Handicap Accessible Bicycle

BME 301 Preliminary Report | February 22, 2017

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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. 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. Three separate methods have been proposed to make entering and exiting the device safer and more convenient for the passenger. These include a swivel chair design, slide bar design, and dip bar design with the latter two requiring change in composition of the frame.

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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 utilised. 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 limb 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 are 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. 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 - Swivel Chair

The first design involves a swivel chair attachment for the sidecar (**Fig 1)**. The idea behind this design is that the seat will be pulled forward and swivel toward the side of the device. This would allow the passenger to be assisted into the seat while whoever is assisting them slides the seat back and helps lift the passengers legs up and over the bar. The seat being used for this design already comes equipped with sliding capabilities. To accomplish the swivel aspect of the design, an attachment must be installed beneath the seat. The attachment itself will have the ability to be adjusted by hand. The problem with this design is that the attachment will be adding some extra weight to the device. It also adds some safety concerns due to the multiple elements needed that, if not used correctly, could potentially break while in use.

Figure 1: Swivel chair- The seat being used for our device will attach to a mechanism that would allow for a swivel action to occur.

Design 2 - Slide Bar

The second design involves an inner rod that can slide open. This design allows for the passenger to be walked right through the frame and into the seat. The inner rod is a smaller diameter than the rest of the frame and would be fastened in using knurled head screws(**Fig 2**). A bolt would be welded to the bottom part of the bar to let the screws be removed and then refastened. Ideally whoever is assisting the passenger would be able to remove the screws by hand and slide the bar over enough for the passenger to walk through. Some issues with this design involve creating a weakness in the frame because it directly interferes with the frame's structure where the rod would be. Additionally, if the screws were not tight enough while the device is in use, shearing stresses on the screws could lead to breaking. To combat this structural weakness, this design also includes the addition of a cross bar at the front end of the attachment. This would provide more stability of the frame mainly while the rod is being moved.

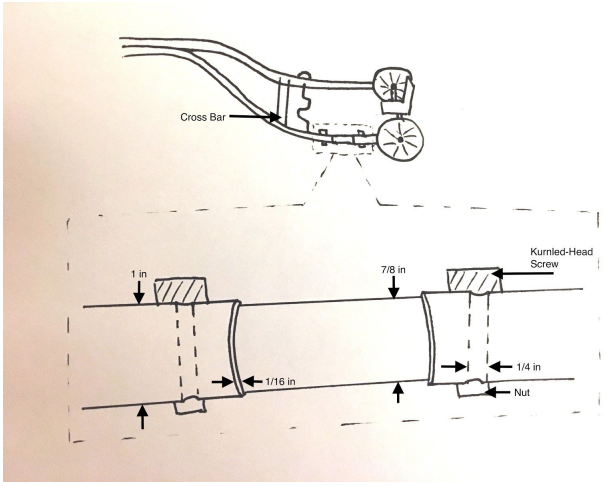


Figure 2: Slide Bar- An inner rod structure connected to the frame by removable screws along with additional cross bar for stability and strength.

Design 3 - Dip bar

The third design would involve additional bending of the frame rod to lower the point of entry (**Fig 3**). This would make it less strenuous for the passenger to get over the bar. The current prototype's frame is raised about 13 inches off the ground. The standard step height for a person with traumatic brain injury is 7-11 inches [4]. The goal for this design is to bend the bar to a height of 7 inches. The purpose of not going any lower is to reduce the chance of the bar coming into contact with the ground or any curbs while the device is in motion. The bends in the bar already contribute to a weakening of the frame's structure. Additional contact with the ground can weaken it further making it more likely to fail. Another issue with this design is that there is still risk of the passenger's foot getting caught by the bar if the foot is not lifted high enough. This presents a risk for tripping if not being supported well enough by the assistant. This design provides no additional cost to the project because we will be using the same rod being used for the frame, while just creating more bends.

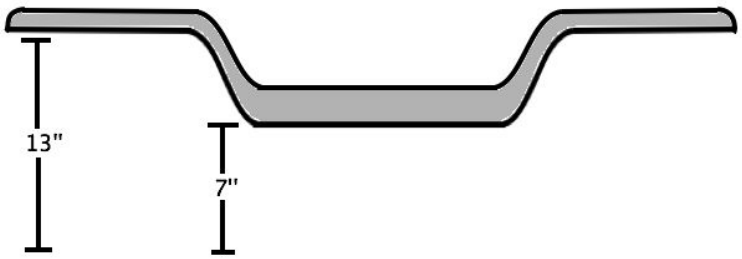


Figure 3: Dip Bar- Additional bending in the frame along the side of the device.

PRELIMINARY DESIGN EVALUATION

The criteria in our design matrix (**Table 1**) includes safety, ease of use, durability, manufacturability, and cost. In our design matrix, safety is defined to be the ability of avoiding any possible injuries and keeping our passenger stable and comfortable. This includes how safe it is for our client to be able to get in and out of the trailer design and how safe and stable she is once sitting in the seat. Avoiding any undesired headaches and possible seizures is the main concern of our client. Ease of use is the ability of our clients to get in and out of the trailer attachment. The main parameters to consider for ease of use is how easy is it for our client to assist his wife in and out of the trailer and how easy it is for our client's wife to get into the trailer with her limited mobility. Durability is defined to be how strong and tough each design will be once manufactured. This includes being able to withstand stresses applied to the specific design features of the frame and of the seat over a long duration of time. Also taken into consideration is how well it performs in rough terrain/bike paths. Manufacturability is the ease at which our team will be able to fabricate our design. This includes how much time and effort will go into welding, cutting metal, drilling, etc. The cost is defined to be the amount of money that will be spent to completely fabricate each of our designs. This includes the purchasing of every part that makes up the design, as well as any extra frame materials.

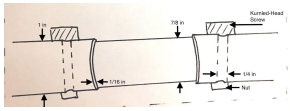
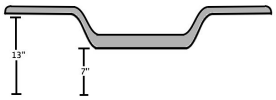
Criteria	Swivel Chair 		Slide Bar 		Dip Bar 	
Safety (25)	3/5	15	2/5	10	4/5	20
Ease of Use (25)	3/5	15	4/5	20	3/5	15
Durability (20)	5/5	20	3/5	12	4/5	16
Manufacturability (15)	2/5	6	3/5	9	5/5	15
Cost (15)	2/5	6	4/5	12	5/5	15
TOTAL (100)	62		63		81	

Table 1: Design matrix that evaluates three preliminary designs. Criteria are listed in descending order of importance. The Dip Bar received the highest score overall due to its performance in safety, manufacturability, and cost. The Slide Bar received the highest score in ease of use because the knurled head screw will allow for easy removal of the inner rob by sliding it to one side, allowing walking space to enter the trailer. The Swivel Chair scored highest in durability because it doesn't disrupt the structural integrity of the frame as the other two designs will do.

The Swivel Chair scored highest in durability because it doesn't disrupt the structural integrity of the frame as the other two designs will do. It scored low in cost because to fabricate this design, multiple expensive pieces will need to be purchased. It also scored low in manufacturability due to the fact that a significant amount of time and effort will go into fully fabricating the design as well as require a significant amount drilling, welding, and mechanical set up that our team is not extremely familiar with.

The Slide Bar scored highest in ease of use because it will not require our client to step over the trailer's frame. This is an attractive feature knowing that the mobility of our client and other traumatic brain injury patients is very limited. Another attract feature includes the ease at which our clients will be able to maneuver the slide bar. It only requires the loosening and fastening of two knurled head screws in order slide the bar lying internally to one side for free access into the design. It scored low in safety because a lot of the structural integrity will be sacrificed in the

frame of the trailer attachment which will result in a greater failure risk. Once our clients slide the bar to one side, it is possible that the weight of the trailer could result in the collapsing of our design.

The Dip Bar scored highest in safety, manufacturability, and cost. The Dip Bar scored highest in the category of safety because the design does not sacrifice the structural integrity of the frame bars to the same degree that the other two designs will. It was not awarded a perfect score for safety because when lowering the height of over design, the concern of our design scraping curbs, paths, and other environmental factors starts to arise. There is also a slight concern that our client will still struggle to get in and out of the trailer attachment, ranking the ease of use lower than the Slide Bar, but tying the ease of use of the Swivel Chair. The Dip Bar scored the highest in manufacturability because it only requires a small amount of additional bending of the trailer's frame. This bending feature also reduces the overall cost of the design because it does not require the purchase of any extra materials.

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 a foldable chair with armrests and a seatbelt. It will be the approximate height off the ground of a Tsunami rigid frame wheelchair. In front of the seat there will be pedals modeled after a paddle boat this will then be connected to a gear on the side which will connect and power the back tires.

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.

The wheels will be enable 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 masterlink 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 the help prevent grease building up on the chain and other components of the drivetrain. The attachment will locked into place on the bike it is being linked to through a clamp attached to the seat post through the burley travoy hitch. The bike will include features such as a mirror to check in on the posterior rider, fenders to prevent splash back, and custom 3D printed pedals.

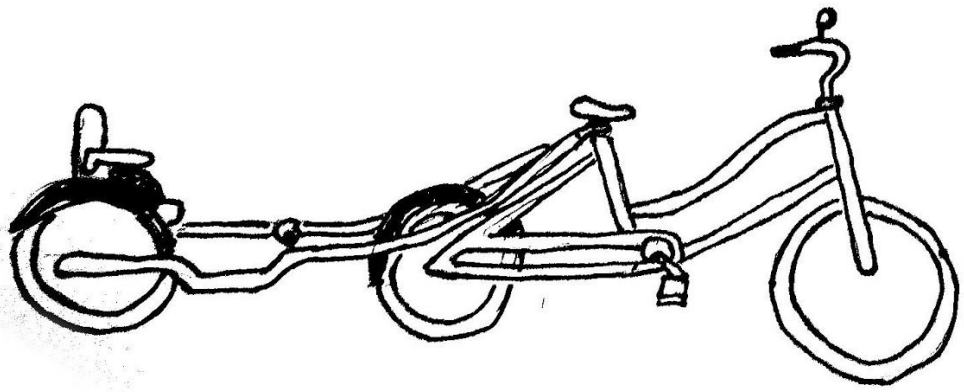


Figure 5: Final design consisting of a 2 wheeled, double framed trailer attachment. Contains independent drivetrain mechanism powering rear wheel of trailer.

FABRICATION AND DEVELOPMENT PROCESS

Materials

The majority of our design will be composed of steel. The frame will be made from steel that will be welded together to create the supports for the seat and the drivetrain. Many of the drive train components will also be composed of steel including the pedal arms, the cassettes and the chain. The seat will be made of leather and other plastics. Our wheels will be made of aluminium or steel with rubber tires and inner tubes. The fenders and pedals will be made of plastic. Most of the attachments to our frame will be secured using steel nuts and bolts and well as screws.

Methods

For fabrication we will use a standard conduit bender to create the curve down in the trailer frame. To attach the bars, we will use MIG welding for the steel bars. As a part of the frame, attachment points will be created for drivetrain, and seat. The seat will be attached directly to the frame through the inclusion of a seat tube in the frame. It will be fabricated to the dimensions so that it can fit the post of the seat we select. The seat post will then be lubricated and locked into the proper height through the incorporation of a seat post clamp. The drive train will be incorporated into our design through two specific attachment points. The first being the side gear located to the left of our pedal attachment, and the second being at the rear wheel

where our cassette will be located. Our frame will have to be fabricated with the proper dimensions to allow for bottom bracket incorporation and the rear wheel will have the be anchored in a way that allows for our chain to propel the attachment without impediment.

Testing

Important future testing includes load-bearing capabilities, axle displacement, turn radius, and on-site trials.

To test the load-bearing capabilities of the trailer, team members weighing the same weight as the client as well as team members with weights exceeding the client will ride in the trailer. The trailer will be considered a success if, when the rider weight exceeds that of the client's, there is no failure of any components of the bike or trailer and if another team member is able to successfully pedal the bike forward.

Axle displacement will be tested using a spring damper test. This is a calculation to estimate a steady state deflection of the axle with the client's weight as the external force on the system.

Turn radius will be defined as the radius at which the bike is able to turn without being jackknifed by the trailer. A team member will ride the bike at an average pace of 5-10 mph in a straight line on a flat surface with another team member in the trailer. The biker will then turn at designated angles, beginning wide and slowly sharpening, until a smooth turn is no longer possible due to the forward force of the trailer. This angle radius will be compared to that of when the bike is ridden without the trailer.

For on-site trials, the team will take the bike and trailer to Lakeshore path and Lake Monona paths that the clients would like to ride on. Here, several observations will be made, such as the curves, hills, bumps, and widths of the trails. These will be compared to the trailer's turn radius, weight, height, and size, respectively, to determine if the product is suitable for these locations.

CONCLUSIONS

The 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. The trailer design encompasses the model of our clients' current wheelchair with arm bars and harness for added safety. For extra stability, the design includes large winter tires at a low PSI providing extra cushion on the uneven parts of the trails. The design is removable, allowing for maximum usage and storage. The new addition of the dip bar allows for safer and easier entry into the trailer.

Additional features that have been added to the design this semester better accommodate a wider range of potential riders. An adjustable seat will allow riders of different heights to still be able to comfortably reach the pedals. 3D printed pedals which hold the foot in the proper pedaling position allow for riders with different levels of coordination to still be able to safely pedal while riding. Fenders around all three wheels protect riders who may be going on more rocky or muddy terrains. Added storage on the bike allows the couple to bring needed items such as medications. A mirror on the bicycle allows the bike rider to see the passenger at any

time and a horn next to the trailer seat gives the rider the ability to alert the bike rider if needed, even if there is a lot of background noise.

The wide variety of additional features added to last semester's prototype will make the second prototype much more accessible to both the client and disabled riders in general, offering them an opportunity to engage in stimulating physical activity while enjoying bike rides again.

REFERENCES

[1] "Facts About Traumatic Brain Injury", *Brainline.org*, 2016. [Online]. Available: http://www.brainline.org/content/2008/07/facts-about-traumatic-brain-injury.html. [Accessed: 09- Oct- 2016].

[2] "TBI: Severe Traumatic Brain Injury Symptoms | Severe Brain Injury | Symptoms of TBI", *Traumaticbraininjury.com*, 2016. [Online]. Available: http://www.traumaticbraininjury.com/symptoms-of-tbi/severe-tbi-symptoms/. [Accessed: 17- Oct- 2016].

[3] S. RJ, "Benefits of sport and physical activity for the disabled: implications for the individual and for society. - PubMed - NCBI", *Ncbi.nlm.nih.gov*, 2016. [Online]. Available: https://www.ncbi.nlm.nih.gov/pubmed/1832786. [Accessed: 17- Oct- 2016]

[4]"Visual Interpretation Of The International Residential Code", *Stairways.org*, 2006. [Online]. Available:http://www.stairways.org/Resources/Documents/2006%20Stair%20IRC%20SCREEN%20web%20download.pdf. [Accessed: 15- Feb- 2017].

Appendix

A. Project Design Specifications

Handicap Accessible Bicycle

Product Design Specifications | February 1, 2017

Client: Mr.Ted Elias and Mrs. Tabea Elias
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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 pedals
  - Seat belt for safety in case of uneven surfaces
  - Arm rests on seat

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 it is 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 sidecar 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 it 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.