1967 Mustang Rear Suspension Redesign

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By

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ABSTRACT

The original rear suspension used on a 1967 Ford Mustang is a leaf spring suspension. This type of suspension relies on the leaf springs to locate the axle and suspend the car. This allows for the axle to rotate slightly on the springs causing what is called axle wrap that leads to a reduction of traction. Installing a modern triangulated 4-link suspension system that uses coilovers allows the axle to be rigidly located by the links while the car is suspended by the coilovers. This would greatly reduce the amount of axle wrap, but more importantly increasing the amount of anti-squat making the acceleration of the vehicle more consistent with improved traction.

My portion of the team project was to design the links for the suspension as well as the link geometry relative to the axle and car. The link geometry is very important since this is what governs the amount of anti-squat the suspension system will have. The geometry was designed to achieve approximately 100% anti-squat, this would allow for maximum force between the rear tires and the road. In designing the links themselves, 7075 aluminum was used for weight reduction but still maintaining strength.

The links were designed to meet the customers requirements based on the surveys that were returned, which weight and ease of installation were most important for the links. With the use of the aluminum there was a significant amount of weight reduction, while still having a simple installation process of the link mounts. The only modification the customer will need to do on the car is drill four holes for brackets and weld mounts on the axle, for a project of this magnitude the customer will have the required tool readily available to them.
INTRODUCTION - PROBLEM STATEMENT AND INTERVIEW

**Problem Statement**

The Ford Mustang has been one of the most iconic vehicles in American automotive history. Being introduced in the year 1964 ½, the Mustang is still in full stride and has sold over 8 million vehicles. The 1967 Ford Mustang saw different overall dimensions and more powerful engines than its predecessors. This helped to spark the “muscle car” revolution. Today, the cars are sought after by car enthusiasts and collectors alike. Being built in 1967, this mustang is missing a lot of modern technology which effects performance.

The 1967 Mustang currently utilizes a leaf spring and shock absorber suspension system. The current suspension system causes issues in handling and ride quality of the vehicle. The leaf spring and shock absorber suspension systems also lacks in versatility. This design project will focus on improving handling and ride quality by applying modern technology and components while redesigning a new rear suspension system. Nick Crall will focus his time on suspending the vehicle, as well as managing the team. My role is to design the links and link geometry relative to the vehicle. Jared Niehauser’s task will be designing a sufficient sub-frame that will support the suspension system.

**Interview**

Justin Miller is a current car enthusiast who has personally designed and hand built his own vehicle from scratch. He is knowledgeable in suspension systems from his experience of designing his own. According to Justin, he expressed that the car handling and the adjustability of the suspension system should be our main focuses. This is critical information for designing a sufficient suspension system.
The 1967 Ford Mustang utilizes a leaf spring and shock absorber suspension. At that time this was a great design; however, as time progressed it became out-of-date and various suspension systems were designed for many different purposes. Figure 1 illustrates the components that were used in 1967 for the rear suspension.

![Figure 1 - Current Suspension System – Courtesy of AutoZone](image)

One of the many disadvantages of leaf springs is that leaf springs are heavier than most other suspension systems. In every application it is beneficial for weight reduction. Another downfall of leaf springs is that the leaf springs themselves locate the axle. Because a spring locates the axle this allows the axle to move slightly left, right, forward, and aft. Modern suspension systems locate the axle more precisely.
CUSTOMER FEATURES AND OBJECTIVES

PRODUCT FEATURES AND OBJECTIVES
The product features were obtained from the customer features listed on the survey. According to the survey the product features are listed in descending order from most important to least important. The product objectives are the measurable goals established to meet the customer features.

1. Adjustability (18%)
   a. The coilovers used will provide features that will allow for altering of the preload and valve adjustment.
   b. Multi-position mounting brackets to set desired preload, anti-squat, and roll center for performance needs.

2. Ride Quality (17%)
   a. Spring factor of a suitable nature.
   b. Performance bushings.
   c. Mono-tube coilovers to maximize sensitivity in minimal movement of the suspension.

3. Weight (16%)
   a. Measurement will be performed to compare the mass of the current suspension to the new design
   b. The goal is to have the new suspension system lighter than the current system.

4. Complexity of Installation (14%)
   a. Usage of standard sizes for hardware and components.
   b. Ability to complete installation with use of standard tooling.

5. Initial Investment Cost (13%)
   a. Based on customer survey results the investment cost shall not exceed $2,000.

6. Serviceability (13%)
   a. Inspectable parts will be visible and easily accessible without removing any components.

7. Material Used (9%)
   a. Material used will meet desired weight and factors of safety.
   b. Material used will withstand environmental conditions.
ALTERNATIVE DESIGNS

LEAF SPRING RESEARCH

The 1967 Ford Mustang was equipped with a Hotchkis-type rear leaf spring suspension. This type of spring was made up of 4 layers of arc-shaped metal leafs bound together to form a single spring. The leaf springs were attached directly to the solid rear axle using U-bolts and spring plates. The front mounting eye included a rubber bushing to reduce shock and noise and to allow for slight horizontal movement. The rear end of the spring was held in a rubber-bushed compression shackle to allow flexing on lighter impacts and resistance on greater impacts. The overall suspension unit also included angle mounted shock absorbers that were attached to the spring plates. The shock absorbers were filled with viscous fluid to help reduce side sway and oscillation in the springs. (1)

Figure 2 - Leaf Spring Suspension – Courtesy of superproly.de

The leaf spring suspensions have their disadvantages. The leaf spring suspension is heavier than most alternatives, which can be an issue for racing enthusiasts. Leaf spring suspensions tend to require a significant amount of space and offer little to no adjustability. Adding horsepower to the 1967 Ford Mustang can greatly affect the performance of the stock leaf spring suspension. Increased acceleration with stock leaf springs can cause the rear axle to wrap and alter the pinion angle. Also, when cornering hard, the leaf springs can cause lateral movement and negatively affect the handling of the car. (2)

Modified leaf springs do offer advantages over other suspension upgrades. Because the leaf springs are already installed on the car, modifying the existing springs requires a lower cost of investment and involves easier installation. Some of the most popular upgrades to a stock leaf spring rear suspension include but are not limited to: adding a Panhard rod or Watt’s link, swapping out the bushings, and adding traction bars. The Panhard rod and Watt’s link (see Error! Reference source not found.) are both axle centering devices that reduce
the amount of lateral movement of the axle when cornering. Both devices can lower the car's rear roll center to improve the overall handling. Unlike the Watt's link; however, the Panhard rod can be adjusted to change the height of the roll center. (3) With a significant amount of acceleration or extreme braking, the rear axle tends to wind-up and twist the leaf springs into an "S" shape, which causes wheel hop. Traction bars (see Error! Reference source not found.) can be installed to "locate" the rear axle and sure the axle to the car. As a result, the axle wind-up can be reduced in extreme situations. However, the traction bars reduce the overall ride quality by adding extra weight and increasing the roll stiffness when cornering. (4)

Figure 3 - Traction Bar – Courtesy of cartechbooks.com

Figure 4 - Panhard Rod and Watts Link – Courtesy of ve-blog.local-motors.com
**Air Suspension**

Air suspension on a vehicle can be described as a shock absorber that is filled with compressed air that is supplied by an onboard compressor. The compressor pumps air into each individual shock. This replaces the conventional spring, which absorbs the energy transferred from the road. Because each shock is individually filled with air, sensors can be placed so that the suspension can self-adjust in various situations allowing for maximum adaptability. (5) Whether the vehicle is cornering or traveling at high speed, air suspension has the capability to adjust for maximum performance.

![Air Suspension System](https://www.discoweb.org/image)

Figure 5 – Air Suspension System – Courtesy of Discoweb.org

Error! Reference source not found. illustrates the basic air suspension setup for a rear axle. One of the benefits that this system offers is the ability to change the ride quality of the vehicle, even while the car is in motion. (5) Adjusting the air suspension for ride quality can allow the car to ride smoothly or roughly. Sporting and racing applications desire a stiff suspension. With more advanced air systems the air springs can adjust for cornering, and also keeps the car more level with the road than conventional springs. Thus, in some situations the anti-roll bar can be deleted.

A contributing factor in high speed performance and fuel economy is wind resistance, also known as drag. To minimize drag, the air suspension system utilizes its adaptability by...
varying the ride height of the vehicle. In most cases, the underside of the vehicle is the location in which the vehicle is least aerodynamic. Lowering the car allows for less air to pass underneath the vehicle, thus reducing the less drag on the vehicle. The air suspension lowers the vehicle at higher speeds when the vehicle encounters fewer large inconsistencies in the road. In our application for the 1967 Ford Mustang, the front suspension will also need to be converted to an air suspension for this particular feature to be utilized. (5)

Another benefit that air suspension has to offer is the ability to adapt to heavier loads in the vehicle without negatively affecting the handling of the vehicle. This feature is known as self-leveling, where the suspension increases the volume of air within a suitable camber range. Self-leveling, with the proper sensors, can also adapt to uneven roads where one side of the road is higher than the other. (5)

A drawback of the air suspension system is the overall weight compared to conventional coil-over suspensions. Air suspensions are also very complex, requiring wiring of the compressor and running air lines throughout the vehicle. Because the vehicle is suspended by air pressure, if there is a leak in the system, the car becomes useless from the lack of suspension. (5)

**COILOVERS**

A coilover is a suspension component short for coil spring over shock absorber. They consist of a shock absorber with a coil spring encircling it. The weight of the vehicle is supported by the coilover. More accurately by the coil spring itself. The coil spring will react to energy by extending and releasing the energy. If there wasn’t a shock absorber present the spring would simply oscillate until it reaches equilibrium or until another force was applied. This would result in very unsatisfactory conditions and an uncontrollable vehicle. This is where the shock absorber is used for damping.

There are three kinds of coilovers; OEM-style spring-over-shock assemblies, slip-fit coilovers and full-bodied coilovers. OEM-style spring-over shock assemblies are based off of a conventional strut assembly surrounded by a coil spring. These are non-adjustable and are made of a fixed-length (depending on the model). Slip-fit coilovers consist of a hollow, threaded cylinder that sits on an existing shock perch shown below. (6)

![Figure 6 – Adjustable Coilover – Courtesy of Super Street Online](image)

These are able to be adjusted by compressing or decompressing the spring, thus directly affecting the ride height of a vehicle. The two types mentioned earlier use existing parts on a vehicle. A full-bodied coilover is an entire system. The full-bodied coilover will
be the focus due to not using any existing components.

**Shock Body**

The shock is in the center of the coil spring. The upper mount of the coilover will mount to the chassis or sub-frame while the bottom mounts to the rear axle. The shock controls unwanted spring oscillation and reduces vibrations caused by the chassis and also the environment that the tire is on. As a vehicle hits a bump the springs will compress and then decompress. The energy is then transferred to the shock from their upper mounts and the piston inside of the shock absorbs the load. Hydraulic fluid is inside of the shock tube where the piston is located. The piston will exert a force to push the hydraulic fluid through the shocks valves. The kinetic energy released by the suspension system is transmitted to the shock which turns into heat energy. This heat will conclusively dissipate within the hydraulic fluid. This process can be changed or altered by variations in shocks internal components. Softer shocks will result in more spring movement while stiffer shocks will reduce spring movement.

There are two configurations of shocks offered in coilovers, Mono-tube and Twin-tube. The mono-tube structure consists of a rod and piston assembly housed within the shock tube where both compression and rebound service occurs. Twin-tube shocks consist of two cylinders. The inner cylinder is where the piston and rod move up and down. The outer cylinder is where the hydraulic fluid is held. A benefit of twin-tube over mono-tube, is the increased piston stroke capabilities. On the contrary the mono-tube style generally has a larger diameter which is beneficial in dissipating heat and displacing more fluid. This results in increased sensitivity of the shock in minimal suspension movements. (7)
Shock Travel

Shock travel is the distance the shock is able to act before “bottoming out.” Bottoming out is when the shock runs out of travel before emitting all of the acting energy to heat. (6) A combination of shock travel and spring choice can prevent bottoming out.

Preload

Preload is the amount of force applied to the springs. This can be determined by how much the spring is compressed during static conditions. Adjusting the shock can allow more load onto the spring. Adding preload can be beneficial in increasing tire contact while cornering for example. Ride height is directly dependent on preload. (7) That is only the case if the lower mounts for the coilover are non-adjustable. Adjustable lower mounts will allow for preload adjustment while maintaining a consistent ride height (if that’s what you want).

Conclusion

Coilovers can be dialed in to best fit a specific application by a combination of position, spring constant of the coil spring, and the shock absorber used. A correct combination of the various styles can help create a sufficient suspension system.

THE WATT’S LINK

When using a leaf spring style rear suspension the rear axle is able to move side to side. The Watt’s link absorbs much of the lateral stress that the leaves were once receiving. This allows the leaf springs to perform better by keeping the axle centered under the vehicle. With the axle being centered it will not work against the front suspension. The Watt’s link has the same response when corning left or right. (2) It’s also easily adjustable. The Watt’s link is fairly complex, and due to its complexity it is the least common devise used in centering a rear axle.

PANHARD

A Panhard rod, or also commonly referred as a track bar, is another method of centering the rear axle. This is more prevalent when compared to the Watt’s Link. A Panhard rod is a lateral bar that runs from a frame of a vehicle to the axle. The goal is to have the rod as close to horizontal as possible. (2) This allows the axle to stay more centered under lateral load compared an angled Panhard bar. An angled Panhard bar may be necessary depending on its application.

FOUR-LINK

The overall main function of a four-link system is to maintain the proper location of a rear axle under the vehicle. When a vehicle accelerates, makes a turn, or hits a bump the rear axle will constantly want to move. There are two links, one on each side of the vehicle, two upper links and two lower links. The lower links are used to keep the axle in place front to back. The upper links keep the axle from rotating and keep the pinion angle as constant as possible. Bret Voelkle of Air Ride Technologies was quoted saying “In a leaf-spring
suspension, the leaves perform two functions. First, they hold the rear axle in the car. Secondly, while they are doing this, they also support the load of the vehicle. With a four-link suspension, the functions of locating the rear axle and supporting the vehicle have been separated. We like the four-link rear suspension because of its ability to properly locate the rear axle no matter how soft we want to make the spring. With a leaf-spring rear suspension, softening the spring rate can cause other problems such as side-to-side flex or axle wrap, which is when the axle tries to twist the leaves out of the vehicle.” (2)

**TRAINGULATED FOUR LINK**

A triangulated four-link uses the upper links to keep the rear axle centered under the vehicle. This eliminates the need for a Panhard Bar or Watt’s Linkages. The upper links are placed at angle compared to the lower links. Without the need for a Panhard Bar or Watt’s Linkage, the area under the rear of the car becomes more open. This allows for other modifications for example; re-routing exhaust, fuel cells, and batteries. When contemplating a triangulated four-link one must consider “roll blind.” Roll blind is a non-linear resistance to body roll. Body roll is the load transfer of a vehicle towards the outside of a turn. When a vehicle is cornering the pivot points of all four links are resisting body roll. During this resistance a side load is placed on the pivot points. Roll blind can cause snap oversteer or an unanticipated transition from understeer to oversteer. (2) Methods to combat roll blind is by using urethane bushings and or heim joints.

![Tri-link from top.](image)

**PARALLEL FOUR-LINK**

A parallel four-link functions very similarly. The upper and lower links are parallel to another. The main difference of a parallel four-link compared to a triangulated is that a Panhard bar or Watt’s link must be used. With the upper linkages being in parallel they are unable to keep the rear axle centered under the vehicle. (8)
The conducted research reviewed many styles of rear suspension systems along with their components. The research looked into the improvement of the original suspension system. Improving the existing components includes upgrading the bushings, shock absorbers, and spring leaves. Improvement of the original design also includes installing traction bars and a Panhard bar or Watt’s link. These modifications would improve overall handling, but from a marginal stand point. Improving the original design requires a lower cost investment and involves an easier installation. However, enhancing the original suspension system lacks in versatility, adjustability, and other key customer features.

The research directed itself in to the technology of air ride suspension systems. While this type of suspension system provides many benefits towards handling and adjustability, the components that would have to be implemented are not only very expensive but also involve a complex installation process. The benefits that this system could supply would be the reduction of body roll while cornering and automatic body leveling while under various loads. These features would greatly improve the overall performance, but a compromise had to be made with installation time and budget.

Through further research it was concluded that a 4-link coilover suspension meets the desired customer features. The 4-link coilover suspension offers a lower cost alternative to the air ride suspension, while also providing adjustability, greater performance, and greater overall ride quality than the original design. The design of the suspension will be separated into three major categories. The first category will include the selection of the coilover shock absorber and the design of the multi-positioning mounting brackets. The second category will include the selection of bushings and the design of the links and corresponding mounting brackets. The final category will include the design of the sub-frame to properly support the system.
CALCULATIONS

Figure 10 - Link Force Calculations
MANUFACTURING PROCESS

The manufacturing process for the links would be strictly machining processes. The raw round stock of 1.5” diameter 7075-T6 aluminum will be saw cut to rough in the finished length. Once cut the links will then be machined to length and drilled and taped to achieve a ¾-16 thread which is 2.00” deep. As for the bracket that will attach the rod ends for the links, they will be steel plate with a machined hole. Once all the parts are machined, everything will be bolted together and tack welded into place on the car. After the parts have been tacked welded, everything will be disassembled for welding. Welding the brackets in the axle will required a pre heating process to allow for a sufficient weld.

Figure 11 - Model of 4-Link Assembly
Figure 12 – Link Drilling

Figure 13 – Link Tapping
The loads for the links were calculated from the vehicle accelerating at 4 g’s. A car in top-fuel drag will see around 6 g’s, we determined 4 g’s was sufficient because this particular car will only see 1-2 g’s of acceleration. This was determined to be used so the customer cannot be limited for acceleration by the aluminum links. The link in Figure 12 is under compression during acceleration and the link in Figure 13 is under tension during acceleration.
Testing the system will be determined by the amount of squat recorded by our testing apparatus. A marker will be attached to the rear of the car, and will draw a black line on the white testing apparatus as the car accelerates away. Because this particular car has an automatic transmission, we will be able to accurately repeat this test. This will allow us to hold the brake and reach a specified RPM and release the brake, resulting in an almost identical launch of the car. Figure 14 shows the testing apparatus, which is 4’ x 4’ sheet of plywood attached to 2”x 4” for bracing. The car will mark the flat side which is shown in the figure.

Figure 14 – Model of Testing Apparatus
RESULTS

The results from testing the system improved the amount of squat the car underwent at all tested RPM’s. The addition of the links allowed for the force built up from holding the accelerator down while holding the brake to be transferred into the links, instead of the leaf springs. This allowed for a great reduction in axle wrap, this can be seen from the amount the car rose while under stress from building up the RPMs. The leaf spring suspension rose nearly three inches while the 4-link suspension didn’t raise at all during this step. Once the brake was released, the leaf spring suspension system allowed the tires to spin, which was caused by how the reduction of downforce from axle wrap, this can be seen on the data board from the twenty four inches of acceleration before the car squats an inch and a half at 2500 rpm from the acceleration of the car finally gaining traction. The 4-link suspension allowed for nearly immediate traction which allowed for the car to only squat 5/8th in. at 2500 RPM. The 4-link board is much more difficult to read, because the car is accelerating much more consistent do to the updated suspension system. The figures below are pictures of the testing boards. The elimination of the leaf spring suspension and the addition of the 4-Link suspension system, almost twenty pounds have been lost.

Figure 14 – Leaf Spring Testing Board
Figure 15 – 4-Link Suspension Testing Board

<table>
<thead>
<tr>
<th></th>
<th>Squat at 1500 RPM (in.)</th>
<th>Squat at 2000 RPM (in.)</th>
<th>Squat at 2500 RPM (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf Spring</td>
<td>0.625</td>
<td>1.000</td>
<td>1.500</td>
</tr>
<tr>
<td>Coilover/4-Link</td>
<td>0.500</td>
<td>0.500</td>
<td>0.625</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>25%</td>
<td>100%</td>
<td>140%</td>
</tr>
</tbody>
</table>

Table 1 – Test Results Data
### 1967 Mustang Rear Suspension Redesign

**Snyder**

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**Table 2 – Test Results Table**

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Weight (lbs.)</th>
<th>Total (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf Spring Suspension</td>
<td>2</td>
<td>26.50</td>
<td>53.00</td>
</tr>
<tr>
<td>Shock Absorber Mount</td>
<td>2</td>
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</tr>
<tr>
<td>Shock Absorber</td>
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<td>3.00</td>
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<tr>
<td><strong>Overall Total:</strong></td>
<td></td>
<td><strong>85.00</strong></td>
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</tr>
</tbody>
</table>

**Table 3 – Leaf Spring Weight Table**

---

**Squat of Suspension Types**

- **Leaf Spring**
- **Coilover/4-Link**

**Motor Revolution Per Minute (RPM)**

- Squat at 1500 RPM (in.)
- Squat at 2000 RPM (in.)
- Squat at 2500 RPM (in.)
**CONCLUSION**

With the elimination of the leaf spring suspension and the addition of the 4-link suspension system we were able to reduce the weight of the vehicle by nearly twenty pounds from eliminating unnecessarily heavy materials. Also, we were able to achieve a much more consistent launch of the vehicle by reducing axle wrap and reducing the squat of the vehicle. This is beneficial for the consumer to fine tune other components of the car for their specific application. Allowing for easy coilover angle and ride height adjustability allows the consumer to achieve their desired look of the vehicle while having multiple racing types in one package. The location of the mounting bolts will allow the consumer to switch between a drag setup to a road course setup in about twenty minutes, also being able to adjust ride height for varying tire sizes. The maximum test improvement of this system was recorded at 140% decrease in squat at 2500 RPM. The general trend of the data would indicate that we would decrease the squat even more at greater RPMs.

---

<table>
<thead>
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<th>Description</th>
<th>Quantity</th>
<th>Weight (lbs.)</th>
<th>Total (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Links</td>
<td>2</td>
<td>4.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Upper Links</td>
<td>2</td>
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<tr>
<td>Upper Links-Brackets</td>
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<td>0.50</td>
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<td>Lower Coilover Brackets</td>
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<td>0.50</td>
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<tr>
<td>Chassisworks Offset Bracket</td>
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<tr>
<td>Additional Hardware</td>
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<tr>
<td><strong>Overall Total:</strong></td>
<td></td>
<td></td>
<td><strong>65.55</strong></td>
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Table 4 – Triangulated 4-Link Weight Table
WORKS CITED
APPENDIX A – COMPILED CUSTOMER SURVEY

CUSTOMER SURVEY

Redesign of a 1967 Ford Mustang Rear Suspension

The Ford Mustang has been a popular choice for car enthusiasts and collectors alike throughout the cars history. This design will be focused on implementing modern technology on a classic vehicle. The rear suspension of a 1967 Mustang uses leaf springs and shock absorbers. This design entails the usage of coil-overs and a 4-link suspension system to enhance overall driving characteristics and performance.

**How important is each feature of the proposed rear suspension design?**

Please circle the appropriate answer.  
1 = Low Importance  
5 = High

<table>
<thead>
<tr>
<th>Importance</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Investment Cost</td>
<td>1</td>
<td>2(1)</td>
<td>3(1)</td>
<td>4</td>
<td>5(1)</td>
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</tr>
<tr>
<td>Complexity of Installation</td>
<td>1</td>
<td>2</td>
<td>3(1)</td>
<td>4(2)</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Weight</td>
<td>1</td>
<td>2</td>
<td>3(1)</td>
<td>4(1)</td>
<td>5(1)</td>
<td>N/A</td>
</tr>
<tr>
<td>Serviceability</td>
<td>1</td>
<td>2</td>
<td>3(2)</td>
<td>4(1)</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Adjustability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(1)</td>
<td>5(2)</td>
<td>N/A</td>
</tr>
<tr>
<td>Ride Quality</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(2)</td>
<td>5(1)</td>
<td>N/A</td>
</tr>
<tr>
<td>Material</td>
<td>1</td>
<td>2(2)</td>
<td>3(1)</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**How adequate is the current leaf spring and shock absorber suspension system?**

Please circle the appropriate answer.  
1 = Very Unsatisfied  
5 = Very Satisfied

<table>
<thead>
<tr>
<th>Importance</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Investment Cost</td>
<td>1</td>
<td>2(2)</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A(1)</td>
</tr>
<tr>
<td>Complexity of Installation</td>
<td>1</td>
<td>2(1)</td>
<td>3</td>
<td>4(1)</td>
<td>5</td>
<td>N/A(1)</td>
</tr>
<tr>
<td>Weight</td>
<td>1</td>
<td>2(1)</td>
<td>3(1)</td>
<td>4</td>
<td>5(1)</td>
<td>N/A</td>
</tr>
<tr>
<td>Serviceability</td>
<td>1</td>
<td>2(1)</td>
<td>3(2)</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Adjustability</td>
<td>1(1)</td>
<td>2(1)</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A(1)</td>
</tr>
<tr>
<td>Ride Quality</td>
<td>1(1)</td>
<td>2(1)</td>
<td>3</td>
<td>4(1)</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Material</td>
<td>1</td>
<td>2(2)</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A(1)</td>
</tr>
</tbody>
</table>

**How much would you be willing to spend on this technology?**

<table>
<thead>
<tr>
<th>$1,000-$1,500</th>
<th>$1,500-$2,000 (2)</th>
<th>$2,000-$2,500</th>
<th>$2,500-$3,000</th>
<th>$3,000+ (1)</th>
</tr>
</thead>
</table>
## APPENDIX B – QUALITY FUNCTION DEPLOYMENT (QFD)

### Engineering Characteristics

<table>
<thead>
<tr>
<th>Importance Weight</th>
<th>Adjustable Linkages</th>
<th>Multi-Position Mounts</th>
<th>Invasive Installation</th>
<th>High Grade Hardware</th>
<th>Spring Constant</th>
<th>Dampening</th>
<th>Lightweight Materials</th>
<th>Standard Size Equip.</th>
<th>Rounded Surfaces</th>
<th>Customer Satisfaction Rating (0.00 - 1.00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Requirements</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>CP</td>
</tr>
<tr>
<td>Initial Investment Cost</td>
<td>13%</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>0.40</td>
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<td></td>
</tr>
<tr>
<td>Complexity of Install</td>
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<td>1</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td>0.60</td>
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<td></td>
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</tr>
<tr>
<td>Weight</td>
<td>16%</td>
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<td>3</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>0.67</td>
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<tr>
<td>Serviceability</td>
<td>13%</td>
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<td>1</td>
<td>0.53</td>
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<td></td>
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<tr>
<td>Adjustability</td>
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<td>9</td>
<td>3</td>
<td>1</td>
<td>3</td>
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<td></td>
</tr>
<tr>
<td>Ride Quality</td>
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<td>3</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>0.47</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
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<td>3</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>1</td>
<td>0.40</td>
<td></td>
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</tr>
</tbody>
</table>

Table 5 - QFD
# APPENDIX C – TIMELINE

**Figure 16 – Timeline of Project**
## APPENDIX D – BUDGET

<table>
<thead>
<tr>
<th>Component</th>
<th>Supplier/Vendor</th>
<th>Estimated Cost</th>
<th>Actual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x Coilovers</td>
<td>Ridetech</td>
<td>$850.00</td>
<td>$665.00</td>
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<tr>
<td>Coilover Dropdown</td>
<td>Ridetech</td>
<td>$50.00</td>
<td>$60.00</td>
</tr>
<tr>
<td>2x Lower Coilover Offset Mount</td>
<td>Chassisworks</td>
<td>$120.00</td>
<td>$93.00</td>
</tr>
<tr>
<td>Material</td>
<td>Raw Material</td>
<td>$400.00</td>
<td>$236.50</td>
</tr>
<tr>
<td>Hardware</td>
<td>McMaster Carr</td>
<td>$280.00</td>
<td>$291.76</td>
</tr>
<tr>
<td>Machining</td>
<td>In-House</td>
<td>$-</td>
<td>$-</td>
</tr>
<tr>
<td>Welding</td>
<td>In-House</td>
<td>$20.00</td>
<td>$-</td>
</tr>
<tr>
<td>Bending</td>
<td>In-House</td>
<td>$-</td>
<td>$-</td>
</tr>
<tr>
<td>Painting</td>
<td>In-House</td>
<td>$50.00</td>
<td>$26.90</td>
</tr>
<tr>
<td>Car Transport</td>
<td>U-Haul</td>
<td>$80.00</td>
<td>$67.36</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1,850.00</strong></td>
<td><strong>$1,440.52</strong></td>
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</tr>
</tbody>
</table>

Table 6 - Budget
APPENDIX E – DETAIL DRAWINGS

Figure 17 – Upper Link Drawing

Figure 18 – Lower Link Drawing
Figure 19 – Upper Axle Link Mount – 1 Drawing

Figure 20 – Upper Axle Link Mount – 2 Drawing