Handicap Accessible Bicycle

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ABSTRACT

The life of some adult TBI(traumatic brain injury) patients is very limited in physical ability and the capacity to participate in activities such as going for bike rides. Although there are adult sized attachments and recumbent bikes on the market, none of them fit the need for that of an adult that lacks normal mobility, but has enough ability to still participate. These current designs are mostly passive, do not provide adequate stability required for TBI patients, and are not cost effective. Four potential designs were proposed to create a safe, interactive, and cost effective design for a disabled adult. The final design is composed of steel rods welded in a tricycle formation that attaches to the seat of a standard bicycle. This two wheeled attachment includes features of arm bars, shock absorbent tires, and a separate drivetrain allowing for passenger participation.

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INTRODUCTION

Motivation

Family activities are important to creating a positive family environment. One such activity is a family bike ride. Unfortunately for family members suffering from disabilities, bicycle rides are made difficult. Family members suffering from paralysis are often left behind on these family adventures and lose the opportunity to grow closer with their family. In order to combat this issue, bicycle sidecars should be utilized. Currently, there is a limited market for bicycle sidecars. Many of these sidecars are expensive and difficult to use.

The Elias family has requested that an inexpensive sidecar be created for Mrs. Elias who suffers from partial paralysis below the waist and suffers from a traumatic brain injury. This sidecar should be easily accessible to the client, should not aggravate her brain injury, and if at all possible should include pedals for her to use to act as a form of rehabilitation and to keep her engaged during the journey.

Problem Statement

A Madison area family is in need of a handicap accessible sidecar for a bicycle. Mrs. Elias, a client, sustained a traumatic brain injury several years ago that left her with limited use of her legs and several long term effects on her brain. Her husband would like to be able to go on bike rides as a family. They have requested a sidecar be built, so that she can enjoy bike rides with her family. The current market for bicycle sidecars is limited and very expensive for the few available options. This sidecar should be inexpensive and easy to use.

BACKGROUND

Traumatic Brain Injuries (TBIs)

About 1.7 million people in the U.S. sustain a Traumatic brain injury each year. Levels of brain injury vary between each individual and their circumstance, being classified as either mild, moderate, or severe. Mild for example being the result of a minor concussion and severe being most commonly an open head injury [1]. Those affected by traumatic brain injuries are more likely to experience trouble with engaging in different levels of physical activity. Loss or weakening of the use of one's limbs is a common happening amongst those with moderate to severe TBIs [2]. To deal with this, patients will work with a physical therapist to regain some or all ability. Not all may be able to return to their preinjury status, but can still improve in tasks such as walking or in being able to operate a wheelchair independently.

Handicap Accessible Bicycles

Current Handicap accessible bicycles come in a variety of styles including sidecars, trailer attachments, front end attachments, tandem, and others. They are passive products, and offer no engagement of its passenger leaving them to sit while someone else operates the bicycle. This type of design may be ideal for those who have extremely limited or no use of some of their limbs, but for our purposes is not ideal for the client and his wife, who does have some use of her limbs. The benefits of exercise for someone who spends most of their time sitting stationary in a wheelchair are helpful not only physically but can have a positive effect psychologically. It can reduce anxiety and depression as well as boost self-esteem [3]. In addition, the passenger is unable to get the full effect of going on a bike ride without some kind of engagement.

In most of the detachable on the market designs, the handicap accessible part can be used independently of the device, however the bicycle portion cannot. This means that independent usage of a bicycle would require the possession or purchase of a single bicycle. With the average current market price of handicap accessible bicycles falling mostly in the $1000-$4500 range, having to buy an additional bicycle would mean higher overall cost to the consumer. Adding to the cost, insurance for such an investment would most likely be required. This could cause a decrease in the consumer market because these products are not necessities and may not be worth buying if the consumer will get only a limited amount of use from them.

Design Specifications

The device to be fabricated is intended to be detachable to make storage easier and allow independent use of bike possible. The height of the passenger chair should be about the height of a wheelchair for an easier transition, and the overall size of the attachment should be small enough to store easily in the back of the client's minivan for transportation.
It needs to also be stable and comfortable for the passenger so as to avoid any potential damaging movements of the head. The current budget for the device is $1000 or less if possible.

The client's need for easy access of medication has created the need for a storage space to carry supplies that might be needed. The position of the sidecar relative to the bicycle is preferred to be a side or back attachment. In order to add a more engaging and therapeutic element to the device, pedals should be attached for use by the passenger. A detailed list of design specifications can be found in **Appendix A**.

PRELIMINARY DESIGNS

Design One - Trailer

The first design involves a trailer design for the sidecar (**Fig 1)**. This trailer would attach to the seat of driver's bicycle with a clamp, and it would be easily removable when the seat is removed from the bicycle. This removable design allows for independent use of the bicycle. The trailer seat would be similar in height to the client's current wheelchair model allowing for easy access into the trailer. This design also incorporates independent pedals for the trailer. This would allow the client to contribute to the movement of the bicycle thus taking strain off of the driver. These pedals would also allow for the passenger to remain active and engaged during the bike ride. The trailer was designed to have two wheels. The seating in the trailer would be wide, and have movable elbow rests that would secure the passenger. As the passenger would be behind the driver in this design, this design is flawed because conversation is made more difficult.

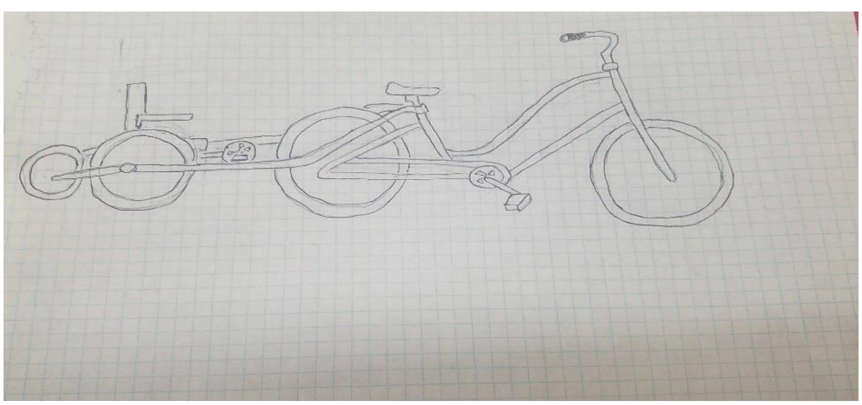

Figure 1: The trailer sidecar is attached to the seat of the driver's bicycle.

Design 2 - Sidecar
The second design involves a sidecar that is directly clamped to the bicycle (**Fig 2**). This attaching mechanism does create a problem. The clamps would have to be designed specifically for each bicycle, and would be difficult to adjust for other bicycles. This sidecar is detachable, so the bicycle could be used independently. This design incorporated one wheel for the sidecar and also involves pedals to allow the passenger to stay engaged and stay involved during the ride. One issue with the pedals in this design is it could lead to the steering being offset as one side of the bicycle would have more force applied given the offset pedals and wheel. Another issue with this design is that the sidecar would take up a great deal of space on bicycle paths and could lead to potential accidents. The sidecar would be very stable as it has a wide center of gravity and keeps a majority of the weight centered. The seating in this design would be wide and would have movable armrests that would secure the passenger. The passenger would be next to the driver in this design. This would allow for the passenger and driver to engage in conversation during the bike ride.

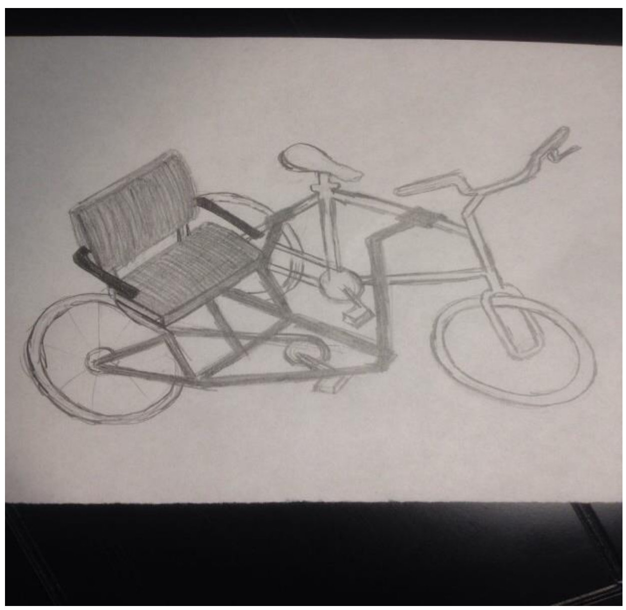

Figure 2: The sidecar would be clamped to the bicycle.
It is actually a sidecar as it is directly next to the bicycle.

Design 3 - Tandem
The third design would involve taking a tandem bicycle and modifying it to have more secure seating for the passenger (**Fig 3**). These seats would be reclined and would be more secure than traditional bicycle seats. Because this bicycle is a tandem, the bicycle could not be used independently without the passenger. This design is very simple and very cost effective as it would simply involve removing the traditional seats, replacing the seats with more supportive seats, and adjusting the pedals and drive train. This design also incorporates pedals for the passenger thus decreasing the workload on the driver and increasing the activity of the passenger. The issue with the pedals for the passenger in this design would be adjusting them to meet the passenger's physical abilities. An issue with this design is the passenger being placed behind the driver decreasing personal interactions during the bike ride. Another issue with this design is stability. Tandem bicycles are very unstable and prone to tipping. This flaw could lead to potential injury to the driver and passenger if the bicycle were to fall over.

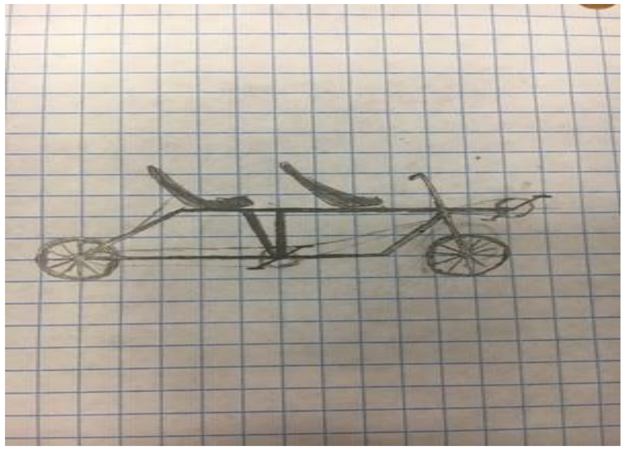

Figure 3: In the modified tandem bicycle, traditional seats would be removed for more secure seating thus providing a safer experience for the passenger than traditional Tandem bicycles.

Design 4 - Recumbent

The fourth design involves creating a recumbent bicycle with two seats (**Fig 4**). The recumbent bicycle would be very stable as the seats would be close to the ground thus lowering the center of gravity. The design's stability would also be increased by the wide base. The passenger and driver would be next to each other allowing for a personable ride. This design also incorporates pedals for the passenger thus decreasing the workload on the driver and making the ride more active for the passenger. Because the steering would be in the middle of the bicycle, the recumbent design would not have the same steering issues the sidecar design would. The main issue with the recumbent design is the cost. Most single seat recumbent bicycles are beyond the client's price range. Creating a dual seated recumbent bicycle would put a financial strain on the client. This design would also be very difficult to manufacture as it would need to be designed built from parts whereas other designs would utilize bicycles for the driver.

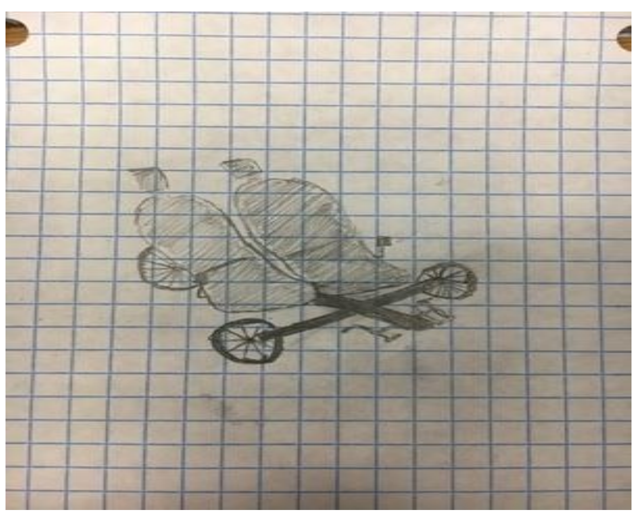

Figure 4: The recumbent bicycle design would involve modifying a traditional tandem bicycle to put two seats side by side on the frame.

PRELIMINARY DESIGN EVALUATION

The criteria in our design matrix (**Table 1**) include safety, size, manufacturability, detachable, appearance, versatility, and cost. Safety is defined as the ability to keep the passenger stable, safe, and comfortable. This is important in considering possible seizures and undesired headaches. Size in this design project is how effectively the sidecar will be able to be stored in the clients' minivan as well as how much space the sidecar will take up on the path of choice. Manufacturing is the ability to make the product and the ease at which the product will come together. This takes into account the amount of time the team will need to spend on the fabrication of our design as well as the processes that will need to be used, such as welding, by our team. Detachable is the ease at which the sidecar will attach and detach from the client's bicycle. Appearance is the designs ability to stay away from any inconspicuous or "clown car" looking attachments that will draw a lot of undesired attention to our client and his wife. Versatility will be the design's ability to be used in a variety of settings. Finally, the cost will be how much money the design will require to be manufactured.

Criteria	Trailer		Sidecar		Tandem		Recumbent	
Safety (25)	4/5	20	5/5	**25**	2/5	25	3/5	15
Size (20)	4/5	**16**	3/5	12	1/5	4	2/5	8
Manufacturability (20)	3/5	12	3/5	12	4/5	**16**	1/5	4
Detachable (15)	5/5	**15**	4/5	12	0/5	0	0/5	0
Appearance (10)	4/5	**8**	3/5	6	4/5	**8**	2/5	4
Versatility (5)	4/5	**4**	3/5	3	4/5	**4**	2/5	2
Cost (5)	3/5	3	3/5	3	4/5	**4**	1/5	1
TOTAL (100)	**78**		**73**		**46**		**34**	

Table 1: Design matrix that evaluates three preliminary designs. Criteria are listed in descending order of importance. The Trailer received the highest score overall due to its performance in size, safety and because it is detachable. The sidecar received the highest score in safety because of its position of attachment and its position relative to the clients. The tandem scored highest in manufacturability because it will only require modifying a store bought tandem bicycle. The recumbent did not score highest in any category because of its difficulty to manufacture, high cost, it's not detachable, it's large size, inconspicuous appearance and low versatility.

The trailer design scored highest in size and detachable and tied for appearance and versatility. The design is detachable and beat the other designs because it attaches at only one position on the back of the bike. The cost did not score the highest because it will require a lot of material to manufacture. It scored high in appearance because there are a lot of trailer attachments that are on the market such as a Weehoo for kids that can compare to this design. The safety scored high as well because of the attachment position of the sidecar. It attached to the back of the bike which would protect the passenger from any head on collisions. It is also safe because it does not take up a great width of trails.

The sidecar design scored the highest in safety. This is due to the fact that the weight of both the client and the passenger will be evenly distributed and will lead to less tipping. This sidecar design scored reasonably well in the detachable criteria because the design is able to attach and detach from the bicycle. It fell one point below the detachable criteria of the trailer because instead of the one attachment point of the trailer design, the sidecar would have two attachment points to the bike. On the other hand, it did not score high in manufacturability because it will require a lot of welding and time spent on fabrication. It also did not score the highest in appearance because the attachment point on the side of the bike draws a considerable amount of attention compared to the trailer and tandem. This can be explained by the fact that the sidecar will have a completely different look than the bike itself.

The tandem design ranked highest in manufacturability and cost while tying for the highest ranking in appearance and versatility. The tandem scored very low in size and detachable. The size of the design is undesired because it is not detachable requiring a large space for storage. This tandem design will most likely not fit in the clients' minivan which is preferred. It did get a one in detachable because we would be sure to make the seat foldable. It performed well in the manufacturability because the only fabrication it would need are modifications to a purchased tandem bike. Consequently, these minor modifications to the back seat would also keep the cost low for this design. The appearance also scored high because tandem bikes are used by many people and the alterations made would not be substantial enough to make this design stand out. Although this design scored highest in four categories like the trailer design, the categories it excelled in happened to be smaller weighted criteria.

The recumbent design did not score highest in any of the listed criteria ranking it the lowest out of all four designs. This design received a zero out of five for detachable because the side by side recumbent design would stay in this position and would not allow for individual biking. With no detachable sidecar, the size of the recumbent design would not be likely to fit in the clients' minivan, scoring the design low in the size criteria. The cost and manufacturability of this recumbent design would be highest out of all of the designs because it would be completely self manufactured to fit the specific needs of the client and his wife. Manufacturing would require a significant amount of money.

FINAL DESIGN

The proposed final design consists of a double framed trailer attachment designed to be attached to the seatpost of a separate bicycle. The frame will be made of steel tubes that will be welded to create a frame to support a seat as well as a complete drive train. The seat on the trailer attachment will not be a traditional bike seat, but rather it will consist of either a separately bought seat, or a fabricated seat. It will be the approximate height off the ground of a Tsunami rigid frame wheelchair. The seat will also have grab bars attached to both sides of it in an effort to help stabilize our client without the use of a seat belt. In front of the seat and as a component of the frame there will be a bottom bracket either fitted or manufactured that will contain pedals as well as the front gears.

As the frame continues back towards the rear of the trailer attachment, there will be attachment points for wheels. We plan on using wide wheels similar to those found on winter bikes. They will be operated at a lowered PSI in an effort to reducing strain on our client during the ride. The two side wheels will also contain independent brakes on the side wheels. These will likely consist of caliper brakes operating with standard cables and housing and utilizing standard resin brake pads. The two side wheels will not be connected to the drive train.

The initial design planned on only two wheels, however, incorporated pedals with this design proved problematic. Therefore, alterations were made to the design to simplify the drive train mechanism. The solution was the addition of a third wheel in the rear of the trailer attachment that can be position in line behind the pedals as seen below. The rear wheel will operate as a similar PSI to the two side wheels. The wheel will contain a freewheel mechanism enabling our client to coast without continued movement of her legs during some durations of the ride. The rear wheel will be connected to the pedals by a custom length chain, preferably containing a master link to simplify changing the chain as well as during cleaning. Due to the extended length of the chain, and the lowered height of the attachment, a chain guard will be incorporated into our design to help prevent grease building up on the chain and other components of the drivetrain. The rear wheel will also contain an individual cassette. Should the decision be made to add on multiple gears the rear or front cassette, derailleurs will also have to be included. The attachment will lock into place on the bike it is being linked to through a clamp attached to the seat post through a clamp mechanism found on existing trailer attachments.

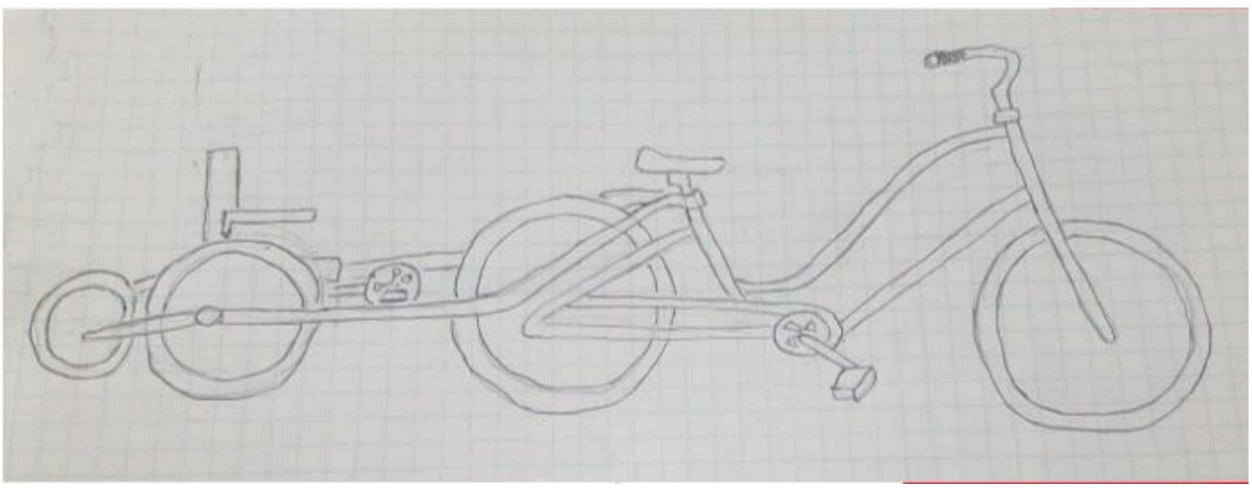

Figure 5: Final design consisting of a 3 wheeled, double framed trailer attachment. Contains independent drivetrain mechanism powering rear wheel of trailer.

Materials
The frame was made from steel conduit that will be bolted together to create the supports for the seat and the drivetrain. The pedals and axle are made from solid steel. The seat is made from a polyurethane foam. Our wheels will be made of aluminum with rubber tires and inner tubes. Most of the attachments to our frame will be secured using steel nuts and bolts and well as screws.

Methods
For fabrication we used 1-inch diameter conduit tubing and a rod bender mechanism to create the curve down in the trailer frame. To attach the bars, we used a combination of ⅜" nuts and bolts secured through holes drilled in the frame with a hand drill. To further secure the frame and to support the attached seat, we attached two additional conduit bars that had a slight bend in them to act as a spring damper. These were also secures using ⅜" nuts. Following the attachment of the two bars, we attached our ordered seat by drilling additional holes in the frame and bolting the seat into place.

To attach the frame to whatever bicycle it would be anchored to, an attachment plate was built using 3 steel plates and a ball bearing to allow the attachment to rotate to aid in turning. The plates were welding using MIG welding into an offset I beam design. The ball bearing was then welded onto the central plate of the I beam. Holes were then drilled through the peripheral plates of the I beam so they could be anchored with a ⅜” bolt to the frame. The ball bearing was then placed through the seat post of our bike to serve as our attachment point.

Fabrication of the drive train began with the creation of our pedals. ¼” steel rod and ¼” steel threaded rod was cut at 45 degree angles and specific lengths and then welded together using MIG welding. One of the ends of our pedals was then secured to the frame by using the threaded rod and two nuts, one on the interior of the frame, and one on the exterior. On the other end our pedals, a bike cog was welded onto the rod at a right angle. In the rear of the attachment our two mountain bike wheels were attached using holes drilled into the frame. Through these holes our wheels were secured using an axle composed of 10mm threaded rod welded to the two 9.4 mm bolts that came with our bike wheels. This axle was then ran through the holes in the frame and the wheels were secured to it using the hardware that came with the wheels. To connect the action of our pedals to that of our wheels, we utilized two bike chains connected using a chain tool to our specified length.

Final Prototype

The final prototype changed slightly from the final design idea. The first change made was removing a wheel from the final design. Three wheels were found to make turning too difficult. Two wheels will allow the trailer to turn in an easier manner. The next change was to the gear system. Initially, the chain was going to be placed in the middle of the trailer. The chain was going to run from the pedals to a gear under the seat where it would turn an axle which would turn the wheel. This idea was changed to have the gear run on the outside of the cart and turn the wheels from a gear on a wheel. This change made the gear system simpler, and reduced the risk of the passenger cutting themselves on the chain. A final change was positively curving the bars under the passenger’s seat. This would allow the bars to act as a natural spring thus reducing the effects of the passenger’s weight on the frame.

Although there were a few minor changes, many key parts of the design were kept. The frame of the bike was curved and made of two pieces instead of being composed of several bars welded at ninety degree angles. If the trailer was welded together at ninety degree angles, there would be too much stress on the welds, and the risk of weld failure would be very high. The attachment point was also kept the same. The trailer was attached with a circular ring on the seat post. Finally, a padded seat was kept to make the ride very smooth for the passenger.

Figure 6: A final prototype consisting of self-fabricated pedals, a gear system similar to a paddle boat, and a padded seat on a positively bent bar.

Testing

After our team constructed our prototype, we conducted three mechanical tests. Our first mechanical test was the spring damper test. Our seat attachment presents a passive suspension, similar to that of a truck or bus driver seat which means that it has a resonance effect. Bike suspension is the system used to suspend the bicycle and the rider in order to insulate them from the roughness of the terrain. In our final design, we wanted to model a spring damper system that would limit this resonance effect for safety purposes because too much resonance in this system could cause our client unwanted headaches and possible seizures. The spring damper test is a calculation to estimate a steady state deflection of the seat with our clients weight as the external force on the system. The next mechanical test was testing the structural integrity with the ride test. To do this, two team members rode the prototype down the lobby of ECB at a fairly slow pace. In the first ride, both passengers were pedaling and in the second ride, only the bike passenger was pedaling, leaving the feet of the prototype passenger at rest. We felt ECB was a good representation of the actual terrain our clients would ride it on. They wouldn't ride in the winter or on very uneven trails, sticking to even and smooth surfaces. We also tested our prototype moving at small turns that didn't exceed 5 degrees. The last mechanical test performed was the displacement test. Our displacement test was conducted by measuring the distance from the parallel frame bars to the top of the positive arch before and after a variety of weights were put in the seat, up to 195 lbs. We conducted the same test measuring the distance from the ground to the axle of our design.

Discussion

Results and implications

Mass-Spring Damper Model

To model the mass-spring/damper system of our seat, we used purely theoretical conditions due to the fact that the actual prototype had not been fully fabricated. It was modeled after a slightly underdamped system because the oscillation that occurs because of this is desirable to limit the transmittance of force to our client during the ride by not being so rigid. The weight of our client was used as the external force on the system. The graph below (**Fig. 6**) shows the change of deflection over time of the positively arched rods supporting the seat, which are acting as the mass-spring/damper system. The steady state deflection of the bars is approximately 5mm.

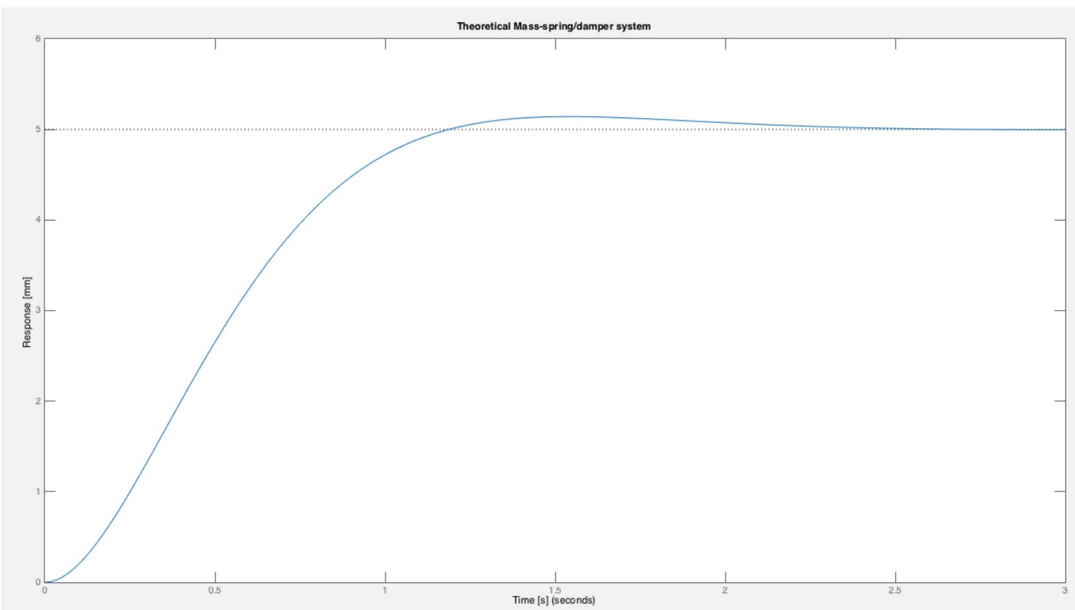

Figure 6: Mass-spring/damper model of the seat. The equation of motion used for this is ($\sum F_{x=}$13.6(kg)x''+62.837(Ns/mm)x'+129.034(N/mm)=645.17 N$_{)}$. Steady state deflection with our client's weight as the external force is ~5mm.

Ride Test

The ride was very smooth during the test. Although the structure was overall stable, the seat needs to be more secure as to avoid too much extraneous movement of the passenger during use. The seat itself is comfortable and firm enough to provide adequate support. The pedals on the prototype are not perfectly aligned causing the user to turn their body slightly to use them causing slight discomfort. Additionally, because estimates rather than actual measurements were used to determine spacing, the pedals are too far from the seat for comfortable and consistent use for someone of our client's height.

Displacement Test
The steel conduit frame beneath the seat had minimal displacement of 6.35 mm for the maximum load of 195lbs during static testing. This is relatively consistent to the theoretical deflection calculated in the mass-spring/damper model test above. This assures us that the system will closely resemble the conditions we desire. The dynamic structure of the axle support showed an additional displacement of 3/4in with the same 195lb weight. This is undesirable because too much deflection of the axle will increase the likelihood of breaking.

CONCLUSIONS AND FUTURE WORKS

Our task is to create an attachment for a standard bicycle to allow a TBI (traumatic brain injury) patient to be able to ride along with a companion. This attachment needs to be considerate of the patient’s needs for stability and limited mobility. Our trailer design encompasses the dimensions of our client’s model of wheelchair and the final design will add armrests to allow for side to side stability. The design also includes large winter tires at a low PSI providing extra cushion on the uneven parts of the trails to allow for less force transmitted to our client. Our design is removable, allowing for maximum usage and storage. Between the prototype and final product, making the overall length shorter by decreasing distance from pedals to seat is desired to make even more compact and easily storable.

Other features could be included to make our design more suitable for customers with varying degrees of TBI symptoms as well as clients of differing size from our own. The first of these is the incorporation of a seatbelt and swiveling seat. Potential users of our design may have more problems getting in and out of the seat as well as having more problems staying in the seat when the bike is moving on trails. Incorporation of a swiveling seat would allow customers to enter and exit our trailer more effectively. A seatbelt would also allow customers that are less stable than our own to be secure within our attachment. To make our design fit consumers of different heights, weights, and leg lengths, the seat and/or the bottom bracket would be incorporated into a rail or sliding and locking mechanism. In addition, the actual seat itself could be made wider to fit a variety of sizes as well as be adjustable to accommodate for each individual’s sense of comfort. For the pedals, footholds should be installed to help with those individuals who lack the coordination to keep their feet on them, as well as a locking mechanism to keep the pedals horizontal when the user becomes too tired to continue pedaling. A final feature that would make our attachment more useful to clients is the incorporation of storage in various parts of the trailer that could be used to hold food and water for long rides, simple repair kits, and medications for customers that would need it.

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Appendix

A. Project Design Specifications

Handicap Accessible Bicycle

Product Design Specifications | September 23, 2016

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Function: Handicapped Accessible Bicycles vary greatly in style and design based on the specific person's needs, age, and financial income. The objective of this design is to create an easily accessible bike attachment for an adult client who has limited mobility and is still affordable for most persons. In addition to its function this design should be similar in dimensions to that of a common wheelchair.This design will improve the quality of life and also provide therapeutic exercise for the client.

Client Requirements:

- Budget
    - Sidecar cost must stay within a $1,000 budget but under $500 is preferred
    - Bike cost preferably no more than $100
- Sidecar
    - Height must be around the height of clients Tsunami rigid frame sn: ts009326 wheelchair
    - Should contain a small storage space for medications
    - Preferably detachable
    - Must be able to fit in trunk of minivan
    - Sidecar must be on the side or the back of bike
    - Prefer sidecar to have peddles
    - Seat belt for safety in case of uneven surfaces

Design Requirements:

1. Physical and Operational Characteristics:

a. *Performance Requirements:* The sidecar must have the proper size to contain the client's 5'4" height. The totality of the bike and the sidecar must be able to hold around 350 pounds of maximum weight. The seating for the client must also be very secure. If the client is moving around too much, her brain injury could be aggravated. Ideally, the bicycle should be easily storable in a minivan and in a basement. Ideally, the sidecar will be next to the bicycle driver, or behind the bicycle.

b. *Safety:* Safety is a major concern for our sidecar design. Biking is a dangerous endeavor by itself, and when the sidecar is attached, it will increase the space the bike takes up on the road and increase its risk of getting hit. We need to ensure our bike is as visible as possible to prevent any accidents. In addition to the risk of impact injuries, our client specifically needs a smooth ride to prevent injuries from excessive bouncing due to a bumpy road. A final safety concern that must be accounted for is in the stability of our sidecar attachment. Our client doesn't have the best stability, so we will need to make sure she is secured with a seatbelt or harness style design.

c. ***Accuracy and Reliability:*** The accuracy and reliability of the side car must be of top priority. Faults in this category can cause severe headaches and potential seizures for our client. This design must provide a smooth reliable ride.

d. ***Life in Service:*** Our sidecar should withstand the conditions of the terrain and maintain mechanical stability for as long as the client decides to use it to demonstrate its durability.

e. ***Shelf Life:*** The sidecar itself should be durable enough to withstand the weight of the passenger. It should also hold up during long periods of storage in the winter months.

f. ***Operating Environment:*** The bicycle must be able to withstand the bumping from standard bicycle trails. The sidecar and bicycle may also be ridden on roads on occasion. It must also be able to withstand the total weight of our clients, about 350 pounds maximum.

g. ***Ergonomics:*** Our sidecar must be comfortable for the rider to be in for extended periods of time. The attachment also must be easy for the rider to be assisted into and out of the sidecar. Should we pursue a design that includes a detachable aspect, it should also be easily removed and attached so our clients can spend less time setting up their bike and more time enjoying it.

h. ***Size:*** The size of the sidecar and bike combination must not exceed that of what can be stored within a minivan.

i. ***Power Source:*** The sidecar does not require a power source because does not contain any circuitry or motors. The sidecar care will be powered manually.

j. ***Weight:*** There is no weight constraint for the sidecar but should be light enough to maximize storage convenience. The client should be able to lift it into a vehicle for transportation.

k. ***Materials:*** The client is in need of a bicycle, so a cost effective bicycle capable of having a form of a sidecar must be found and attached. In order to create the strongest possible frame for the sidecar, a strong original frame must be used. It should incorporate thick metal poles and thick metal sheets that must be welded in an appropriate manner. A suitable secure seat must also be used for to ensure our client’s safety. If need be, safety harnesses may be employed to prevent jarring to our client’s head.

l. ***Aesthetics, Appearance, and Finish:*** Our finished product doesn’t have many aesthetic requirements. The one requirement of our client aesthetic wise was that the attachment not look childish. It would also be preferable if the sidecar attachment didn’t substantially increase wind resistance to prevent fatigue for the rider. From a safety perspective, our design’s finish should be highly visible to drivers in a variety of weather conditions.

2. ***Product Characteristics:***

a. Quantity: The client desires one functional product that can allow the passenger to participate in a bike ride.

b. Target product cost: The client would like to keep the sidecar expenses under $1,000 but would prefer it to be no more than $500. A bike purchase will be necessary and should not exceed $100.

3. Miscellaneous:

a. Standard and Specification: None required.

b. Patient-Related Concerns: Bicycles are notorious for being unstable. The bicycle must be made as stable as possible because serious injuries to our client could leave her severely injured given her current situation. Bicycle are also very jarring when going over bumps. The seating system must be made as secure as possible to prevent aggravating the client's handicap situation.

c. Competition: There are competing designs for a variety of handicapped accessible bike attachments. Some incorporated a trailer attachment for placing a wheelchair on and stabilizing it. Some were modeled after bike taxis used in east asia. Others had more of a traditional sidecar design. They range in price from around $1000 up to $4500.

d. Customer: The sidecar is designed for a client with limited mobility and balance who can operate a common the pedals of a stationary bike.