Optimal Design #12 Report

Bicycle Sidecar for 16 year old (CP)
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Team #12
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1. Optimal Design Project 12

1.1 Introduction

For our optimal design, we decided to use alternative design #3. This design was based off of the commercial idea of the Chariot Sidecar and can be seen in the CAD diagrams below (figures 1 through 4). After evaluating each of our alternative designs and discussing their pros and cons, we decided that design #3 would not only be the most comfortable sidecar for Abby, but the safest, easiest to transport and most efficient for our client’s needs. The basic structure of design 3 is an undercarriage frame, a full body supported seat, and a bicycle wheel with a protective fender. In attaching the sidecar to the bicycle we will be utilizing the Chariot Sidecar’s bicycle attachment technique. Since the frame of the sidecar will not only be supporting the seat but Abby as well, it must be strong. It must also be lightweight in order to make transportation and riding easier for her father. Combining these two elements we decided that using an aluminum alloy would be the best material for the sidecar frame.

In order to ensure that there is enough space in between the sidecar and the bicycle, we will be building the front crossbar on the sidecar so that it sticks out further than the rest of the bike. This distance will give Abby’s father enough room to comfortably pedal while still keeping Abby close enough to his side for interaction between them. The most important part of this design is the seat. Abby needs support of her head, neck and torso. The seat must also be comfortable for her to sit in. Unlike the first two alternative designs, design 3 provides two side supports for Abby’s legs for added comfort. These supports will ensure that Abby will not slide around in the sidecar while it’s in motion. Another feature unique to this design is a footplate that Abby’s feet can be easily attached to. This will keep Abby’s feet down so that she can’t kick them around and hurt herself. It will also make sure that her feet won’t get caught in the sidecar or bike wheel.

In alternative designs 1 and 2, there was a dual attachment to the bicycle. For design 3, the device will only be attached at one point. In our design, we decided to use the hitch from the Chariot Carrier Company. This will make assembling and disassembling the bicycle both quick and easy. It will also ensure that the sidecar remains attached to the bicycle as her father is riding. Using this hitch design will secure the sidecar to the bicycle making it safe to use. Rather than building an attachment like we were going to in designs 1 and 2, for design 3 will be purchasing the hitch attachment from the Chariot Sidecar Company. Below are some different angle views of the bike sidecar.
Figure 1: Front angled view.

Figure 2: Back angled view.
Figure 3: Side view.

Figure 4: Front view.
1.2 Subunits

1.2.1 Sidecar Seat

Figure 5: AutoCAD drawing of seat prototype.

Figure 6: Carrie Tumble Chair Design (Small Adult Shown)
http://www.assistireland.ie/uploadedfiles/Product_Images/Seating_and_Accessories/Chairs/Tumble%20Forms%20Carrie%20Seat%20(NRS)%202144.jpg
The seat of the project is possibly the most important aspect of the entire project, at least concerning with safety. Since the Miller family made is very clear that Abby needs full torso, neck and head support the seat was something that needed to incorporate all of those features. In Abby’s past pull-behind bike seat her father made years ago he used a Carrie Tumble Seat. They family recommended that it should be looked into because it was something they felt very comfortable with and had used in the past. The model that would be used in this product would be the Small Adult model with the footrest and bar. The company that makes this product is Carrie and the product number is 9117S. This chair would have all of the support that would be necessary to keep Abby safe throughout the entirety of the bike ride. The seat is going to be attached to the middle of the frame. This will keep Abby centered and as close to the rider as possible.

The seat itself has many safety features. There is optimal padding and support for Abby’s neck, head and torso. Since the seat is made to be portable and for mobile use its design is perfect for the sidecar. There are also two sets of straps around the feet and for the chest. The ones for the feet would be ideal to ensure that they do not interfere with the bike or get caught and hurt her. There is a chest strap that would be able to fully secure Abby in. It is a five point system that will not only secure her in the seat, but will offer some added support. The seat was found online for approximately $525 for a new seat. This was a very good deal from the over $1,000 price on many similar seats. The team is still looking for better prices or possibly an alternative seat with the same capabilities for a smaller price. Since many aspects of the project are based around the size and dimensions of the seat finding the correct make and model is the first priority. Below is a list of the dimensions that the Miller family gave us to base the design off of. The measurements for some of the seat where given to allow for some growing room to make the sidecar something that Abby could use for longer.

Overall height: 59in
Weight: 70lb
Length under-arms to seat bottom: 16in
Shoulder to elbow: 10in
Elbow to hand: 9in
Hip (joint) to knee joint: 13in
Knee joint to heel (bottom of foot): 16in
Her current wheel chair seat measures seat bottom to just below ears: 26in
Hip width: 12in

Optimal Seat Back = 22-25 inches
Optimal Seat Depth = 19 inches
1.2.2 Sidecar Frame

The frame of the bicycle sidecar for Abby is one of the most important parts of our design since it is the base structure for which all of our parts will be attached to. Since there are no frames on the market that are optimally designed to suit all the specifications needed for this project, we will be putting the frame together ourselves. The most important feature of this frame is that it will allow easy attachment of the necessary parts used for the sidecar design. The open design of the frame will allow for Abby’s parents to easily get her in and out of the sidecar chair used in this design. The frame will be made of high strength aluminum. This is an optimal metal since it is very lightweight (making for easier transportation of the device) and will make the necessary welding much easier to do. The frame will have a low center of gravity to the ground, which will increase the stability of the sidecar when in use. A main component to the sidecar frame will be the wheel attachment. For this, 2 metal wheel slots will be welded to the frame to allow for the wheel height to be adjusted. A bent metal strip (approx. 4mm thick) will be attached using bolts to the outside of the frame to support the other end of the wheel and metal slot attachment. The bending of the metal strip will be designed in order to allow the wheel to turn easily without rubbing against any of the sides it is enclosed in. By using this design, the wheel will be easily detachable from the sidecar in case

Figure 7: Frame Design.
anything happens to the actual tire. This will also allow the optimal height of the frame to be obtained, in order to connect to the bicycle.

Another important part of the frame is the attachment of the sidecar to the hitch on the bicycle. The hitch is secured on the down tube and connected near the chain rings on the bicycle. We will be constructing our frame in order to comply with where the hitch is attached. The attachment of the hitch will be from the middle-left side of the frame in order to keep a relatively low and stable center of gravity.

Stability of the frame will be our primary concern so the 2 metal wheel slots will need to be centered on the sidecar frame. This will optimize maneuverability and turning when the sidecar is in use. Actual dimensions for the sidecar frame will be determined once an optimal chair is found that suits all of Abby’s specified needs. Once a suitable chair is found, dimensions for the sidecar frame can be made in order to comply with the other parts.

1.2.3 Wheel for Sidecar

![Figure 8: Wheel for Sidecar.](image-url)
The wheel is another important part to the sidecar design. Placement of the wheel will be at an optimal height that will coincide with the sidecar attachment to the bicycle. The wheel will be located on the right side of the sidecar, in between the frame and the bent metal strip. Two nuts will securely fasten the wheel and will allow for easy removal and modifications if needed.

The wheel for this project will be much wider and smaller than the bicycle tires used on the client’s bike. This will improve the sidecar’s ability to turn and will provide more stability than a regular bicycle tire. The wheel being used for the sidecar is the 20” x 2.10” Schwalbe Dirty Harry bicycle tire. This type of tire is optimally designed for both dirt and street riding. This tire has very wide tread, which will allow for extra grip when the road is wet. The diamond texture of the actual tread has a very high resistance to slipping and will allow the sidecar to ride smoothly. The wheel is fairly low cost and is optimally designed to suit the needs of the client and sidecar. Below is a CAD drawing of the sidecar tire.
1.2.4 Wheel Fender

Figure 10: Wheel Fender (Inside View Facing Abby).

Figure 11: Wheel Fender (Outside View Facing Street).
To make sure that the Abby does not come into contact with the wheel while riding in the sidecar, a wheel cover will be added to the frame. The client has requested that the wheel cover surrounds at least the top half of the wheel to make sure Abby’s arms do not have a chance at getting caught in the wheel. Abby does not have much control of her upper body so having the wheel cover in place is optimal for the safety of Abby. For this wheel cover design, sheet metal will be welded to a 20” bicycle tire guard. The sheet metal will be cut to have a similar shape as the 20” bicycle tire guard, in order for easier assembly. The sheet metal will allow for full covering of the tire in order for Abby’s safety. The cover will be bolted into the frame and will be secured. To ensure that Abby stays safe and does not hurt herself neoprene material will be added to the inner portion of the fender. This will make sure that if she does bump or hit the fender that she does not get injured at all.

1.2.5 Back Wheel Fender

Figure 11: Back Wheel Fender.
This piece of the bike sidecar is entirely for safety. Abby’s parents noted after they had seen the alternative designs they would feel more comfortable with something that would help shield the rider’s back bike tire. This would not only keep Abby’s arms safe from being caught in the wheels but would also keep the rider from any unexpected movement. The design of the actual part was designed to make it as small and as minimally invasive as possible. The goal of the sidecar is for as much interaction between Abby and her parents so a large metal fin would not be adequate. The protective fin will be at a 90-degree angle to the back of the frame in between the seat and the actual bicycle. The placement of the fin that far behind will optimize the face-to-face time with Abby, but will not interfere with safety. The fin is curved so that if she were to move her left arm more to the left towards the bike the fin will stop her lower arm making it near impossible to maneuver over it. She will be strapped into the seat so moving towards the front tire or frame is not a concern, nor will a secondary fin for the front half need to be installed. Abby will not be able to see very much behind her on the left side due to the fin, but since there is not much to look at that way and since she leans and faces to the right it was decided that the limitation on viewing was acceptable.

The fin itself is going to be made of metal to ensure that it has strong enough mechanical properties to withstand and pressure or impacts that it may take during a ride. The fin will be secured to the base of the frame with bolts. A series of six or seven evenly spaced bolts will secure the fin in place. Since metal is a very hard and possible injury can occur if there was a hard impact with it, the material Neoprene will be added as a buffer. It will be attached to the top and the inner side facing Abby. This will make sure that Abby does not get hurt if she were to come in contact with it, yet will not be weight burden by covering the entire fin where it is not needed. The seat that is going to be used will determine the dimensions of the fin. Due to the length of the seat and the height of the back varying from seat to seat, the exact dimensions will not be determined until the specific chair is purchased.
1.2.6 Footrest

The footrest of this design is a very major safety issue that was determined was necessary. Since the bicycle will be moving relatively quickly along the road, it was a concern that Abby's feet might possibly drag and essentially get caught and pulled backwards on the pavement/road. This could cause serious injury to her, which is easily avoided by using a footrest. The main purpose of the footrest is to keep Abby’s feet form wandering and possibly hurting herself. She sometimes becomes animated when in conversation so it is important that if she were to kick her feet to the side that she does not bumped into the sidecar's or the actual bike’s tires. This would obviously hurt Abby, but could also throw the entire bikes movement off possibly causing more injury. Also, since the frame is going to be a dense metal kicking it would surely leave a bruise and hurt Abby’s leg if she were to kick it. Keeping her feet stationary throughout the ride would minimize any possible injury to her lower body.

Depending on the seat chosen for the project the footrest with either be incorporated into the manufactured seat or it will have to be fabricated by the team. The current seat that is being researched for the sidecar has a footrest, but due to budget restraints and continuing to look for better prices it is still uncertain.
whether or not the specific chair will be bought. If the footrest is built into the seat than the required safety equipment is already attached so it would ready for use. If the footrest ends up not being part of the seat that is used than a completely new designed footrest will be created. In Fig. 12 a simple diagram of what it might look like is depicted. There would be a single metal bar that would go from the frame and lined up with the seat so that Abby’s legs would rarely come in contact with it. The bottom or footplate of the footrest would be made out of metal as well. Since the Miller family would like this sidecar to be something that could be used for years to come the footplate will be a few shoe sizes larger than necessary to allow for any growth. There will be to outside bars that fully lock Abby’s feet and would not allow them to slide off the sides. Some that is not depicted in the diagram is the straps. The basic idea behind how the straps will work is two “X” straps. Each foot will have a “X” over it to ensure that they can not move. Keeping the feet separate on the footplate will make sure that the feet individually are secure and that it was no just the position of both feet at strap in time. The straps will be adjustable so as Abby grows the footrest would not restrict her form riding in it. Overall the footplate is something that is a large safety feature that will make sure that her lower body stays safe for the entirety of the bike ride.

### 1.2.7 Chariot Attachable Hitch

![Figure 14: Chariot Attachable Hitch for the Sidecar.](http://babyshack.com/product_images/sidecarrier_hitch.jpg)
The hitch attachment for the sidecar and bicycle is a very important accessory that is needed for this design. The client has specified that they would like the sidecar to be detachable from the bike so that it can allow them to easily transport both the bike and sidecar in their truck. The hitch being used for this design is the Chariot Sidecarrier hitch. This is an optimal hitch to use since it is easily securable to the bicycle and will allow for easy attachment of the sidecar as well.

One of the most important features of this hitch design will be its attachment to the bicycle. The hitch will be secured firmly around the down tube of the bicycle and the top of the chain rings. This positioning makes securing the sidecar much easier for the family when attaching and detaching it from the bicycle. The sidecar will have the ability to lock in and out of place when attaching and detaching from the bicycle. This securing mechanism is the most optimal for the sidecar design.

The Chariot Sidecarrier hitch attachment will provide enough strength and durability so that the bicycle can safely and securely pull the sidecar along its right side.

### 1.2.8 Padding Material

![Neoprene Fabric](http://www.asia.ru/images/target/photo/51665688/Neoprene_Fabric.jpg)

Figure 15: Neoprene Fabric
The padding is a very necessary part that will be used throughout our design to allow for optimal comfort when riding. The type of padding used for this design is Neoprene. Neoprene is a material that is very durable, easy to clean and manage, and waterproof. The neoprene will be a good use for the sidecar since it is able to withstand outdoor conditions. A thick neoprene foam will be used for the sidecar seat, fender, and cover. The neoprene will be attached through the use of adhesives for easy attachment. It is available and large quantities and is fairly cheap to buy. A yellow neoprene foam will be optimal since Abby’s favorite color is yellow. A picture of the neoprene padding is seen below.

2. Realistic Constraints

Our bicycle sidecar has been devised in order to allow Abby to ride recreationally. The device needs to be fun so that Abby will enjoy riding it but also safe so that her health and well-being will not be compromised. The main constraints of this proposed design are budget and safety. A list of our needed parts and their estimated costs can be seen below in Table 1. The majority of our money will be spent building a seat for Abby similar to her current wheelchair seat so that she can sit comfortably and with the necessary support. She will be completely strapped in to the seat in the same manner that she is in her wheelchair.

<table>
<thead>
<tr>
<th>Parts List</th>
<th>Estimated Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Stock</td>
<td>$150.00-$200.00</td>
</tr>
<tr>
<td>Wheelchair-Type Seat</td>
<td>$500.00-$600.00</td>
</tr>
<tr>
<td>Torso/Neck/Head Supports</td>
<td>$100.00-$200.00</td>
</tr>
<tr>
<td>20” Tire for Sidecar</td>
<td>$50.00-$80.00</td>
</tr>
<tr>
<td>Attachable Hitch</td>
<td>$60.00-$80.00</td>
</tr>
<tr>
<td>Miscellaneous Hardware</td>
<td>$60.00-$80.00</td>
</tr>
</tbody>
</table>

Table 1: Parts List for Project

Abby’s parents have stressed that the safety of their daughter comes first and for most so the production of the bicycle must be very safe. Some of the conditions that must be addressed would be the fact that her neck, head, and torso need to be supported. To ensure her safety she must be strapped in so that she does not fall off. Her parents have mentioned that when she talks she uses a lot of body motion so keeping her arms and legs secured on the bike is a must. Since our client lives in Illinois on a big hill, her parents would need to transport the bicycle to the nearby park before Abby could get out and ride. Because of this constraint, the sidecar also
needs to be able to be disassembled and reassembled in order for them to be able to easily transport it. In either case, the device would have to be safely secured into place before Abby can ride, in order to ensure her safety and so that it won’t collapse once she is on it. Further details on safety issues can be seen below.

3. Safety Issues

In order to make our device as safe as possible, we have considered any safety issues that may arise. In general, our device will be extremely safe for Abby to use. The strap constraints will ensure that she not only stays seated in an upright position, but also so that she won’t fall out of the device once it’s in motion. With our side leg supports, Abby won’t slide around in her seat. The footplate will help to keep her feet still so that she won’t harm herself when she kicks. Without necessary cushioned supports, the device could be dangerous for Abby to use. If Abby’s head, neck and torso aren’t properly supported, she can be injured. To make sure that she does not injure her arms when moving neoprene will be added to the fenders.

One of the biggest safety issues with our device is making sure the sidecar will not detach from her father’s bike while he’s riding. In order to do this we decided to use the hitch attachment design from the Chariot Sidecar Company. This hitch design is safe and efficient for easy attachment and detachment. We also considered the size of the wheel when considering safety. If the tire on the sidecar is too big, it won’t turn as quick as the bike and the device could possibly flip over. Also, if the sidecar is attached too closely to the bicycle, it can cause difficulty in pedaling. In order to prevent this, we are going to build the front crossbar on the sidecar so that it sticks out further than the rest of the bike, maintaining a distance far enough to ensure comfortable pedaling but close enough for Abby and the bicycle rider to be able to interact.

4. Impact of Engineering Solutions

Although this device is being made specifically for Abby, the design can be modified for anyone with a similar condition. This sidecar design can be used for people who can’t ride a normal bicycle either because they need extra supports or because they can’t control their arms or legs in order to pedal or steer. Although there are devices built similar to ours, there aren’t many sidecars that are wheelchair compatible. Our first two alternative designs, were modeled off of the JEINKEL-HEIMER sidecar design which unlike the Chariot sidecar, was created for anyone with limiting disabilities. However, this design is more bulky and heavy than the Chariot sidecar. This would make it harder on the Miller family to transport the device as well as ride with it attached to their bicycle. When we were deciding between our optimal designs, we decided we wanted to stray away from this design and modify the Chariot sidecar instead.
Once our device is made, it can be marketed and sold to families similar to the Millers. Our seat design can be modified to fit smaller children or adults. It can also be modified by either adding or taking away from the supports. If needed, some of the strap constraints can be removed and instead a seatbelt can be incorporated to still ensure the safety of the client. Each client is different, but our design is something that can be marketed to thousands of people who aren’t able to ride bicycles otherwise. Our design proves to be a breakthrough in wheelchair compatible sidecars. It is lighter and less bulky than the JEINKEL-HEIMER sidecar. The attachment to the bicycle is easy to attach/ detach making it more convent for transporting purposes. It also has many safety features as mentioned above.

5. Life-Long Learning

Since we first began designing our device, we have learned many valuable lessons. We’ve learned how to interact with a client and keep in constant contact, whether through email, phone calls, or video chat. We have learned how to formulate questions that we would need answered from our client in order to better understand what exactly it is that they want our to design and build. We learned how to take the client’s thoughts, ideas, and concerns into consideration when coming up with our designs and how to come up with a device that not only fits the problem statement, but that is safe and easy to use. We’ve learned how to work in team settings, including not only dividing and delegating work but also working together to formulate and think through various ideas and situations. We have learned to think about our device from all angles, including any safety issues that may arise. After we came up with our alternative designs we sat down and discussed the pros and cons of each design. This is also a skill that we have acquired. From this, we learned how to analyze a design and decide which components are the safest and most efficient, and which aren’t necessary. We’ve also learned how to budget our design by researching the cost of our needed parts. Through our designing period, we learned to use CAD in order to draft our designs and Dreamweaver in order to update our team website with our reports and project description.

Although we have learned a lot thus far, we realize that it is only the beginning. Once we start purchasing our parts, we will learn how to decide which parts to order and how to go about the ordering process and when it’s time to actually build our device we will learn how to build various parts, sauter and put everything together. Other important things that we have learned so far include giving presentations in front of large groups, writing reports and meeting all deadline in a timely and effective manner.
6. References

For picture references please refer to under the figures.