OHIO University Mechanical Engineering Project Proposal Report

Foot Powered Wheelchair

Team B-Ballin

Andy Fay
Evan Gilliland
Sam Hallam
Haowen Huo
Trace Lydick
Kyle Sullivan

11/11/2011

> Good overall work on problem definition and specifications, including the incorporation of the 360 degree customer perspective.
> Report content and quality meets expectations, though there is room for improvement as indicated in comments throughout report.
> Specs are acceptable as a starting point but need clarification / further explanation before being used to finalize concept selection.
> Please see comments throughout report and in CD presentation.

Abstract

This report includes a project introduction, an initial needs statement as specified by several sources including the client, benchmarking of current systems that apply to our overall goal, target specifications, and a conclusion of our findings. Our client is a female wheelchair athlete who suffers from cerebral palsy that restricts movement on the left side of her body. The goal for this project is to allow our client to power the wheelchair in a way that frees movement for her hands while playing sports.

1.0 Introduction

The partner for this year-long senior capstone project is the Wheelchair Sports League in Lancaster, OH. Drawing young adults from a 7 county area in southeast Ohio, this organization empowers handicapped individuals by providing them the opportunity to play team sports. They play sports such as Basketball, Football, and Bocce Ball. In past years, other capstone teams or, Senior Design teams (SrD), have worked with this organization and have provided engineering solutions to these special needs individuals and their families.

The specific client is Ashley Stump, a young woman with Cerebral Palsy. This disease affects 10,000 new babies born every year and is the second most common disease to children in America. In Ashley's case, she has full function on the right side of her body; however she is limited in both function and dexterity on her left side. This causes extreme difficulty when playing sports because of the struggles she experiences while attempting to maneuver the chair. Currently, her method to propel the wheelchair involves ~~using her right foot to move the chair across the court~~. Though ~~effective~~, her ability to track straight with any level of speed is limited. The goal for this project is to develop a mechanism that will allow Ashley to propel her wheelchair using only her right foot. The main focus of the design is to allow her to have free use of her hands to more effectively play sports. Research for previous patents and ideas pertaining to the overall design of this specific project will be integral. Using the needs of the client, covered in Section 1.1, as a basis for creating design ideas and specifications, full analysis of both the problem and solution will then be possible. This analysis may include relevant illustrative pictures, figures, finite element modeling and analysis etc. that will allow for prototype construction. An iterative process will be used to correct mistakes and design flaws, leading to a successful working product to be presented to the client.

1.1 Initial Needs Statement

The need of the client is to be able to more efficiently and safely maneuver a wheelchair, with no hands, in a variety of situations and conditions, most importantly sports. The design is to be human powered with no external sources in order to keep ~~the~~ level of activity at a maximum. The adaptation should also be lightweight, easy to use and maintain, and comfortable.

2.0 Customer Needs Assessment and Revised Needs Statement

In order to get a more complete customer needs statement, the team used the 360 degree perspective to make sure all viewpoints were taken into consideration, helping to ensure complete coverage in terms of the overall need with all individuals involved. This includes the customer (Ashley), her parents and her coach. The team also gained some firsthand experience during one of the practices at the Lancaster Wheelchair Sports League. It was quickly realized that, the many obstacles and difficulties we experienced, weren't even comparable to some of Ashley's struggles.

Ashley is a 19-year old young woman who currently uses her chair almost exclusively when competing in sports. Whenever possible, enjoys walking under her own strength, without the use of a chair. Due to the fact that the left side of her body is severely limited, walking for long distances can become increasingly difficult however. The modified wheelchair could be something Ashley would like to use to enhance her mobility both on the court, and in select settings of daily life. If she can gain greater control and speed in her chair, she could likely improve her play to keep up with some of the better athletes in the league, giving her more involvement and sense of accomplishment.

Ashley's mother, Jane Stump, observes the struggles her daughter goes through every day due to her condition. Though she knows Ashley would rather be independent and walk, Jane is very open to the idea of her chair being used on a more regular basis. Currently, Ashley only uses the chair during athletic events and the occasional long distance trip, such as the fair or going to the mall. Some of her concerns centered around the chair modifications and what effects those modifications would have on portability. The family car is a Jeep Liberty, and Jane has to load and unload the chair from her car when taking Ashley places. The design would want to allow the chair to be lightweight and compact, so this unloading process for Jane could be as easy as possible. Any design that could make things easier for Ashley, while keeping some of the current benefits, would be a definite positive from Jane's perspective.

Ashley's coach, Anne LaDuke, was also able to provide valuable insight in terms of what she what like to see from this project from an athletic standpoint. Anne also serves as Ashley's personal trainer, and was able to provide the team with data (leg length, force capability of each foot, etc.) to help better understand Ashley's limits and constraints concerning her mobility. Anne's main goal for this project would be to allow Ashley to be able to increase her mobility in the wheelchair to aid her athletic ability. She currently has difficulty moving the chair at any effective speed, and is restricted in her maneuvering and handling abilities. Any design that could aid Ashley in accomplishing her athletic aspirations would be beneficial from Anne's point of view. Anne's input was a driving force behind the aspect of maneuverability becoming a high priority. Being able to move how one desires is essential in sports, and the team has put an emphasis on maneuvering and safety ~~within the chair at a premium~~.

The team has attended several practices at the Lancaster Wheelchair Sports League thus far, and most recently participated in some activities with the individuals during practice. Using both hands to propel the wheelchair forward proved to be much more difficult than expected, with a maximum estimated speed of 2mph. Any force behind the wheel only moved the chair several feet, and they did not seem to coast along as well as anticipated. This made it seem that, if possible, using both feet to power the chair would be beneficial to Ashley in terms of more effective mobility. Contact often occurred while on the court, and it became clear as to why there are both bumpers and seat-belts on the sports chairs.

From our own experiences, and from the information given to us from both Ashley's coach and mother, were able to determine the most important factors and issues that should be taken into consideration. A compilation of our ideas and concerns can be seen below in Table 2.1. This helped us categorize and visually identify which of the six design concept themes were most important. Specific wants and needs were listed below their respective heading and were labeled as either 'F' for feature, or 'C' for constraint. The constraints were labeled and selected based upon their relationship to the customer needs statement. Any and all items that would be necessary for project completion were labeled as a constraint, while all other items that would be nice to have on the final product were labeled as features.

Table 2.1. Initial Needs of Customer from Interview and Observation

1.Portable • Light (C) • Inside standard wheelchair dimensions (C) • Easy to load into car 2.Simplicity • Easy to learn how to use • Easy to operate (C) 3.Safety • Factor of Safety 2-3 (C) • Restraint (C) • Limited max speed (C) • ADA, ANSI Regs (C) 4.Maneuverability • Control/Steering (C) • Braking (F) • Power/Driving Force (F) • Foot to Power (C) 5.Comfort • Ergonomic (C) 6.Maintenance • Parts Fatigue is low - high life cycle (F) • Common Parts/Tools (F) • Cheap

2.1 Evaluation of Customer Needs

After finding out the needs of the customer the next logical step was to decide on which of these needs should be the focus of our efforts. To begin, the need categories previously determined were listed on a board. The specific needs were then listed beside the categories so that direct comparison could be made. The benefits of each need were openly discussed and a risk analysis chart was created in a design notebook to indicate possible troubles. The need categories were then ranked in importance by each team member. This was done in order to highlight which aspects were deemed most important by the group, giving a basis for designing toward one need over another in critical situations later in the process. Using this as a base for weighting the needs, the list was put into a table and set against every other need to determine relative importance. Safety was weighted the highest in order to maintain consistency with the engineering code of ethics. Maneuverability was rated second highest due to the need of being competitive in sports, and because our client is already suffering with restricted movement due to having CP. The results of our analysis can be seen below in Table 2.2.

Table 2.2 AHP Pair Wise Comparison Chart

	Portability	Simplicity	Maneuverability	Safety	Maintence	Comfort	Total	Weighting
Portability	1.00	0.50	0.39	0.38	1.00	0.80	4.07	9.53%
Simplicity	2.00	1.00	0.77	0.75	2.00	1.60	8.12	19.01%
Maneuverability	2.60	1.30	1.00	0.97	2.58	2.07	10.52	24.63%
Safety	2.70	1.33	1.03	1.00	2.67	2.13	10.86	25.42%
Maintenance	1.00	0.50	0.39	0.38	1.00	0.80	4.07	9.53%
Comfort	1.25	0.63	0.48	0.47	1.25	1.00	5.08	11.89%

2.2 Revised Needs Statement

After further research into the needs of the client, Ashley, one of the main concerns will be maneuverability. The reason for this was that from observations and experiences on the field, maneuverability was one of the most difficult and important aspects. The wheelchair is to be safely powered by foot movement with as little assistance from the arms as possible. The design will make it easy to learn and use while maintaining a suitable comfort level. The design should make the product easy to maintain by using as many common parts as possible and by not making it overly complex in function. The product will fit within the dimensions of a normal wheelchair and will follow the requirements set by ANSI. Lightweight material will also be used to make the product easily transported in and out of the client's vehicle.

3.0 Benchmarking, Standards and Target Specifications

Figure 3.1: Ashley's Current Wheelchair [6]

3.1 Benchmarking

PROPULSION

A treadle was looked at for powering the wheelchair. Treadles are foot powered cranks that were used to power a multitude of machines such as sewing machines and lathes in the 19th and early 20th century. If a treadle were to be used in this project, then a custom design would have to be built. No designs could be integrated directly from another current use due to design constrictions such as dimensions and weight. Old sewing machine treadles can be found from multiple sources, but they are all made of cast iron making them heavy and much too large to be added to the design directly. Instead a custom fit treadle would have to be designed by using a more simple treadle design, such as the designs found in toys, The treadle would be designed to be powered by Ashley's right foot with negligible assistance from the left.

Figure 3.2: Treadle Powered Sewing Machine [3]

Another form of propulsion that was considered was a differential. This technology is rarely if ever found in wheelchairs, but can be found in many other machines. These machines include: ATV's, cars and trucks, motorcycles, and many other forms of transportation. Because of the size and application of ATV's, if this mode of ~~propulsion or aspects thereof~~ were to be chosen, we could likely source and use actual ATV parts.   At the very least we could scale the design of the ATV parts to fit our needs for weight and load. From this information, shaft diameter, bearing size and gear ratios could be modified and determined. With respect to maneuverability, straight tracking in forward motion as well as providing the ability for a turning motion to happen without binding are benefits of this system.

Figure 3.3: ATV Rear Differential [5]

Another form of propulsion that was considered to base our benchmarks off of was a hand crank mechanism. This technology is commonly found and used by individuals in wheelchairs to achieve greater torque and speed. The mechanism is human powered and utilizes either gears or belt system. Since this design is human powered, desired speed is easily controlled. This design was first created in the early 1990s; as a pair of hand cranks and system of ring gears were employed to this design. Later on, some similar designs using belts replaced the geared systems and had forward, coast, reversed, and braking capability. The pair of the hand cranks were independently controlled the left and right wheel, thus allowing the wheelchair to be turned.

Figure 3.4: Hand Crank Mechanism [2]

The final form of propulsion considered is an exercise device often referred to as the “NordicTrack Ski-machine”. This device uses a series of cables with a directional gripping apparatus that only allows the cables to move in one direction. The cables then spin a flywheel at high rpm that has a resistance strap attached to it. For our application, the spinning flywheel could be used with a belt and geared to propel the chair forward. Other benefits of this design is that gear ratios have already be calculated to achieve a certain speed, the load experienced by the machine was designed around a human being, and it can be dimensionally scaled for our purposes.

STEERING

One of the initial desires requested by Anne LaDuke (Ashley's coach) was to operate the wheelchair completely hands free. In order to do that the steering of the wheelchair would have to be done using only the feet. In the industry today there are limited products that use just the feet in order to steer a wheelchair. One product that is used to steer a boat using only your feet is the Minn Kota Riptide Corded Foot Pedal. The device itself only weighs 2 pounds and is only 14X10 inches. The problem is that this system is electrical and our proposed design is mechanical. The system itself costs about $140 and is somewhat complex to learn. With that in mind another possible mechanical system on the market allows users to steer a car with the left foot while operating the gas and brakes with the right foot. The main problem with this design is that it requires both feet to operate and Ashley only has full function of only her right foot. The conclusion then is that any type of steering using only feet would be either too complex or too difficult with the use of only the right foot.

Figure 3.5: Electronic Foot Control Pedal [7]

Another form of steering considered is the same mechanism used to help turn tractors, individual wheel braking. A single hand lever would likely be designed to brake either the right, left, or both sides. The chair would then pivot about the wheel with the applied friction. The idea however cannot be directly compared to the style of brakes used on a tractor however. Complex drum brakes are not a natural addition to a wheelchair, however overall braking force could possibly be scaled to our project and other control aspects may otherwise be incorporated. An example of which can be found below in Figure 3.6.

Figure 3.6: Individual Wheel Brake Pedals [1]

The final idea for steering involves actually using the front stabilization wheels for control. Our benchmark for this is actually another wheelchair design. Specifications such as turning rate, ease of use, and maneuverability could all be affected by this. Identifying bearing sizes, uses of cables and gears, and chair capabilities could all have direct application to our project. An example of this can be seen below in Figure 3.7.

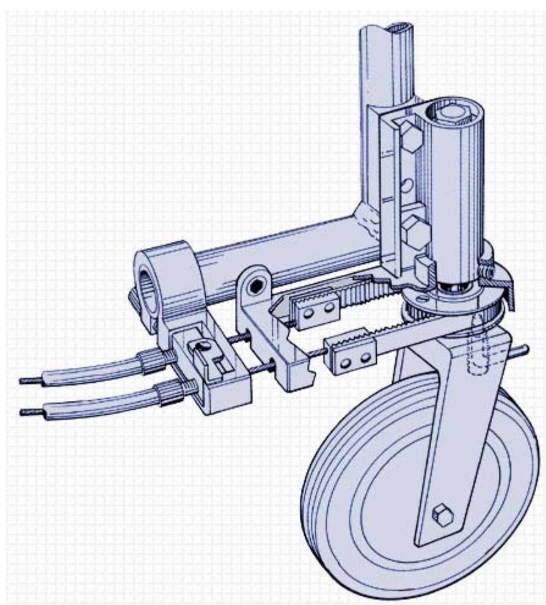

Figure 3.7: Caster Steering Example [4]

3.2 Standards

We began the search for standards by first considering and searching for organizations and laws that could be applicable to our proposed designs. The most broad and overseeing laws and organizations were first sought out. The Americans with Disabilities Act (ADA) and American National Standards Institute (ANSI) were chosen for their national recognition.

In regards to the ADA, the design proposed calls for an adaptation to a wheelchair and therefore would be required to follow standards governed by the ADA. The wheelchair adaptation needs to follow the ADA specifications for buildings with accessible design. This would impact the outer dimensioning of the wheelchair adaptations so the wheelchair dimensions comply with ADA building requirements for handicap individuals. If the dimensions were not to comply, the client would have difficulty maneuvering within an ADA compliant building.

The wheelchair design must also follow ANSI standards. These standards govern different aspects of how wheelchairs are tested. ANSI standards cover electric as well as manual wheelchairs. Most wheelchairs have already passed these tests and the design concept will focus around an already designed wheelchair. The design that will be decided upon will be tested to make sure that the wheelchair will not be compromised from the modifications added to it.

3.3 Target Specifications

From the initial needs statement and the research done through products and safety standards, benchmarking standards were made, as seen below in *Table 3.3*. The table shows the benchmark, marginal, and ideal values for each of the desired metrics. Design values such as overall width were chosen on standards put forth by the ADA. Other, less obvious metrics, such as ankle angle were decided off of research for maximum ankle movement. These specifications addressed the needs of comfort and safety, such that the risk of injury could be limited. Items such as turning radius, turning speed, and maximum speed were set as estimated average values for other athletes on her team; while the maximum applied force to power the chair was set by her personal trainer and coach, Anne. These specifications address the needs of maneuverability as well as comfort for the maximum applied force. To meet the need of portability, the modifications to the wheelchair will be as light weight as possible while still maintaining the structural integrity of the chair. With respect to maintainability, the design will be as simple as possible and will use as many common parts as can be reasonably sourced. Those parts are to be corrosion resistant and familiar, with an emphasis placed around the life of parts. The benchmarking was done using the ‘Quickie All-court’ wheelchair as we have yet to receive our actual wheelchair.

Table 3.3 Target Design Specifications

1	Metric	Units	Benchmark	Marginal Value	Ideal Value
2	Overall Weight	kg	9	<18	<15
3	Chair Width	m	0.508	<0.762	<0.508
4	Applied Force to Power Chair	N	90	<130	<90
5	ANSI Standards	y/n	y	y	y
6	Cost	USD		<2000	<1000
7	Max Speed	m/s	0.25	>0.75	2>x>1.5
8	Stopping Distance From Max Speed	m	0	<1	0.3>x>0.15
9	Durability	cycles	-	10^8	inf
10	Maximum Ankle Angle (up)	Deg.	0	10	<10
11	Minimum Ankle Angle (down)	Deg.	0	-25	<-25
12	Safety Factor	-	3.3	1.5	2
13	Learning Curve	min	0.5	5	2
14	Turning Radius	m	0.3	<0.5	0
15	Turning Speed	w(rad/s)	0.628	>0.785	>1.55
16	Req'd Limbs	-	2	2	1
17	Maintenance(cost)	$/year	20	<20	0
18	Maintenance(time)	min	10	<20	0

4.0 Conclusion (and request for support)

After gathering input from Ashley, her mother and her coach, the team was able to conclude what all of the needs for this project were. A desired outcome would be to adapt her current wheelchair, or another, to allow her to move more efficiently while playing sports with a secondary goal of using it as a multi-purpose system when going on long distance trips such as the fair. The new system will allow Ashley to independently move herself in a more effective manner than she currently does. The design is to be simple, portable, safe, easily maneuvered, comfortable, and easily maintained. The benchmarks created took everything into consideration that was found from the customer's perspective and revised needs statement. The team will use this information to create a working conceptual design in the near future based on the customer's needs. Several wheelchairs have been donated to the team to use as prototype chairs, and progress is thus-far on track for completion of the working model by the end of spring quarter.

References

[1] "4-H Junior Farm." *Agricultural Tractors and Machinery*. Lake County 4-H Tractor Club, 2002. Web. 11 Nov. 2011. <http://www.four-h.purdue.edu/tractor/fjs.html>.

[2] "Da Vinci Chair with NuDrive Levers." *Living With Ataxia - Online Support Group - We Are Patients Living with Ataxia, Here for Your Support.* Ed. Ben Munoz. 25 May 2009. Web. 11 Nov. 2011. <http://www.livingwithataxia.org/photo/da-vinci-chair-with-nudrive>.

[3] Kohler, Donna. "Vintage Sewing Machines." *Treadlelady.com*. Web. 11 Nov. 2011. <http://treadlelady.com/>.

[4] "Lever Drive Wheelchairs Mechanical Details." *Inventions for License, Homepage*. Forethought Designs, 2010. Web. 11 Nov. 2011. <http://www.forethoughtdesigns.com/My_Homepage_Files/Page40.html>.

[5] Lewis, H. M. "Yamaha FJR1300 Photos." *Yamaha FJR1300 Supersport-Touring*. 2004. Web. 11 Nov. 2011. <http://www.fjr1300.info/photos/html/H0035.html>.

[6] "Quickie LXI Ultralight Wheelchair - Wheelchairs - Quickie-Wheelchairs.com." *Quickie-Wheelchairs.com*. 2011. Web. 11 Nov. 2011. <http://www.quickie-wheelchairs.com/products/Quickie-LXI-Ultralight-Wheelchair-2410.html>.

[7] "Riptide ST Foot Pedal (Corded)." *Minn Kota » Minn Kota Trolling Motors :: Electric Fishing Boat Motor :: Shallow Water Anchors :: Battery Chargers*. Johnson Outdoors Marine Electronics, Inc., 2011. Web. 11 Nov. 2011. <http://store.minnkotamotors.com/products/418621/Riptide_ST__Terrova_Foot_Pedal>.