Basic Utility Vehicle (BUV)  
Steering and Suspension System

A Baccalaureate thesis submitted to the  
School of Dynamic Systems  
College of Engineering and Applied Science  
University of Cincinnati

in partial fulfillment of the  
requirements for the degree of  

Bachelor of Science  
in Mechanical Engineering Technology

by  
Kabimbi Kalubi

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Thesis Advisor: Janak Dave, PhD
ACKNOWLEDGEMENTS

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With your dedication and support, we succeeded in designing and fabricating a vehicle for change.

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To J&N Auto Electric, for the company’s contributions to the project.

To Systecon, for the company’s contributions to the project.

To Dr. Allen Arthur, for your support in the project.

And last but certainly not least, to Dr. Janak Dave, for your steadfast advisement of our project. Without your tireless support and guiding hand to lead us, we surely would not have succeeded.
ABSTRACT

In third world countries, there is a need for cheap, reliable transportation. The Institute for Affordable Transportation (IAT) will hold a contest on April 19, 2014 in which ten teams will competed in an endurance race while transporting water around the course. Not only did the vehicles need to endure the course for eight hours, but the purpose of the vehicle is also to be inexpensive, practical, and meet the specifications of the competition.

The University of Cincinnati College of Engineering and Applied Science had a team of five members who contributed to the design, fabrication, assembly, and competition. The design was broken into the drive train, the brakes and electrical system, the frame and chassis, the irrigation system, and the suspension and steering. I, Kabimbi Kalubi, am in charge of the suspension and steering. The overall project was headed by Anthony Price and the advisor for the project was Dr. Janak Dave. The following report explains in detail the design work for the suspension and steering.
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INTRODUCTION

PROBLEM STATEMENT

The Institute for Affordable Transportation, also known as IAT, is the innovator for BUV’s. They were formed in 2001 as a non-profit organization in order to facilitate third world countries by providing them with basic utility vehicles, BUVs. The vehicle is meant to be an inexpensive and simple vehicle to help third world countries sustain economic growth and relieve them of daily encumbrances such as bringing home goods from far away stores or transferring heavy goods. As far as innovation design for the vehicles goes, IAT hosts the BUV competition every year around April. The teams are comprised mainly of clubs and senior design projects.

For the 2014 event, there will be a total of 10 teams from across the nation. The competition will last about a day and a half in Batavia, Ohio. The vehicle is meant to handle off-road terrain since paved roads are not a common thing to see in third world countries. The vehicle should also be made for low maintenance since the countries lack the funds and tools. Because of this, the assumption is the vehicles are not readily available to repair these BUVs. To encourage teams’ designs to meet these criteria, IAT gives out a spec sheet every year for the teams to follow. See Appendix A for all competition specifications.

TEAM MEMBER RESPONSIBILITIES

Anthony Price
- Drive-train, Engine and Transmission

Kabimbi Kalubi
- Suspension and Steering

James Tierney
- Electrical Systems and Brakes

Nick Isaac
- Frame and Chassis

Chris Burkett
- Irrigation System
The research that aided to design the 2014 BUV comprised of past BUV competitions, the BUV website, other Utility Vehicles, and other components that pertained to our field for the research process. We also paid close attention to vehicles with a strong performance from past competitions. The norm of all of BUV steering and suspension systems are Y-shaped handle bars configured with the uni-strut design. However, since the design specifications require our final design to be cheap and affordable, it makes sense that the uni-strut design is a common for BUVs. Due to the design specifications of the competition any choice steering/suspension combination can work as long as it positively affects speed, acceleration, and the weight of the vehicle to mention a few. The 3-wheel design helps with coming up with an easier design for the suspension. With a 4-wheel design there a lot of elements and components working off of that one suspension. The 3-wheel suspension limits unknown elements. Having a 4-wheel vehicle would aid in steering more weight and that is not a beneficial approach. The suspension should be able to sustain any type of terrain. Some styles of suspension have been used more than others due to their consistent production and ease of design. Steering for a BUV has to comfortable for types of drivers. Regardless of weight, height, and age the steering must be universally comfortable.

In the example below, you can see Alfred State College’s (ASC) final choice of a suspension. Also they won the 10th National BUV competition.

Figure 1- Alfred State College 2008 (1)
BUV’s have different designs for steering. Some designs consist of handle bars extruding from one piece of pipe. Sometimes handle bars will be made as two whole bars and then bolted at the bottom near the wheel. The image below is of the first BUV that was sent to Haiti. In this picture, the handle bars are two separate pieces but welded at the fork to give the ability to turn. Also if you notice the front suspension of the vehicle is that of a uni-strut suspension.

Figure 2 – BUV in Haiti (2)

In the next image, the steering design for the vehicle was a regular steering wheel. It’s the same as any wheel you would see on any kind of vehicle.

Figure 3- Calvin College BUV

The known consensus for having a steering wheel is that it is accompanied by a four wheel vehicle just like the BUV in Figure 3. Their front suspension is supported by coil springs to help impact any hard impact from certain terrains.
For the 2014 BUV competition, the design specifications for the suspension system is stated as followed: Suspension is required on all wheels. Require at least 1” of travel on front wheel; 3” on rear wheels. The suspension is one of the most important parts of the vehicle. There are plenty of different types of suspension. The suspension has to be simple yet delicate enough to sustain the punishment it will go through with the tough terrain. In Figure 3, this group went with a low brace design.

Figure 4 – University of Missouri BUV (3)

This group’s suspension of choice is a low brace design. A low brace design has its pros and cons. A low brace suspension helps keep the center of gravity low. It also a good way to keep your suspension lightweight and inexpensive. Unfortunately, this type of suspension is not as stable of a design as other suspensions when it comes to connecting with the chassis of the vehicle. It’s also a design that tends to stray away from simplicity of the project overall.
As far as the steering goes for the vehicle, there were no requirements from the design specifications. However amongst the group, we decided that we were going with the norm for BUV’s, steering handlebars, instead of a steering wheel. Handlebars are usually the ideal choice for BUV’s because eliminates complications in the building process. Handlebars are more simplistic than the steering wheel. IAT’s vehicles contain handlebars. As it is shown below in Figure 4.

![Figure 5 – IAT BUV (4)](image)

The only problem with handle bars is the fact that once installed it may require more power to steer the vehicle. Unlike the steering wheel where the driver’s motion is all in his/her arms. Handlebars may require the driver to use other parts of his body to turn.
CUSTOMER NEEDS AND REQUIREMENTS

PRODUCT OBJECTIVES

The Product objectives from Appendix C are comprised of the design specifications of the BUV competition, engineering characteristics, and customer features. The product objectives are listed in order of importance for the design. This serves as a guideline to help formulate a Proof of Design contract with the advisor of the project. The results were justified within the team through weekly meetings. Listed below are the BUV product objectives.

1) **Has sufficient capacity (13%)**  
   a) Maximum payload will be 2500 lbs. including the driver.

2) **Durable (13%)**  
   a) Materials and parts will be selected from mathematical analysis to withstand the stresses the vehicle will face on the course.

3) **Handle rough terrain (12%)**  
   a) Vehicle will be equipped with off-road tires.  
   b) Vehicle will have suspension capable of handling the course terrain.  
      i) Front suspension will have 3 in. of travel  
      ii) Rake angle will be at most 20°  
      iii) Rear suspension will handle a maximum payload of 2500 lbs.  
      iv) Front wheel can endure the stresses of a 3 foot drop

4) **Affordable (11%)**

5) **Easy to Maintain (8%)**  
   a) Access to each component in the vehicle.  
   b) Flat head screws will be used.  
   c) Vehicle will be maintained using standard tools.

6) **Easy to Manufacture (11%)**  
   a) Will use standard parts.  
   b) Vehicle can be assembled without the use of custom tools or specialized professionals.

7) **Easy to Operate (10%)**  
   a) Handle bars instead of a steering wheel.  
   b) Turnkey or push button ignition.

8) **Long life expectancy (6%)**  
   a) Standard paints and lubricants will be used to increase the life of vehicle parts.  
   b) Engine, transmission, and electronic components will be enclosed to prevent water
from damaging them.

9) Fuel Economy (16%)
   a) Vehicle will go 4 laps during the competition without refueling.

10) Safety (16%)

11) Weather resistant (16%)
   a) Electronics, engine, and transmission will be enclosed.

12) Has the ability to tow (16%)

13) Small turning radius (16%)
   Wheel base and handle bar range will be designed to allow a minimum 10ft. turning radius.

14) Has sufficient driver visibility (N/A)
   a) Headlight
   b) No windshield
   c) Cargo bed will not block drivers rear view

15) Operated by one person(N/A)
   a) Only one person required to drive the vehicle

The product objectives that you see above represent qualities with the most importance. The most important qualities are at the bottom of the list. Some of the requirements with the highest importance are safety, fuel economy, and being weather resistance.
STEERING AND SUSPENSION SYSTEM REQUIREMENTS

1) Affordable (25%)
   a) Low material usage

2) Light Weight (16%)
   a) Low material usage
   b) Low number of components for suspension

3) Durable (20%)
   a) Use mathematical analysis to determine stresses

4) Easy Maintenance (17%)
   a. Access to each component in the vehicle.
   b. Flat head screws will be used.
   c. Vehicle will be maintained using standard tools.

5) Easy to Manufacture
   a. Will use standard parts.
   b. Vehicle can be assembled without the use of custom tools or specialized professionals.
DESIGN

DESIGN ALTERNATIVES SELECTION

FRONT SUSPENSION

When researching different types of suspension, I came across four types that could possibly make it to becoming a part of our vehicle. Each one of the suspensions was researched with deep thought. The four types of suspension systems that I researched were Hossack Suspension, Earle’s Fork, Motorcycle Design, and Uni-Strut.

1) Hossack Suspension

The Hossack Suspension is normally found on the front of racing cars. The tetrahedron design helps reinforce the suspension. The tetrahedron is a collection of triangles, the strongest geometry. The Hossack Suspension hasn’t been seen in past competition to my knowledge. (6)

This style is complicated as you see all the points that would need to be welded. It would require a lot of material on the other hand. I believe this is so because Hossack provides a lack in stiffness. Thus more material is required to take up for the lack of stiffness.
2) Earle’s Fork

The Earle’s Fork Suspension System is made for a low center of gravity at the front of the vehicle. This suspension system has been used by other teams for previous BUV Competitions. Notice the design of an Earle’s Fork Suspension in Figure 7.

![Figure 7 - Earle's Fork Suspension](image)

Unfortunately for this kind of design, the Earle’s Fork Design, tends to be costly to make. There are a lot parts that go into making this kind of system. For BUV standards, we would like to stay away from this.

3) Double Strut

This original design was made strictly for our frame due to the fact that our frame contains a collar. It would make a great fit. This is another design that people will not see often.

![Figure 8 – Motorcycle Design](image)

This design helps with steering the vehicle. It provides length and does contain require a lot of material when building.
4) Uni-Strut with Outside Coil

This design was the suspension of choice for the 2012-2013 BUV Team. This design was also used by the 2011 BUV Team. This design has shown success with UC’s team and other teams that have entered the BUV Competition in the past. Figure 9 shows the Uni-Strut design of the suspension below.

Figure 9 – 2012-2013 BUV Group Suspension System

This will be our final choice for the suspension as well. However, our frame will not allow our spring to be as big due to a collar on the front. Therefore, we’ll have the steering handlebars come through the collar and have the handlebars supported by bearings and clamps to help turn the front wheel as well as make sure the suspension does not separate from the frame itself. Our final design will look like the front of a motorcycle. This was decided systematically with Weighted Ratings Method. The table is in Appendix D

DRAWINGS/SKETCHES

Concept sketches of steering can be viewed in Appendix E.

LOADING CONDITIONS

The front suspension is design to withstand the forces from the weight of the vehicle including a driver and passenger, and two full water barrels. The front suspension is also designed to withstand a three foot drop.
DESIGN ANALYSIS

I started off finding out the forces by using a moment equation. I found two forces: Force A and Force B. Force A was the force that represented the force for the suspension and it turned out to be 1043.64lbs. Force B represents force at the back wheels and that came out to be 1180.82lbs. I calculated the static displacement with a Moog-7588 with a K that equaled 880lb/in. This deflected 6.03in. With this deflection, a spring force from a 3ft drop resulted in 7928.80lb. Because of the three foot drop I designed the suspension for, the spring will oscillate for 0.952sec. The shear stress was calculated out to be 11252.98psi. The shear stress was calculated for the bolt that keeps the brakes down and ready for a 3ft drop. You can see the calculations in Appendix G.

FABRICATION AND ASSEMBLY

FRONT SUSPENSION

The suspension was calculated from every aspect possible. This includes spring deflection, shear stress on the bolts, and the forces during moments. Some of the sample calculations can be seen in Appendix G.

FABRICATION

The fork for the front end suspension was made out of 2”x2”x0.25” square tubing with a 45 degree angle cut. You can see the image below

![Figure 10- Uni-Strut Fabrication](image)

The handle bars were made from 1” piping with a 0.25’ thickness. I chose a thick piping to insure the handle bars would not go through any cracking or shear. The piping was cut into three pieces. It was cut into two 18” pipes and one 8” pipe to represent the connecting piece for the two 18” pipes. Then the handle bars were bolted to the strut shaft with three Grade 8 bolts. This is gives the user freedom to take the handle bars out whenever. This can be seen this in Figure 11.
ASSEMBLY

Once all the parts were made to their proper measurement, assembly for the front could commence. The strut shaft was welded to the fork. Then bolted the wheel hub to a 6”x6”x0.25” plate which was welded to the fork of the front end. The full assembly can be seen below.

Figure 11- BUV Handle Bars/Steering Fabrication

Figure 12- Assembly of Front Suspension
COMPONENT SELECTION

FRONT SUSPENSION

The spring for the front suspension could not turn without the aid of a bearing to allow it to move when steering. As this was the case, a UCF-210-32 flange bearing was selected in order for the spring to rotate. The flange bearing also gave rigidity and easier turning to the overall steering of the vehicle.

STEERING

The steering design that has been decided are handlebars. Handle bars are way better than the wheel because of the complications that come with a steering wheel. Plus we only need the vehicle to turn a certain distance. These handle bars are similar to BMX handlebars. They are easy to manufacture and provide a wide range of area in the handle bars to provide leverage in different areas of the handle bars.

TESTING AND MODIFICATIONS

TESTING

Due to the lack of an appropriate terrain, most of the testing will be done at the competition. Objectives were set in the proof of design in Appendix J. Unfortunately, while testing there was nothing for me to do the drop test. The spring used was also supposed to be tested for the 3ft drop but was inconclusive. However, to test the strength of the suspension, jumping up and down as hard as possible seemed to be the best way to test the strength. Also shaking the vehicle back and forth as it was moving was another way to test the vehicle.

However, once the vehicle made it to the race course, the real test commenced. The wheel hub that was used for this year’s front end failed. As a result of the wheel hub failing, it made the original design futile. Due to the tough terrain, the wheel hub literally came apart. That seems to be the only reason for the wheel hub to come apart. All the buildup from the mud and soft terrain may have added extreme resistance when turning the wheel.

Initially, after all the pre-tests done at the Victory Parkway Campus, one would think it would have come apart before the vehicle ended up on the race course. Many ideas were brought up to rectify the suspension system but unfortunately it all resulted in a matter of time before the hub would fail again. Due to the original design not being able to work, I decided that the 2013 Suspension would be able to work. Since it was a uni-strut design as well, it made for a good backup plan. The test results for the 2013 Suspension passed. It was able to withstand the terrain of the course. There wasn’t a 3ft drop in the course so that was not able to be tested. This was also a good idea for the vehicle to not go through that test for the safety of the driver. Also the rake angle was measured at 19.8 degrees which was less than 20 degrees. The 2013 suspension was designed to carry a payload of 3,000lbs so it was more than capable of being able to carry the payload of 2,500lbs for this year’s vehicle.
MODIFICATIONS
The initial design for the fork was somewhat of a “U-Fork.” Due to the incapability to put a shaft through the front wheel, I modified the “U-Fork” to the traditional Uni-Strut design along with a wheel hub that fit the bolt pattern. Due to the failure of the initial design, we made a few modifications to the 2013 suspension. For the handle bars to go with the 2013 suspension, we had to drill holes in the shaft. This way we can detach the handle bars from the vehicle if need be.

SCHEDULE AND BUDGET

SCHEDULE

The schedule was created to keep each one of us on track and not fall behind. Concept designs, presentations and the competition are included in the schedule. You can see the schedule in Appendix J. The schedule has been upheld so far. It may change in the future when dealing with fabrication and building the vehicle

BUDGET

The purpose of the budget is to interpret how much money should be raised through sponsorship to build the 2013 competition BUV. The proposed budget is $5,500 for complete fabrication and traveling of the vehicle. The overall cost of the suspension and steering together equaled $354.71 as it states on the next page. You can see the items that make up the suspension and steering in Appendix H

Table 1 was a projected amount of what the suspension was going to cost. In actuality, it was a lot cheaper. It was just under $90 cheaper. It was $85.69 cheaper than the projected to be exact. In Table 2 is what all the components together came out to be.
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Table 1 – Bill of Materials (Projected)

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<th>ITEMS</th>
<th>PROJECTED PRICE</th>
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<td>MOOG-7588</td>
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<td>Material for Handle Bars</td>
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<tr>
<td>Tire</td>
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<tr>
<td><strong>Total</strong></td>
<td>$ 269.02</td>
</tr>
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Table 2 - Bill of Materials (Actual)
CONCLUSION

In conclusion, I truly believe that front wheel hub is a good idea despite the fact that it failed on our vehicle. Other teams said that a front wheel hub assembly was used for their vehicle as well. But other teams used a shaft and plates to keep the hub assembly in compression thus keeping it from coming apart. Also, it was proven that the single fork rather than the “welded double fork” from 2013 suspension, works just as strong. The welds were holding even when it was driven on the race course and there wasn’t any fluctuations in the assembly. The key is to keep the system lightweight so there isn’t much stress on the driver when turning. Had the wheel hub not failed, the strength of the original suspension would have been displayed in a better light. The steering was exceptional. The steering was a good fit and was easy to steer. The wide frame of the handle bars aids the driver to provide leverage at different points when steering. Overall, the 2014 Suspension could of been a true success had the wheel hub assembly had not failed.
REFERENCES
APPENDIX A – COMPETITION SPECIFICATIONS

BUV FARM TANKER & TRANSPORTER

2014 Design Specifications:

Engine Use up to 11 horsepower unmodified engine. Use stock fuel tank. No extra tanks allowed.

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 no enhancements added.

Transmission It is builder’s choice, to meet event conditions, but must have reverse and should have two forward speeds.

Electrical A 12 volt 35 amp or larger automotive alternator and 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.

Roll Bar A minimum height of 36 inches above the surface the driver is seated upon. It must be completely padded above the seat height. It must have a cross member that covers the ends of the vertical structures, and 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.

Safety Items To participate in the event, you must have the following items:

1. An engine shutoff device marked with a nine-inch red streamer located within reach of the driver.
2. A spring return throttle with the spring located directly on the throttling device and not on the control linkage.
3. Guarding from all moving parts.
4. Padding of all sharp or dangerous areas.
5. Automotive horn.
6. A fire extinguisher.
7. A high visibility bicycle style safety flag above the vehicle.

Brake System A redundant brake system that will prevent total brake failure. The brakes must be located on all the wheels and not on the driveline. A front wheel brake is not required on three wheeled vehicles. The parking brake is not considered the redundancy that is required.

Parking Brake A parking brake capable of overcoming the engine power. It may be on the driveline.

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 25 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 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.

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.

Cost Target Between $1500 and $2500 to build. See the event rules for details.

Name Plate The school name and team number displayed in 4-inch font on all sides of the vehicle.
# APPENDIX B - RESEARCH

## Hossack Suspension

The Hossack Suspension is the suspension that takes over the motorcycle world. The triangulated design provides strength and extreme rigidity for a smooth ride:
- Hossack Suspension
- Triangulated frame and very rigid
- Good stiffness to weight ratio
- Design helps carry more loads
- Triangulated Frame provides extra strength

Suspension increases leverage
- Increased leverage causes greater loads on spherical pivot bearings, can be improved
- The potential of engine being used as main frame is reduced
# Earles Fork Suspension

The Earles Fork suspension is the base of fork suspensions. They come in different varieties. The frame of the suspension is made to alter strenuous conditions for a smoother and more enjoyable ride:

- Earles Fork Suspension
- Great for stability
- Suspension accounts for weight of vehicle and rider

<table>
<thead>
<tr>
<th>Prone to absorb strenuous riding conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreases the unsprung weight of the vehicle</td>
</tr>
<tr>
<td>Increases torsional stiffness</td>
</tr>
<tr>
<td>More expensive than conventional telescopic forks</td>
</tr>
</tbody>
</table>
The Double Strut Suspension helps change the load capacity. The load capacity is transferred to the upper arms for the best support. It aids the turning radius by providing extra length in the suspension.
APPENDIX C - PRODUCT OBJECTIVES

The following is a list of product objectives and how they will be obtained or measured to ensure that the goal of the project was met. The product objectives will focus on a basic utility

2012-2013 BUV Groups Front Suspension

This design was the concluded suspension for the 2012-2013 BUV Group. This design was used for the competition and was somewhat of a success for last year’s group

- No dampener needed
- No shocks needed

Capable of handling any bending stresses
Minimizes roll or sway
APPENDIX C- CUSTOMER/INDIVIDUAL REQUIREMENTS

1) **Has sufficient capacity (13%)**
   a. Maximum payload will be 2500 lbs. including the driver.

2) **Durable (13%)**
   a. Materials and parts will be selected from mathematical analysis to withstand the stresses the vehicle will face on the course.

3) **Handle rough terrain (12%)**
   a. Vehicle will be equipped with off-road tires.
   b. Vehicle will have suspension capable of handling the course terrain.
      i. Front suspension will have 3 in. of travel
      ii. Rake angle will be at most 20°
      iii. Rear suspension will handle a maximum payload of 2500 lbs.
      iv. Front wheel can endure the stresses of a 3 foot drop

4) **Affordable (11%)**

5) **Easy to Maintain (8%)**
   a. Access to each component in the vehicle.
   b. Flat head screws will be used.
   c. Vehicle will be maintained using standard tools.

6) **Easy to Manufacture (11%)**
   a. Will use standard parts.
   b. Vehicle can be assembled without the use of custom tools or specialized professionals.

7) **Easy to Operate (10%)**
   a. Handle bars instead of a steering wheel.
   b. Turnkey or push button ignition.

8) **Long life expectancy (6%)**
   a. Standard paints and lubricants will be used to increase the life of vehicle parts.
   b. Engine, transmission, and electronic components will be enclosed to prevent water from damaging them.

9) **Fuel Economy (16%)**
   a. Vehicle will go 4 laps during the competition without refueling.

10) **Safety (16%)**
11) **Weather resistant (16%)**  
   a. Electronics, engine, and transmission will be enclosed.  

12) **Has the ability to tow (16%)**  

13) **Small turning radius (16%)**  
   a. Wheel base and handle bar range will be designed to allow a minimum 10ft. turning radius.  

14) **Has sufficient driver visibility (N/A)**  
   a. Headlight  
   b. No windshield  
   c. Cargo bed will not block drivers rear view  

15) **Operated by one person (N/A)**  
   a. Only one person required to drive the vehicle  

### STEERING AND SUSPENSION SYSTEM REQUIREMENTS  

6) **Affordable (25%)**  
   b) Low material usage  

7) **Light Weight (16%)**  
   c) Low material usage  
   d) Low number of components for suspension  

8) **Durable (20%)**  
   b) Use mathematical analysis to determine stresses  

9) **Easy Maintenance (17%)**  
   a. Access to each component in the vehicle.  
   b. Flat head screws will be used.  
   c. Vehicle will be maintained using standard tools.  

10) **Easy to Manufacture**  
   a. Will use standard parts.  
   b. Vehicle can be assembled without the use of custom tools or specialized professionals.
APPENDIX D - WEIGHTED RATINGS METHOD

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance Weight (%)</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
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<td>0.64</td>
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<td>1</td>
<td>0.2</td>
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<td>Easy Maintenance</td>
<td>17%</td>
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<td>Easy Manufacturing</td>
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Rating Scale

- Unsatisfactory 1
- Poor 2
- Average 3
- Good 4
- Excellent 5

CONCEPT ALTERNATIVES

Weighted Rating Method

Hossack | Earle's Fork | Double Strut | Uni-Strut

Rating Scale

- Unsatisfactory 1
- Poor 2
- Average 3
- Good 4
- Excellent 5

D1
APPENDIX E – STEERING DESIGN SKETCHES
The 2014 UC Senior Design Basic Utility Vehicle (BUV) Team is a student design group from the University of Cincinnati. We are currently designing our competition vehicle for the BUV competition. This competition is a student competition with all costs for design and manufacture of the vehicle being paid out of pocket by the student teams.

We are seeking sponsorship from organizations that promote academic programs and friendly competition between colleges. We would like your organization to consider sponsoring our team for the Spring BUV competition. Enclosed is our proposal detailing the BUV competition and benefits of sponsoring our team.

We urge you to contact us with any and all questions you may have regarding sponsorship and/or the BUV competition.

We would like to thank you for taking the time and reading our proposal,

Sincerely,

Kabimbi Kalubi
(2012-13 Senior Design BUV Team vehicle post-competition)
**BUV Background**

One of the College of Engineering and Applied Science graduation requirements is to take part in a senior design project which includes designing, building, and testing a product. In order to fulfill this requirement we have formed the University of Cincinnati Basic Utility Vehicle Senior Design Team.

A Basic Utility Vehicle, BUV, is built with the intentions of being a simple and inexpensive vehicle for people in impoverished and/or developing countries that have little to no suitable means of transportation. BUV vehicles are built to specifications provided by the Institute of Affordable Transportation, IAT. The BUV is similar to a dune buggy. It utilizes a 10hp gasoline or diesel engine and has a top speed of about 20mph. It is designed to be used in an off road environment.

IAT hosts a yearly competition in April where teams of students from different colleges around the country compete against one another by endurance racing their BUV vehicles around an off road track. IAT uses this competition as a testing ground for the vehicles and the winning teams’ designs will be evaluated and implemented into IAT kit cars that are sent to 3rd world countries.

For more information about IAT and the BUV competition please visit IAT’s website: [http://www.drivebuv.org/about-us/](http://www.drivebuv.org/about-us/)

**Sponsorship**

Since BUV is a student competition, all costs for design and transportation of the BUV vehicle are paid out of pocket by the team members. Because of this, it is highly encouraged to seek sponsorship. We have an estimated budget of $5,500.00 which includes both the cost of design and the transportation of the vehicle to and from the competition (a detailed cost analysis can be provided upon request).

Sponsorship not only helps the BUV team, it can also be beneficial to the sponsor.

All donations are tax deductible. The University of Cincinnati BUV Team holds nonprofit tax status as an educational entity affiliated with The University of Cincinnati. Monetary and product support will be acknowledged as contributions to The University of Cincinnati and are tax deductible under current applicable regulations.

Sponsorship can provide an advertisement opportunity. BUV vehicles will display sponsorship decals on various location of the vehicle. Completed BUV vehicles will be displayed at various points on the University of Cincinnati’s campus. Sponsorship decals will not only broaden customer reach, but will also show the sponsors’ dedication to furthering academic programs. After the competition BUV can be showcased at sponsor’s premises for few days if so requested.
**Donations**
All checks are made payable to The University of Cincinnati/BUV team and sent to the address below. If you have any questions, please don’t hesitate to ask!

Address:
BUV Team
University of Cincinnati
2220 Victory Parkway
Cincinnati, OH 45206
Attn: Janak Dave

Advisor Contact Info:
Janak Dave, Ph.D.
Advisor
Phone: 513-556-5311
Fax: 513-556-4015
Email: janak.dave@uc.edu

Team Member Contact Info
Kabimbi Kalubi
Suspension/Steering
BUV Team
University of Cincinnati
2220 Victory Parkway
Cincinnati, OH 45206
Phone: 513-967-3764
Email: kabimbik@gmail.com
APPENDIX G – SAMPLE CALCULATIONS

Time To Stop Oscillating

\[ F = k \xi \]
\[ F = \frac{880 \text{lb/} \text{in}}{9.01 \text{in}} = 97.8 \text{lb} \]
\[ \omega = \sqrt{\frac{k}{m}} \rightarrow \sqrt{\frac{880 \text{lb/} \text{in}}{7928.8 \text{lb}}} = 6.59 \text{ rad/s} \]
\[ \sqrt{\frac{32.2 \text{ ft/s}^2}{\text{in}}} \]
\[ f = \frac{\omega}{2\pi} = \frac{6.59 \text{ rad/s}}{2\pi} = 1.05 \text{ Hz} \]
\[ T = (1.05 \text{ Hz})^{-1} = 0.952 \text{ sec} \]

Force on Uni-Strut Suspension

\[ F_{imp} = F \left(1 + \frac{2h}{d_{str}}\right) \]
\[ F_{imp} = 400 \left(1 + \frac{2(36 \text{ in})}{9.01}\right) \]
\[ F_{imp} = 15998 \text{ lb} \]
\[ F_{spr} - F_{imp} = F_{uni} \rightarrow 7928.8 \text{ lb} - 15998 \text{ lb} = -8070 \text{ lb} \]
\[ F_{uni} = 6329.8 \text{ lb} \]
## APPENDIX H – BILL OF MATERIAL

### PROJECTED

<table>
<thead>
<tr>
<th>ITEMS</th>
<th>PRICES</th>
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<tr>
<td>MOOG Coil Spring- 7588</td>
<td>$ 103.96</td>
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<tr>
<td>Uni-Strut (2x)</td>
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<td>Bolts, Nuts, Washers (4x)</td>
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<td>UTV Steering Bracket</td>
<td>$ 71.98</td>
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<td>Handle Bar</td>
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<td>Tire</td>
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### ACTUAL

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<td>MOOG-7588</td>
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<td><strong>Total</strong></td>
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</table>
APPENDIX I – PROOF OF DESIGN

Proof of Design

Suspension

- The vehicle will handle a 3ft. vertical drop
  - This design objective will be a visual test during the BUV competition
- The front suspension of the vehicle will have 3” of travel parallel to the rake angle
  - This design objective will be tested by measuring spring distance with a ruler
- The rake angle of the front wheel will be less than 20 degrees
  - This will be measured using a ruler and a protractor
- The suspension system will handle a pay load of 2,500 lbs
  - This design objective will be tested visually during the competition
# APPENDIX J – SCHEDULE

<table>
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</tbody>
</table>

BUV 2013-2014 - Suspension and Steering
Kabimbi Kalubi

Tasks include:
- Ordered Parts
- Fabrication
- Modifications
- Final Testing
- BUV Competition
Suspension + Steering

Kabimbi Kalubi
Research

- Hossack
- Earle’s Fork
- Double Strut
- Uni-Strut
Steering and Suspension Requirements

1) Affordable (25%)
   a) Low material usage

2) Light Weight (16%)
   a) Low material usage
   b) Low number of components for suspension

3) Durable (20%)
   a) Use mathematical analysis to determine stresses

4) Easy Maintenance (17%)
   a. Access to each component in the vehicle.
   b. Flat head screws will be used.
   c. Vehicle will be maintained using standard tools.

5) Easy to Manufacture
   a. Will use standard parts.
   b. Vehicle can be assembled without the use of custom tools or specialized professionals.
Hossack Suspension

• Pros
  - Great, supporting strength

• Cons
  - Complicated to build
  - Expensive
  - Requires a lot of material
Earle’s Fork

• Pros
  - Low center of gravity
  - Lightweight

• Cons
  - Expensive
  - Complicated
Double Strut

- Pros
  - Helps steer the vehicle better
  - Lightweight

- Cons
  - Hard to fix on the track if something were to happen
Uni-Strut (Selected Design)

• Pros
  - Cheap
  - Durable
  - Less parts

• Cons
  - Hard to fix in the field
### Weighted Ratings Method

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance Weight (%)</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
<th>Weighted Rating</th>
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<tr>
<td>Affordable</td>
<td>25%</td>
<td>2</td>
<td>0.5</td>
<td>1</td>
<td>0.25</td>
<td>2</td>
<td>0.5</td>
<td>3</td>
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<tr>
<td>Light Weight</td>
<td>16%</td>
<td>4</td>
<td>0.64</td>
<td>3</td>
<td>0.48</td>
<td>3</td>
<td>0.48</td>
<td>4</td>
<td>0.64</td>
</tr>
<tr>
<td>Durable</td>
<td>20%</td>
<td>1</td>
<td>0.2</td>
<td>2</td>
<td>0.4</td>
<td>4</td>
<td>0.8</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Easy Maintenance</td>
<td>17%</td>
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<td>0.17</td>
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<tr>
<td>Easy Manufacturing</td>
<td>22%</td>
<td>1</td>
<td>0.22</td>
<td>1</td>
<td>0.22</td>
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<tr>
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<td>N/A</td>
<td>2.95</td>
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<td>3.78</td>
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</table>

### Rating Scale

- Unsatisfactory: 1
- Poor: 2
- Average: 3
- Good: 4
- Excellent: 5

### Concept Alternatives

<table>
<thead>
<tr>
<th>Hossack</th>
<th>Earle's Fork</th>
<th>Double Strut</th>
<th>Uni-Strut</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hossack Image]</td>
<td>![Earle's Fork Image]</td>
<td>![Double Strut Image]</td>
<td>![Uni-Strut Image]</td>
</tr>
</tbody>
</table>
Front End Suspension Design
Testing

- Jumping
- Shaking
- Test Drive
- Major Test at Competition

**Course of Competition**
Static Forces

\[ \Sigma = 0 = -F_A \cos(110)(56) - F_A \sin(110)(4) + 400(31) + 918(4) \]
\[ = -F_A(-19.15) - F_A(3.75) + 12400 + 3672 \]
\[ = 1043.64 \text{ lbs} \]

\[ + \downarrow F_B = 0 = 918 \text{ lbs} + 400 \text{ lbs} + 1043.64 \text{ lbs} \sin(110) - 2F_B \]
\[ 0 = 2361.24 \text{ lbs} - 2F_B \]
\[ 2F_B = 2361.24 \text{ lbs} \]
\[ F_B = 1180.62 \text{ lbs} \]
Suspension Calculations

- These were the main calculations that were needed to conclude the functions of the front suspension

<table>
<thead>
<tr>
<th>Description of Calculation</th>
<th>Results</th>
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<tbody>
<tr>
<td>Static Displacement/Change In Length</td>
<td>1.19in</td>
</tr>
<tr>
<td>Total Displacement Possible</td>
<td>8.28in</td>
</tr>
<tr>
<td>Oscillation Stop Time</td>
<td>0.95sec</td>
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<tr>
<td>Force on Uni-Strut</td>
<td>6329.80lbf</td>
</tr>
<tr>
<td>Shear Stresses</td>
<td>11252.98psi</td>
</tr>
</tbody>
</table>
Spring Deflection

• The spring deflection is needed to determine how the spring of the suspension will act under strenuous conditions. The coil spring of choice is a MOOG-7588.

<table>
<thead>
<tr>
<th>Coil Spring Dimensions</th>
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<tbody>
<tr>
<td>End 1 Type</td>
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<tr>
<td>Square</td>
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</tbody>
</table>
Why MOOG-7588?

- Handles spring deflection
- Strong enough for impact (Severe Service Loading)
- Cheap
- It can handle the load put out by BUV
Modifications

• Made slight change to Fork
• Capable and strong
• Modified handle bars
  • Larger Look
  • Better for turns
Steering Wheel

• Pros
  - Easier steering
  - Less force is need to turn

• Cons
  - Complicated to manufacture
  - Expensive
  - Too many elements for design
BMX Handlebars

• Pros
  - Cheap
  - Easy to manufacture
  - Sturdy
  - Provides different ways to steer
MTB Handlebars

• Pros
  - Cheap
  - Easy to manufacture
  - Provides different ways to steer
Suspension for 2014 BUV
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Schedule
### Budget

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<th>ITEMS</th>
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<tr>
<td>MOOG-7588</td>
<td>$103.96</td>
</tr>
<tr>
<td>Uni-Strut (2x)</td>
<td>$65.08</td>
</tr>
<tr>
<td>Bolts, Nuts, Washers (4x)</td>
<td>$6.01</td>
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<tr>
<td>UTV Steering Bracket</td>
<td>$71.98</td>
</tr>
<tr>
<td>Handle Bar</td>
<td>Donated</td>
</tr>
<tr>
<td>Tire</td>
<td>$24.57</td>
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<tr>
<td><strong>Total</strong></td>
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### Revised Budget

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<tr>
<td>Uni-Strut (2x)</td>
<td>$65.08</td>
</tr>
<tr>
<td>Bolts, Nuts, Washers (3x)</td>
<td>$10.01</td>
</tr>
<tr>
<td>UTV Steering Bracket</td>
<td>-</td>
</tr>
<tr>
<td>Wheel Hub</td>
<td>$38.85</td>
</tr>
<tr>
<td>Material for Handle Bars</td>
<td>$51.12</td>
</tr>
<tr>
<td>Tire</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$269.02</strong></td>
</tr>
</tbody>
</table>