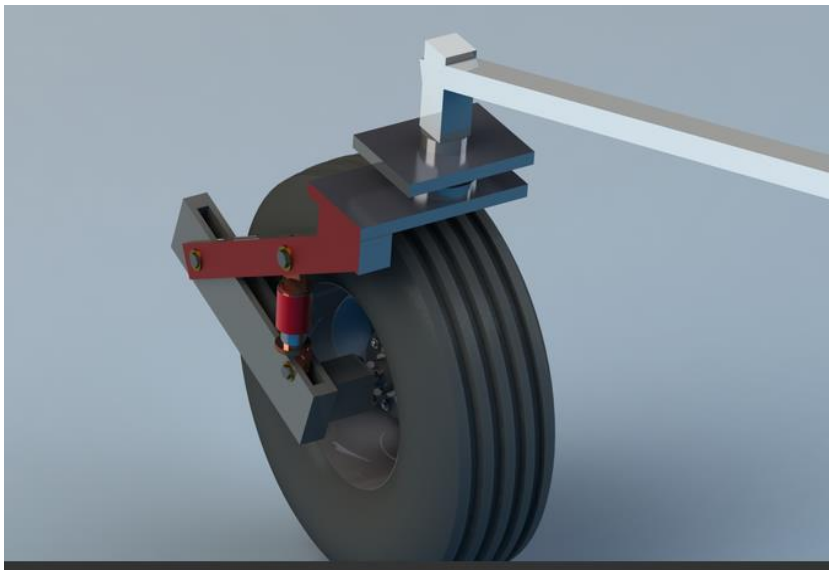

Figure 5: Unit-Strut and Spring Suspension

Concept 3: Unit-Strut Suspension

The Unit-Strut suspension is by far the simplest suspension design that has ever been used on the Basic Utility Vehicle (BUV). Although, it has some few disadvantages: poor damping on tarred roads, poor aesthetic, less parts, and light. However, the design is simple, requires few parts, cost effective, high agility, low maintenance and little to zero skills to manufacture or replace. These make the unit-strut more popular and unique on the Basic Utility Vehicle (BUV).

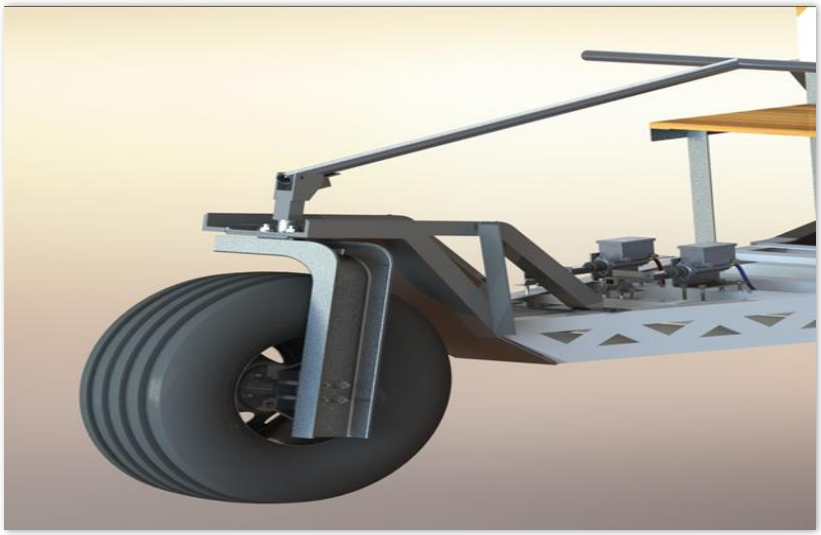

Figure 6: Unit-Strut Suspension

DESIGN SELECTION

Alternative concept/Embodiment Evaluations							
		Earle's Fork		Unit-Strut-Spring		Unit-Strut	
Criteria	Weight (%)	Rating	Wt. Rating	Rating	Wt. Rating	Rating	Wt. Rating
Cost	20	2	0.40	2	0.40	3	0.60
Durability	10	3	0.30	4	0.40	4	0.40
Maintainability	8	1	0.08	1	0.08	3	0.24
Manufacturability	8	1	0.08	1	0.08	3	0.24
Light Weight	5	1	0.15	2	0.10	2	0.10
Reliability	10	3	0.30	4	0.40	3	0.30
Safety	20	3	0.60	2	0.40	3	0.60
Customer Appeal	14	2	0.28	2	0.28	1	0.14
High Agility	5	1	0.05	1	0.05	2	0.10
		N/A	**2.24**	**N/A**	**2.19**	**N/A**	**2.72**
	Rating	Value					
LEGENDS	Satisfactory	0					
	Just Tolerable	1					
	Adequate	2					
	Good	3					
	Very Good	4					

Table 1: Alternative Concepts Rating

Upon further analysis of the three concept designs, the Unit-Strut was selected to be the final design for the University of Cincinnati Spring 2017 Basic Utility Vehicle (BUV) team.

There were many reasons why the team decided to choose this design. The Unit-Strut is built from ASTM A36 structural low carbon steel C-Channel which can be found everywhere and can be fabricated and welded by even an "unskilled person". The material has great properties and may be able to sustain the impacts that it may be subjected through. The combination of malleability and viscoelasticity of ASTM A36 make it a suitable choice for vibration damping.

MATERIAL SELECTIONS

The payload of the Basic Utility Vehicle (BUV) is 1500lbs and therefore the stress on the front suspension may be high. The properties of the chosen material are shown in Table 2 below. The yield strength of ASTM A36 is 36,300 psi which literally means that, the front suspension should be able to sustain the impact load, which the total weight of the BUV may exert including the cargo, the driver and a passenger.

Selected Material	ASTM A36 Structural Steel C-Channel
Parameter/Property	Numerical representation
Density	0.284lb/in3
Tensile Strength, Ultimate	58,000-80,000 psi
Tensile Strength, Yield	36,300 psi
Modulus of Elasticity	29,000 ksi
Compression Yield Strength	22,000psi
Shear modulus	11,500 ksi

Table 2: Properties of ASTM A36 Carbon Steel

LODING CONDITIONS	
Parameter	**Value**
Total weight of BUV	1,200 lbs
Applied force	5,680 lbs
Factor of safety	15

Table 3: Loading Conditions Parameters

FINITE ELEMENT ANALYSIS (FEA)/SIMULATIONS

The C-Channel molded and welded to the wheel hub was subjected to 5,680 lbs of load in order to determine its performance under normal loading condition. The suspension did not pass the test under this loading and this was due to few reasons: First, the angle at which the C-Channel was bend (45°) was the right angle but there was no reinforcement on the sides of the C-Channel and this contributed to the failure of the suspension. Second, the 1/2" steel plate support for the steering column was not thick enough to handle the impact loading. Therefore the steering column and both sides of the C-Channel have to be reinforced. Shown in Figure 7 below is the meshing simulation in SolidWorks.

Figure 7: Meshing Front Suspension

The maximum stress of the result from the Von Missis analysis was 68,880lbs which is far greater than 36,300lbs which is the maximum Tensile Strength of ASTM A36 C-Channel. This may not work under normal loading condition since it failed to pass the simulation test. Hence, modifying the steering mount or column and the wheel hub will cater for some the

excessive stress the may come from the vehicle. The Von Misses simulation results from SolidWorks is shown in the Figure 8 below. As you can see from the simulation results, the load or the force exerted on the bend angle position from the steering is great and from the graph, the light red color at the top indicates the point on the suspension at which the suspension will fail in real application.

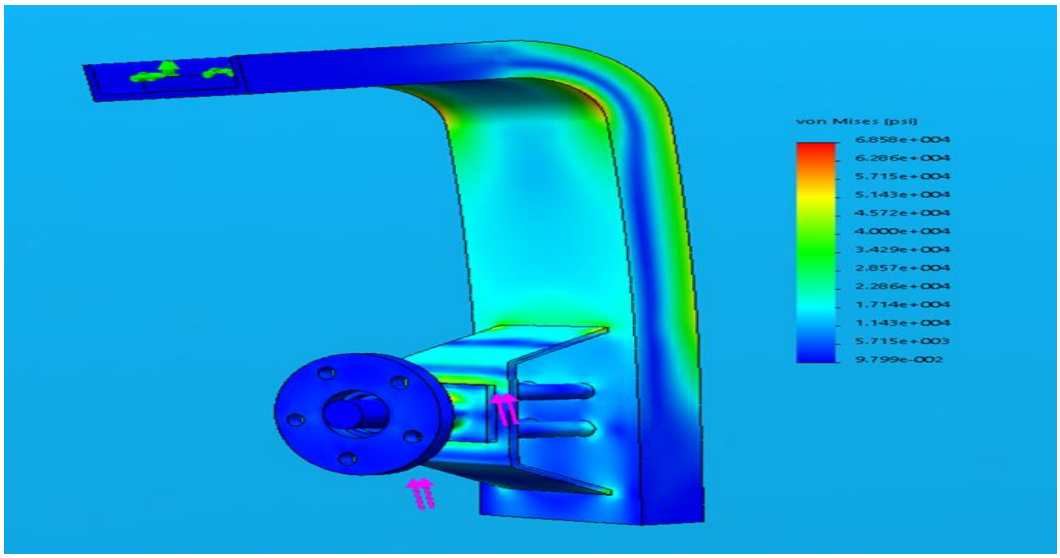

Figure 8: Von Misses Results from SolidWorks

In Figure 9 is the stress on the wheel hub mount. From the figure, the ground force on the agriculture tire may be highly opposing to the force exerted by the total weight of the BUV and may cause the wheel hub mount to fail in application. The far right picture shows the stress concentration on the 45° angle bend of the suspension.

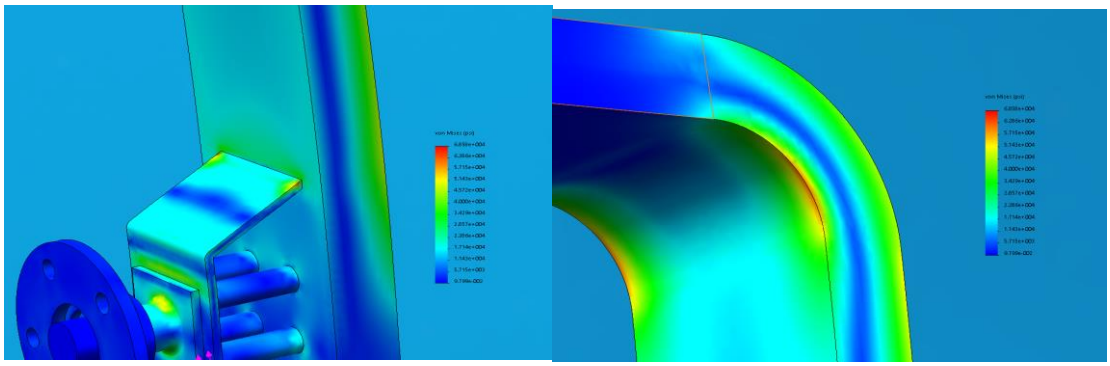

Figure 9: Von Missis Results of the stress concentration on the wheel hub mount

Modification of Front Suspension

In order to ensure that the front suspension bears the load exerted on it, a 4’’x 4’’ x 1’’ thickness steel plate was placed at the steering mount in order to bear the load or force from the vehicle. In Figure 10 is the reinforcement that was made at the top of the suspension to endure the load from the BUV and the entire cargo.

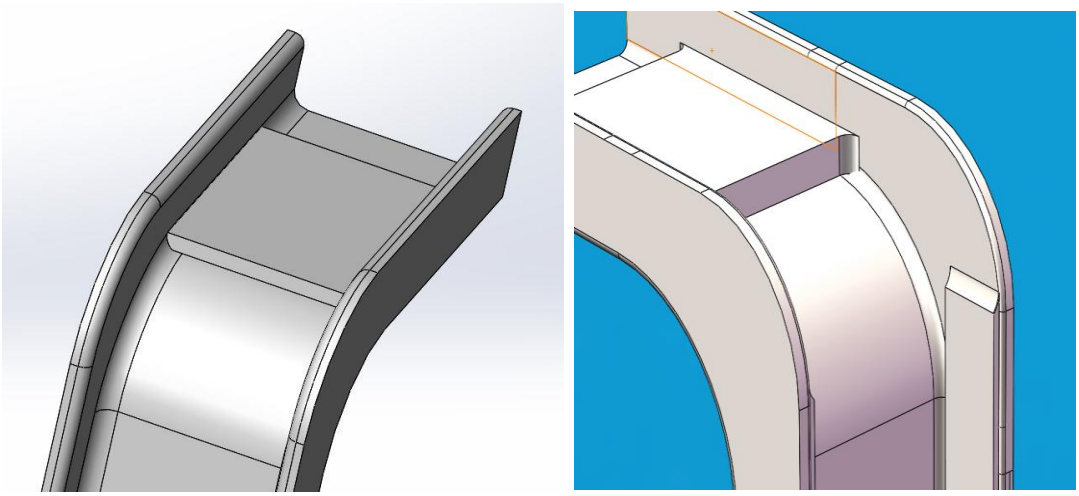

Figure 10: Reinforcement of the steering culumn of suspension

In Figure 11, the thickness of the steel plate for the wheel hub mount was inreased from the ½’’ to 1’’ thickness because it was not able to pass the simulation test. It was realized that part of the issue was due to the fact the plate thickness was small and may not be able to handle the force and vibration from both the ground and the BUV.

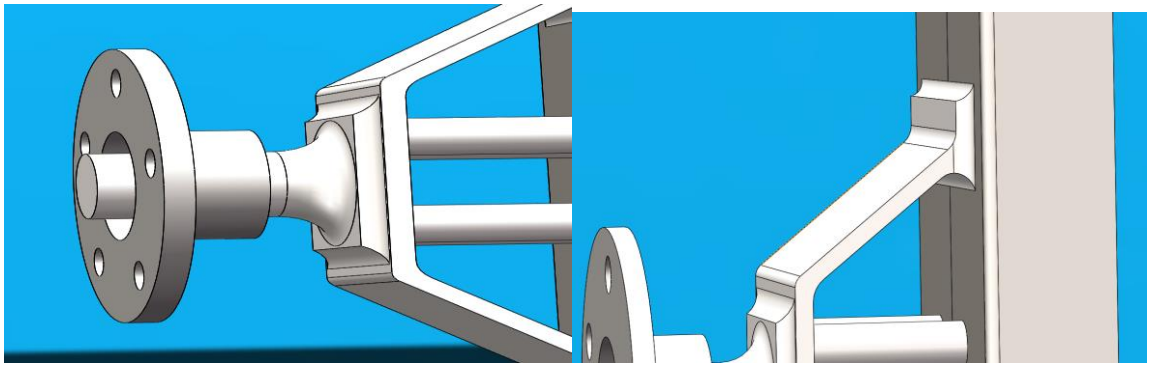

Figure 11: Reinforcement of Wheel hub

After applying the reinforcement, the result of the Von Missis was 28,520 psi which is less than 36,300 psi, the maximum Tensile Strength of ASTM A36 C-Channel. A steel plate of 4’’Length x 4” Width x1” Thickness was used to reinforced steering column to ensure is able to carry the load from the BUV and the steering. This means, the front suspension should be able to sustain the loading conditions that may be exerted by the Basic Utility Vehicle (BUV) and all other cargoes that it be subjected to. Shown in Figure 12 is the Von Misses simulation results after the reinforcement.

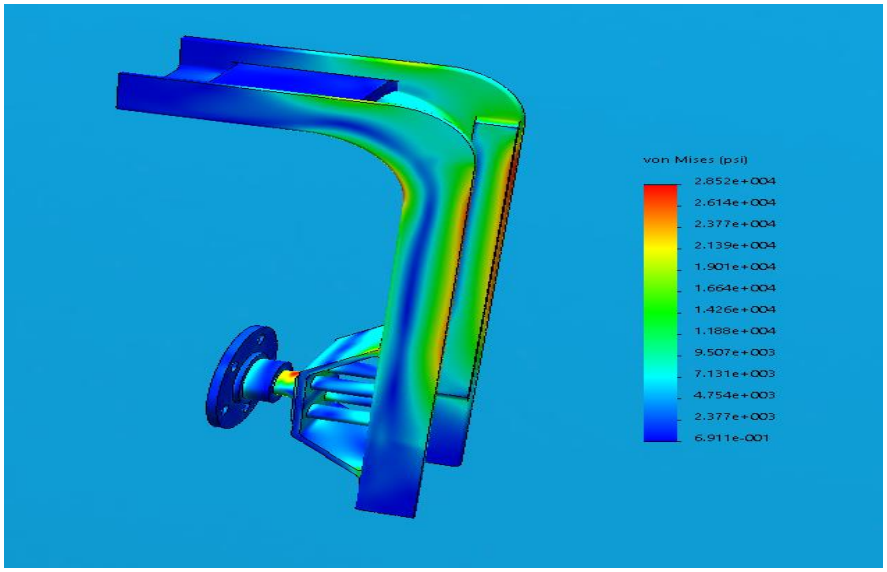

Figure 12: Von Misses Result after Reinforcement

WELDING, FABRICATION AND ASSEMBLY

Upon reinforcing both the steering column and wheel hub mount, the simulation test was successful then comes the welding, fabrication and assembly of component parts. Shown in Figure 13 is the welded front suspension. The 1’’ steel plate wheel hub mount has four 1’’ x 1’’ squared steel pipes through which the bolts that will be used to fasten the wheel hub from Raybestos AGB-713157. These pipes do not only serve as locations for the hub mount but they also serve as supports for the bend steel plate. Also, the 45° bend at the top of the suspension was welded on both sides as reinforcement to prevent any cracking of fracture during application.

Figure 13: Welding and fabrication of suspension

The wheel hub from Raybestos was mounted onto the wheel hub mount. For security reasons, this was a press fit. The hub was pressed to fit into the mount and then bolted to secure it tightly into the hole. In Figure 14 is the wheel hub that was mounted onto the hub mount.

Figure 14: Wheel hub from Raybestos AGB-713157

In Figure 15, after the welding and fabrication works was done, excess material from the weld beads were being grinded to make room for the top hub to be mounted.

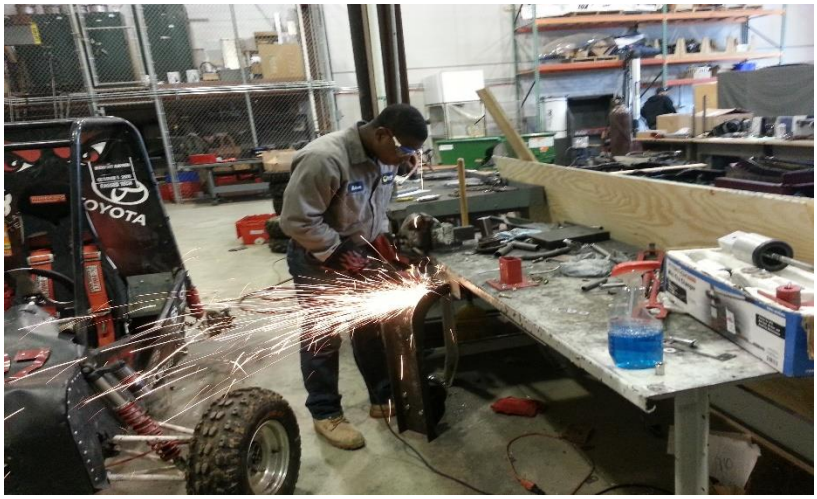

Figure 15: Grinding excess weld beads at steering column

Once all the welding and fabrication works were done, the front suspension was mounted onto the front end of the vehicle and this can be seen in Figure 16 below. The design of the steering hub is just like that of the wheel hub. The steering hub was also mounted into a steel plate welded to the projected end of the frame of the front end or the chassis. One cool thing about the steering hub is that, it allows the steer to be turned at 360° without causing damage to any component of the system. It is a simple design and strong in application.

Figure 16: Assembly of Unit-Strut front suspension

STEERING

The general style of the Basic Utility Vehicle (BUV) steering design is the 'Y-Shape'. It was agreed that the steering will be a single 3/2'' steel tubing at a convenient length that runs from the suspension steering mount column to the drivers cabin of the vehicle. However, after continously accessing the single tubing for the steering, it became advisable that a modification has to be done by changing from single tubing to double with the same size of tube. The complete assembly of the front suspension and the steering is shown in Figure 17.

Figure 17: Steering mounted onto front suspension

TESTING, MODIFICATION AND PROOF OF DESIGN

The vehicle was not completed at the scheduled completion date and because of this most of the testing were done on the day of the competition at the farm and also due to lack of the type of environment or terrain needed to test the vehicle around the workshop where the vehicle was built. Before the commencement of the competition I did the basic tests of shaking and pushing the vehicle back and forth. The vehicle was able to pass most of the required specification tests: The vehicle should be able to have a ground clearance from its lowest point to the ground of at least 9". The vehicle was measured and it was at 10" without any cargo and a driver or passenger at its lowest point and this was done by a tape measure.

To check the resistance of the front wheel to the ground when the brakes are applied, the vehicle was pushed and the brakes were applied. Although the vehicle is equipped with drum

brakes at the rear wheel, braking the whole vehicle has a tremendous impact on the front suspension and because of this, the brakes were applied whiles three team members pushed onto the vehicle from the rear to see if the suspension will shake but it was able to stay steady. In that sense, the brakes tested well as they should during normal driving.
The travel requirement of 1" was measured with a tape measure whiles there was no load in the vehicle and it came out to be 7.5" and then the cargo was added and the measurement came out to be 4.8" which obeys the 1" travel requirement spec of the front suspension. A tape measure was used to obtain these data. The rake angle of the front wheel was measured using a ruler and a protractor. After checking it, it came out to be 21° which surpasses the 20° specification for the rake angle. Since most of the specification test were done in the farm, little was the vehicle familiar with the terrain. Most of the tests went well until during the competition of which the vehicle got stuck in the mud. Shown in Figure 18 is the complete assembly of the front suspension and steering design at the farm during the testing and before the commencement of the competition.

Figure 18: Specification test

The vehicle is required to complete a 2.2 miles course of a rough and muddy terrain, unfortunately, the vehicle did not make it to the end of the competition. There were many reasons why the vehicle did not finish the course; the team did not put into account the how deeper and bumpy some of the areas of the field would be and since all the major tests were made during the competition especially the test driving, the vehicle was not used to the terrain and eventually the front suspension got stuck in one deep hole due to low height from the ground to the lowest end of the suspension which was lower the hole encountered in the course of the competition, also the speculations were that, the engine weight may not have much effect on the front suspension thinking that, once the cargo is loaded, the center of gravity of the vehicle will be closer to the rear. However, upon driving on at a steep area of the course, the total weight of the vehicle, cargo, driver and the passenger all exerted a tremendous amount of force on the front suspension causing it to fail in the process with the wheel hub coming apart. Figure 19 shows the vehicle stuck in the mud.

Figure 19: Vehicle stuck in the mud

PROJECT MANAGEMENT

In order to keep ourselves on track each and every team member created a projected schedule for his or her specific obligation and also the entire project schedule. This was

agreed upon by every team member because it was assumed that falling behind on any of the members will likely hinder our chances of completing the project on time and it was unfortunate although we were able to finish the project but fell few days behind. The vehicle was completed a day before the day of the competition and therefore little testing was done on the vehicle. The major part of the test was done on the day of the competition and because of this, the team was not able to rectify few hindrances. These contributed to the vehicle not to be able to finish the competition. Table 4 shown below is the project schedule for the front suspension.

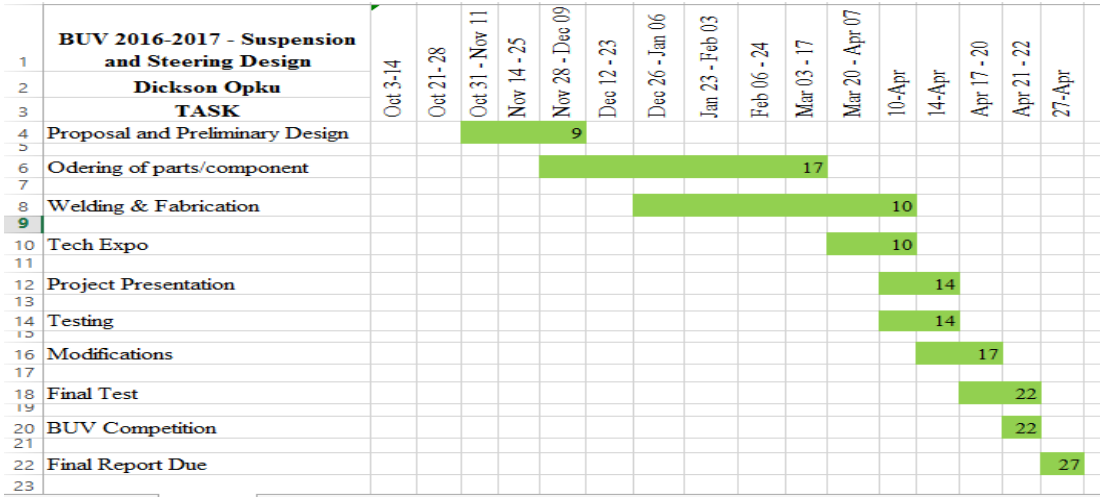

Table 4: Project Schedule

BUDGET

The main goal of the budget is to track how much is spent on the vehicle. The team did not send out sponsorship forms and therefore little to nothing was received from the general public. However, “U pull and Pay” donated a Chevrolet S10 from which the main chassis of the vehicle was built on bringing the total cost of the general proposed budget down. On the front suspension, it was solely sponsored by the designer. The table below shows the total amount or the cost for both the front suspension and the steering.

Bill of Material	Quantity	Unit Price	Total Price
15 x 6 Agriculture Tire	1	$25	$25.00
15 x 6 Rim	1	$51.98	$51.98
½ inch x 2 ½ Hex Bolt	6	$0.75	$4.50
½ inch x 1 Hex Bolt	4	$0.75	$3.00
½ inch Hex Nut	17	$0.38	$6.46
½ inch Flat Washer	12	$0.38	$4.56
Front wheel mount base	1	$8.35	$8.35
6 inch x 32 inch C-Channel steel	1	$14.44	$14.44
4 x 6 x ⅜ Reinforcement plate	1	$5.00	$5.00
4 x 4 Mount base of steering system	1	$11.50	$12.00
Steering Axis unit	1	$12.25	$12.25
5 x 5 ¼ Reinforcement plate	1	$4.00	$4.00
Steering Handle bar	1	$3.00	$3.00
Steering rod	1	$6.00	$6.00
Total			**$160.54**

Table 5: Budget

CONCLUSION

In general, it was a nice experience to design both the front suspension and the steering for the 2017 Basic Utility Vehicle (BUV). The vehicle tested alright despite the fact that we fell few days behind schedule. The Unit-Strut proved that it is capable of bearing the weight of the vehicle which many doubted because, during the final presentation, the moderators wanted to know if the load on the suspension may not cause it to fail since it is placed on one side of the wheel but during the competition the suspension was able to sustain any impact load that it was subjected to. I made the moderators aware that, the suspension was able to pass the simulation test and therefore should be able to strive in the competition. Although, the wheel hub came apart through the process of the competition, it was not the suspension that caused that to happen since the hub itself was a used one that was donated. Overall, the front suspension performed as it should and I am still convinced that, the Unit-Strut suspension is one of the simplest and cheapest to use on the Basic Utility Vehicle (BUV). With the steering, it did performed more than we expected, the double bar provided great stiffness and gripping force in the course of the competition especially in the muddy areas of the course. Overall, it was a great exposure to be a part of the 2017 Basic Utility Vehicle (BUV) team designing the front suspension and the steering. I recommend that, the next team that will take up this challenge should be able to work within schedule because our main short fall was the schedule leading to not enough testing before the competition day.

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APPENDIX A - RESEARCH

Alfred State College BUV: National Winner 2016

http://www.alfredstate.edu/news/2016-05-06/buv-team-ties-first-annual-competition

Feature:

Three wheeled

Front end connected to truck bed

10 hp engine

Great ground clearance

Easy to assemble

"Off the shelve parts"

Great clearance angle

BUV Ghana

https://www.google.com/search?q=BUV+Ghana&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiq4KmVuq_TAhWG1IMKHV9cBesQ_AUICSgC&biw=1252&bih=602#imgrc=5X20G-_-i7s0IM

Features:

"Y-Shape" steering handlebars

3 Wheeled Vehicle

10 hp engine gasoline

Good ground clearance

20 mph

Payload 1200

Original Design

Low center of gravity

Twist grip throttle

Tight turning radius

Electric start

The Gator™ XUV Crossover

https://www.deere.com/en_US/products/equipment/gator_utility_vehicles/gator_utility_vehicles.page

Features:

Four wheeled

Speed 28 mph

Engine 570cc gas

16 hp at 3600 rpm

V-twin Cylinder

Price $8,139

Low center of gravity

 **Gator™ Military A1** http://www.deere.com/en_US/products/equipment/gator_utility_vehicles/military_utility_vehicles/m_gators/m_gators.page	**Features:** 854 cc (20.8 hp) diesel engine Speed 20 mph Four wheeled Good ground clearance

CONCEPTUAL SKETCHES OF SUSPENSION AND STEERING

Earle's Fork Suspension

Feature:

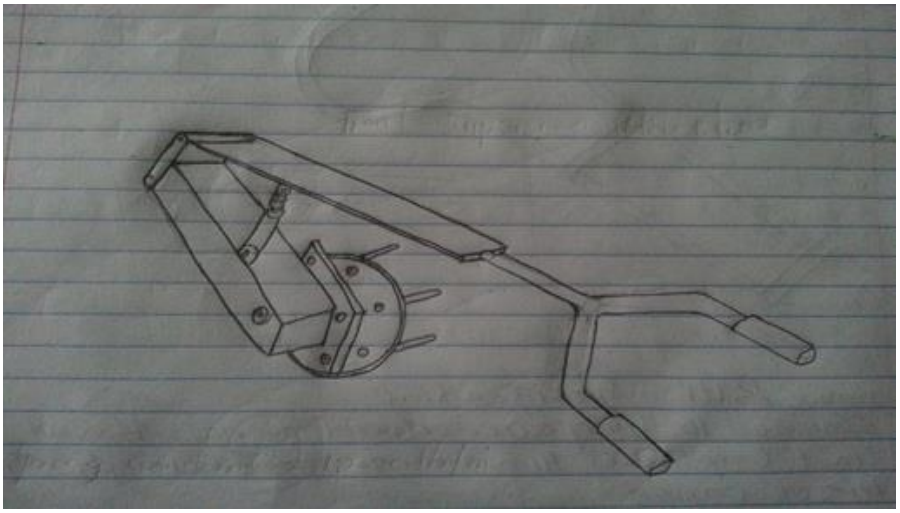
Great damping

Good steering control

Dynamic compensation

Good stability

Requires more parts to build



Unit-Strut Spring and shock

Feature:

Good damping

Durable

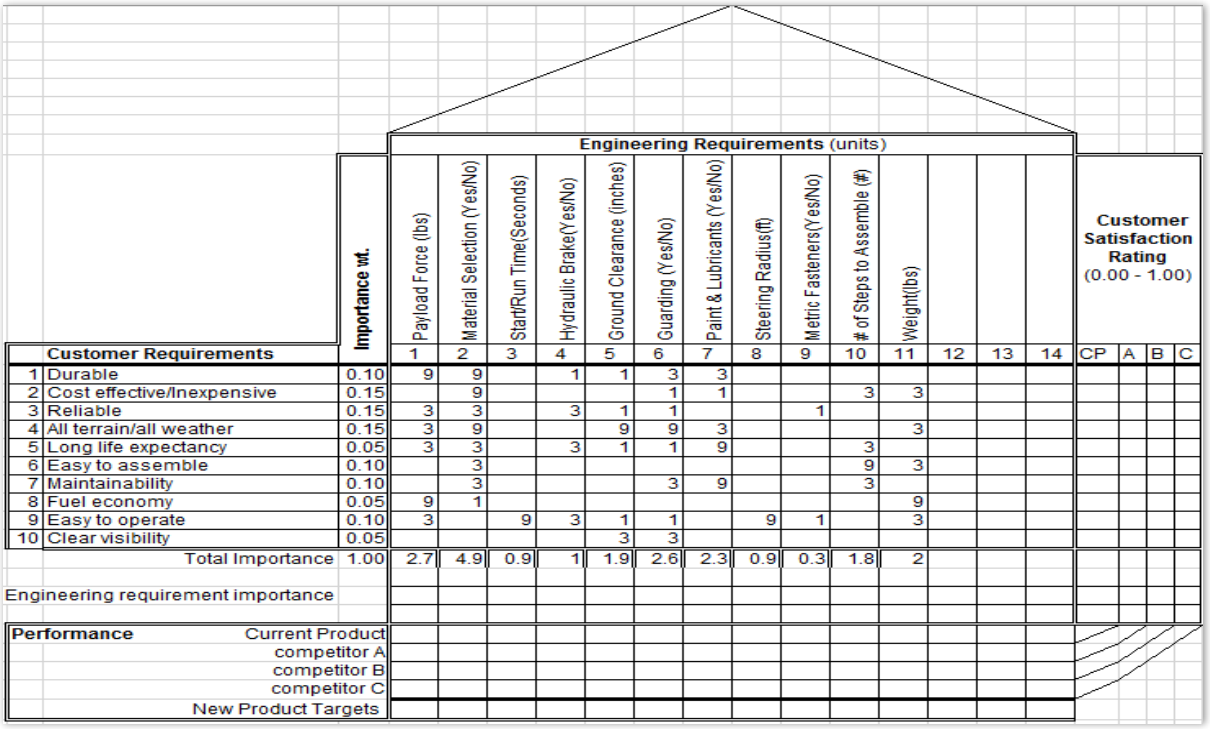
Great turning

Many parts

Expensive than the normal Unit-Strut

APPENDIX B –QFD AND HQ

Quality Function Development (QFD) and House of Quality



	Customer Requirements	Importance wt.	Payload Force (lbs)	Material Selection (Yes/No)	Start/Run Time(Seconds)	Hydraulic Brake(Yes/No)	Ground Clearance (inches)	Guarding (Yes/No)	Paint & Lubricants (Yes/No)	Steering Radius(ft)	Metric Fasteners(Yes/No)	# of Steps to Assemble (#)	Weight(lbs)				CP	A	B	C
			1	2	3	4	5	6	7	8	9	10	11	12	13	14				
1	Durable	0.10	9	9		1	1	3	3											
2	Cost effective/Inexpensive	0.15		9				1	1			3	3							
3	Reliable	0.15	3	3		3	1	1			1									
4	All terrain/all weather	0.15	3	9			9	9	3				3							
5	Long life expectancy	0.05	3	3		3	1	1	9			3								
6	Easy to assemble	0.10		3								9	3							
7	Maintainability	0.10		3				3	9			3								
8	Fuel economy	0.05	9	1									9							
9	Easy to operate	0.10	3		9	3	1	1		9	1		3							
10	Clear visibility	0.05					3	3												
	Total Importance	1.00	2.7	4.9	0.9	1	1.9	2.6	2.3	0.9	0.3	1.8	2							
	Engineering requirement importance																			
	Performance: Current Product																			
	competitor A																			
	competitor B																			
	competitor C																			
	New Product Targets																			

Interaction Matrix

Engineering Requirements		Payload Force (lbs)	Material Selection (Yes/No)	Start/Run Time(Seconds)	Hydraulic Brake(Yes/No)	Ground Clearance (inches)	Guarding (Yes/No)	Paint & Lubricants (Yes/No)	Steering Radius(ft)	Metric Fasteners(Yes/No)	# of Steps to Assemble (#)	Weight(lbs)	0	0	0
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Payload Force (lbs)	1		3		1		3			1					
Material Selection (Yes/No)	2						3					9			
Start/Run Time(Seconds)	3														
Hydraulic Brake(Yes/No)	4								1						
Ground Clearance (inches)	5														
Guarding (Yes/No)	6									9	3				
Paint & Lubricants (Yes/No)	7										3				
Steering Radius(ft)	8									3		3			
Metric Fasteners(Yes/No)	9										1				
# of Steps to Assemble (#)	10														
Weight(lbs)	11														
0	12														
0	13														
0	14														

APPENDIX C - PRODUCT OBJECTIVES

BUV Design Competition

Durability (10%)

- The materials that will be employed will be looked at through a spectrum of materials to ensure the vehicle is able to withstand the challengers that it may be put through

Cost Effective/Inexpensive (15%)

- Affordable vehicle with parts "off the shelf"
- No special parts be involved in building the vehicle.

Reliable (15%)

- Materials and parts may be selected through mathematical analysis to ensure the vehicle meets standardized requirements so that it will be able to withstand the conditions of the course during the competition and thereafter.

All terrain/weather (15%)

- The vehicle will be built to have not less than 10" ground clearance except already assembled members (the differential, the lower end of shocks, leaf spring, etc)

Long life expectancy (5%)

- Standard finishing would be applied, example lubricants, paints to ensure that the lifespan of the vehicle is increased
- All electrical components, transmission, the engine will be covered to ensure water or any foreign material does not go through.

Easy to assemble (10%)

- Standard parts will be used
- No professionals or skilled person needed to assemble the vehicle

Maintainability (10%)

- Easy access to every part in the vehicle
- Standard bolts and nuts will be used and standard tools employed in maintenance

Fuel Economy (5%)

- The vehicle should be able to go through the 2.2 miles course without emptying the fuel tank

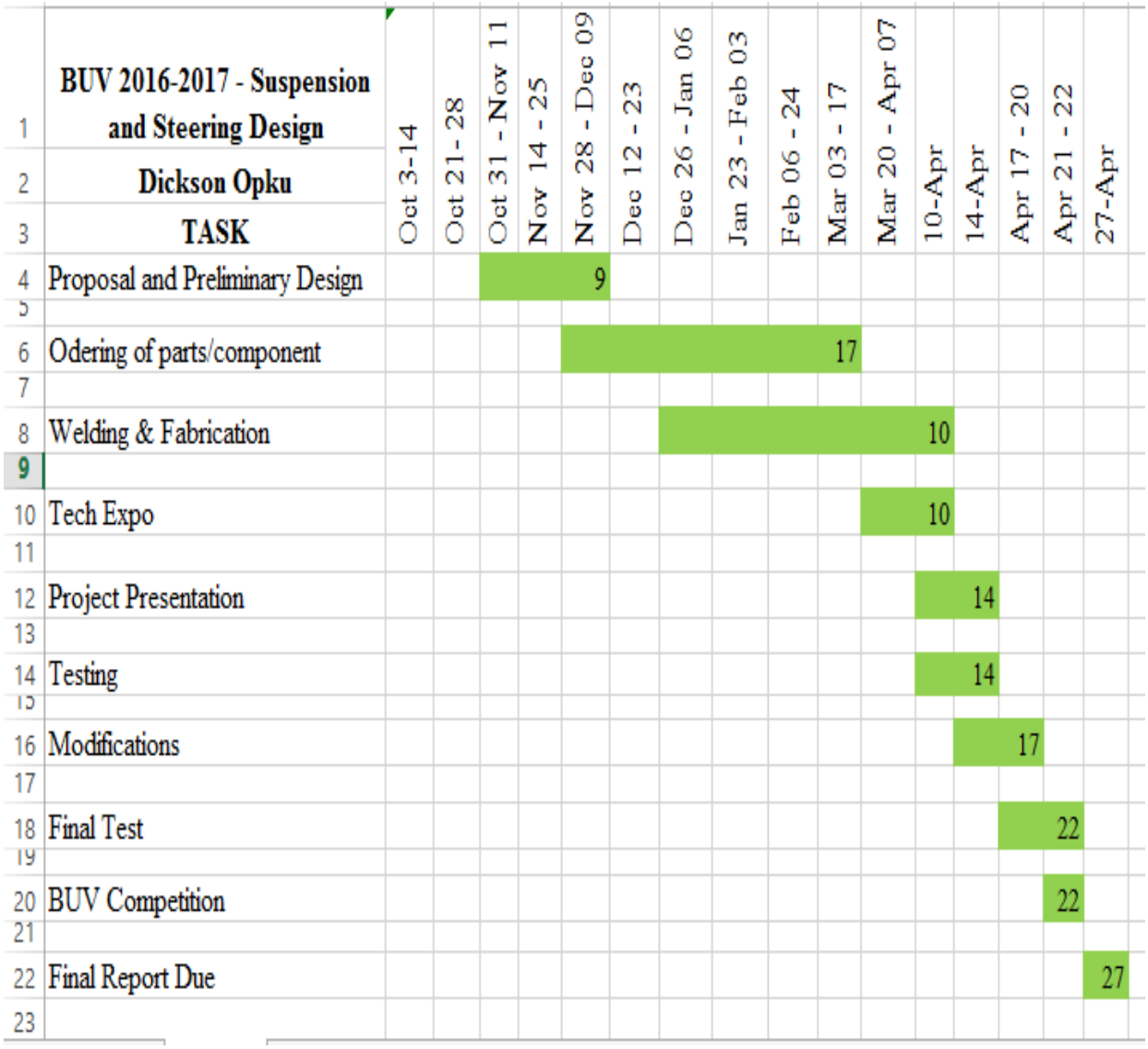
Easy Operate (10%)

- No professional skills required to operate the vehicle
- A 10 horse power engine with easy turn “on” and “off”

Clear Visibility (5%)

- No windshield required on the vehicle
- Helmet required to operate during the course of the competition

APPENDIX D– SCHEDULE



APPENDIX E - BUDGET

Bill of Material	Quantity	Unit Price	Total Price
15 x 6 Agriculture Tire	1	$25	$25.00
15 x 6 Rim	1	$51.98	$51.98
½ inch x 2 ½ Hex Bolt	6	$0.75	$4.50
½ inch x 1 Hex Bolt	4	$0.75	$3.00
½ inch Hex Nut	17	$0.38	$6.46
½ inch Flat Washer	12	$0.38	$4.56
Front wheel mount base	1	$8.35	$8.35
6 inch x 32 inch C-Channel steel	1	$14.44	$14.44
4 x 6 x ⅜ Reinforcement plate	1	$5.00	$5.00
4 x 4 Mount base of steering system	1	$11.50	$12.00
Steering Axis unit	1	$12.25	$12.25
5 x 5 ¼ Reinforcement plate	1	$4.00	$4.00
Steering Handle bar	1	$3.00	$3.00
Steering rod	1	$6.00	$6.00
Total			$160.54

APPENDIX F – DESIGN SPECIFICATIONS

Engine

- 10 horse power (diesel or gas) and will not be enhanced. Backup tank may be allowed on the vehicle. Only stock tank on engine may be allowed.

Transmission

- The transmission is a tuff torq transmission and may not need enhancement. It is required that two forward speeds transmission be used with back/reverse shifts as well.

Exhaust

- The exhaust may be relocated from the stock muffler to keep engine compartment under normal temperature. Exhaust may be shielded to prevent burns.

Electrical

- A battery of must be 12 volts employed with a 35 amps alternator of any trade name choice.

Cargo bed

- The bed would be built to hold three 55 gallons tanks/drums of water amounting to 165 gallons of water in the course of the competition. This will be built with 2”x2” angle iron framing the back and will be fabricated using standard bolts and nuts for easy disassemble. The bed will be made of ½” plywood of which the drums would be stack on it with fasteners to secure the drums in place. It must be at least 18 square feet in area.

Fuel

- Standard fuel from retailers would be used and no premix fuel would be allowed likewise any lubricant (engine oil, brake fluid, transmission oil etc)

Driver Safety

- In the competition, the driver and the passenger are required to wear a helmet. Seat belts are not obligatory.

Vehicle Safety

- A fire extinguisher must be attached to the vehicle.
- All rotating and moving parts must be guarded.

- Engine has a quick shutoff mechanism located on the side of the fuel tank which can be reached as quickly as possible to start and shutoff engine.
- An automotive horn of about 110dB.
- A reflective visibility cyclist safety flag be mounted at a convenient place on the vehicle.
- Steering handle must have a padding as well as a sharp edges.

Appearance

- It must bear the University name and if possible be painted with university colors.

Suspension

- The must be suspension on all the three wheels. The front suspension must have a travel of at least 1" and the rear with at least 3'' travel.

Ground clearance

- The vehicle must have at least 8" ground clearance with cargo and at least 10" ground clearance without cargo.

Water pump

- The pump should be able to fill the three drums in less than 15 minute and must have connecting hoses during the competition to aid in the water pumping.

Towing

- All vehicles involved in the competition must have a 25 foot looped end to aid in towing the vehicle in case is stuck in the event during the course.

Parking brakes

- The vehicle must be equipped with a redundant braking system to prevent the vehicle from rolling over when is parked.