Final Report

Beach Wheelchair

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Team 13

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Table of Contents:
Abstract

1. Introduction
   1.1 Background
   1.2 Purpose of the Project
   1.3 Previous Work Done by Others
      1.3.1 Products
      1.3.2 Patent Search Results
   1.4 Map of the Report

2. Product Design
   2.1 Optimal Design
      2.1.1 Objective
      2.1.2 Subunits
   2.2 Prototype
      2.2.1 Subunits

3. Realistic Constraints

4. Safety Issues

5. Impact of Engineering Solutions

6. Life Long Learning

7. Budget

8. Team Member Contributions to the Project

9. Conclusion

10. References

11. Acknowledgements

12. Appendix
   12.1 Updated Specification
   12.2 Purchase Requisitions and Price Quotes
   12.3 Other
Abstract

The purpose of this project is to design a beach wheelchair for use by Jack Davies, a 12 year-old boy with Cerebral Palsy. Cerebral Palsy (CP) is a disease that affects the neurological system. Usually diagnosed during very early childhood, the disease permanently affects muscular movement. Though there are varying degrees of debilitation resulting from Cerebral Palsy, Jack’s condition requires the use of a wheelchair pushed from behind in order for him to be mobile. Jack’s family spends time every summer in the beaches of Rhode Island. The wheelchair that Jack uses daily is not suitable for sandy terrain, which makes it very difficult for his parents to transport him around the beach. The beach wheelchair will offer the mobility Jack enjoys in his regular wheelchair, but will provide him access to the beach and allow his parents to easily transport him over the sandy terrain.

The wheelchair was designed to be adjustable in multiple locations to ensure Jack could continue to use the chair as he grows. It was also designed to allow for the client to insert a tumbleforms chair designed specifically for Jack’s needs. The wheelchair was designed and fabricated to meet the needs and requests of the client. The final product is a wheelchair that is more user-friendly to the client than any commercially made product available.

1. Introduction

1.1 Background

The client, 11-year old Jack Davies, suffers from cerebral palsy. Jack also suffers from scoliosis. When Jack was born, he was too small. Six weeks after birth he contracted pneumonia and developed cerebral palsy. Jack’s condition is very serious; he has approximately the capability of a 3-month old boy. He relies on a feeding tube and is completely dependent on his parents. Jack weighs 72 pounds and is 52 inches tall. The wheelchair must be tailored to his size and include numerous straps and other precautionary devices to ensure Jack’s safety.

Jack is currently in 5th grade and attends specialized classes. The Davies family travels to Rhode Island beaches for a week every year but have trouble accessing the beaches with Jack due to his limited mobility. Providing this beach wheelchair for Jack will allow him to better enjoy the beach and alleviate the mobility issues that previously plagued him and his family.

1.2 Purpose of the Project

The purpose of this design project is to create a beach wheelchair for Jack that will offer him the security, support and comfort of his daily wheelchair, but allow him to be easily transported around sandy terrain. The current system of transportation for Jack on the beach involves using a tow cart not designed to transport children. Our aim, therefore, is to provide him with a very safe and comfortable wheelchair that will allow his parents to easily push their son across the sand. The wheelchair will have features like his normal wheelchair, including a reclining seat rest, a platform to attach his current cushioning system, neck and back supports, and a place for a feeding tube apparatus to hang. Additionally, the wheelchair will have large, rounded wheels that will travel well over sandy terrain. The chair will also be constructed from a material that has little tendency to rust in humid and salty air.
1.3 Previous Work Done by Others

1.3.1 Products

Many products have been released that allow wheelchair users to access the beaches. One of these products, released in the United States in 2007, is the Joy on the Beach Wheelchair. Manufactured by the Italian company NEATECH, the wheelchair is classified as an “all-terrain” vehicle. In addition to having very large wheels, the chair is lightweight and was constructed similar to some lounge chairs, with the main seating platform created from fabric stretched across a frame. There is no electrical component, so the chair can roll into the water, and can also be used for snow. However, the chair does not feature any safety constraints or neck or back support, and is not really tailored to a small child with cerebral palsy. It is a very simply design, aimed to make beach mobility available to the masses. The cost of this chair is $1,600 before add-ons.

Another beach wheelchair currently on the market is the Landeez Beach Wheelchair, manufactured by Natural Access in Santa Monica, California. This wheelchair is much more similar to the structure of a regular manual wheelchair. It has soft, large tires, is extremely light, and can be collapsed to pack down into a car easily. It also features a tilt-in-space option, which allows the user to recline while taking pressure off of their sciatic nerve, a sore spot for many children with cerebral palsy who are confined to a wheelchair. However, this chair also lacks the very specific restraints that a child with cerebral palsy would require. It retails for $3,600 before add-ons.

Another beach wheelchair currently on the market is the Colours All-Terrain Tremor Beach Wheelchair. This wheelchair has a very basic design simply meant to bear weight with little extra structure or aesthetic appeal. It does not have the ability to recline nor can it fold. The Colours Beach Wheelchair is highly adaptable and is very lightweight, weighing approximately 35 pounds. This chair does not feature the tilt-n-space option that Jack’s parents requested and it also lacks those very specific restraints that a child with cerebral palsy would require. The cost of this wheelchair is just south of $2,700.

1.3.2 Patent Search Results

In 2005, the William Penn Charter School in Pennsylvania passed a patent for a dignified broad footprint beach wheelchair. It has a removable seat, and can be folded like a pair of glasses to fit in a smaller space. It operates using and two front skid wheels with springs, which provide very low resistance over bumpy, sandy terrain. The rear wheels are wide and create a broad footprint to disperse the weight of the chair and rider. Their shape is similar to that of a dog bone, which helps create a wide profile as it rolls through the sand. The body of the chair is able to recline to support the weight of the user’s legs.

1.4 Map of the Report

The remainder of this report will focus on the design portion of the project. Included in this discussion will be the three alternative designs and ultimately the optimal design. The optimal design will provide a detailed look at each subunit and the proof that each subunit will work. The discussion of the optimal design will also cover the realistic constraints and safety issues involved with the optimal design. Based on the optimal design, the impact of engineering solutions will be described in a global, economic, environmental and societal context. The learning that occurred will also be discussed. The budget for the project as well as the timeline for the building of the project will be touched upon. Also
the contributions from each team member will be discussed. The acknowledgements for the people who made the design possible will be stated. The appendix will conclude the report and will include purchase requisition forms, price quotes and data sheets for the individual parts used.

2. Project Design

This design project consisted of three alternative designs and then optimal design based on the best portions of the three alternative designs. A brief overview of each alternative design will be given and the optimal design will be discussed in detail. All of the subunits of the optimal design will be thoroughly discussed. The reasons for creating the optimal design will also be explained. CAD drawings and figures will be used to further explain the method of choosing the optimal design.

Alternative Design 1

Figure 1. Side View of Wheelchair

Figure 2. Front View of Wheelchair

Figure 3. Tumbleforms Chair

Figure 4. Magnified View of Leg Support Adjustability
This design proposes that the two rear tires of the wheelchair be much larger than the front two. All tires are inflatable and constructed from polyurethane. Most of the client’s weight will be positioned over the back wheels so it makes sense for those to be larger as they will better distribute the load. Front and side views of the total wheelchair design are given in Figures 1 and 2 respectively. Figure 1 also gives the name of each of the parts of the wheelchair. The labels “bottom support”, “back support”, “leg support” and “seat support” will be used throughout with the assumption the readers understands what they refer to. It has been proposed that T6061 Aluminum be used for the construction of the beach wheelchair.

The seat used will be provided by the client’s family. The provided seat, tumbleforms chair, is specially tailored to the client’s support needs. The tumbleforms chair is shown in Figure 3. The tumbleforms chair is attached to the beach wheelchair by two large Velcro strips located on the back of the chair and their corresponding parts on the wheelchair frame. The back support portion of the frame will have neck and head pads to help support the client’s head and provide additional comfort. The pads will be made from vinyl-covered foam. The back support will initially be set at a 90 degree angle with the seat support but it will have the ability to recline to a variety of angles to further ensure the comfort of the client. An adjustable locking mechanism will control the degree to which the chair reclines. Figure 5 shows a magnified view of the reclining mechanism.

The seat support will be constructed from a flat aluminum panel. The plate will be supported underneath by crossing aluminum tubing that attaches to both the seat support and the bottom support. The support tubes will be linked together in a way that they can pivot so that the wheelchair will be able to collapse.

Two arm rests will be attached to the seat support. The arm rests will be made from three pieces of aluminum tubing. On top of each arm rest, there will be a vinyl-covered foam pad. The arm rests will be attached to the seat support by means of hinges. This will allow the arm rests to fold down to facilitate easy transport and storage of the wheelchair. When in use, a quick release pin will lock the arm rests in place to ensure they do not fold down unexpectedly.

The back support will have two aluminum handles coming off the back. The handles will have a small notch cut into them to allow for a backpack to hook over them without falling off. The end of the
handles will be angled downwards to allow for easy pushing of the chair. The end of the aluminum handles will be covered with rubber grips. The handles will feature a quick release pin to allow them to fold close to the back support for easy storage and transportation.

The leg support will consist of two aluminum tubes linked by an aluminum footplate at the bottom. A vinyl-covered foam pad will run between the aluminum tubes and will provide structural support along with comfort for the client. The top of the leg support will be linked to the seat support by means of an aluminum tube. The leg support system can pivot at the point where it connects to the rest of the frame. The whole leg support apparatus will be adjustable using an adjustable locking mechanism. A magnified view of the adjustable locking mechanism is shown in Figure 4. This will not only allow the client to adjust the leg support for comfort purposes but will also allow the whole leg support to fold upwards and rest on top of the folded back support for easy storage and transport.

The front tires will be significantly smaller than the rear tires. The steering will be done through the smaller, more agile front tires while the much larger rear tires will be used for load distribution. The front tires will have be connected to the bottom support by the means of a swivel joint. An aluminum tube will connect each side of the tire to the swivel. The swivel joint allows for maximum maneuverability in any direction and will provide a small turning radius. A small brake will be attached to the bottom aluminum tubing. The brake will pivot on the tube which will allow it to swing towards and away from the rear tire. The brake will consist of a small aluminum arm with a rubber pad at each end. When the arm is pushed towards the wheel, the rubber grip will contact the wheel and will ensure that the tire does not rotate and the whole wheelchair stays in place. This is a crucial safety feature. A magnified view of the braking mechanism is shown in Figure 6. The back tires will be fixed to the back end of the bottom support and will be locked into a single point, unable to turn or maneuver.

One of the most important features of the beach wheelchair is that it will be able to quickly and efficiently fold for easy transportation and storage. A description has already been provided for the folding of the back supports, leg supports, arm rests and handles but other parts of the frame will also fold. Quick release pins will allow the crossing aluminum tubes to fold downwards and the whole chair will collapse vertically upon itself. The large rear tires will also feature quick release pins so they can be easily removed to facilitate easier transportation of the chair.

Alternative Design 2

Figure 7. ProBasics Full Reclining Wheelchair
This design is centered on an existing wheelchair frame. Figure 7 shows the frame, a ProBasics full reclining wheelchair. This frame has several features that make it very appealing. The ProBasics wheelchair is capable of reclining anywhere from 90 to 180 degrees. This will allow maximum comfort for the client. The frame is hinged and is capable of folding which will allow the client to easily store and transport the chair. It has padded, removable arm rests and also padded elevating leg rests. There is adjustability in the angle of the leg rests which will serve to provide maximum comfort for the client. The ProBasics chair also comes equipped with anti-tipping bars at the bottom of the frame. These bars will ensure that the wheelchair does not tip and will also provide extra safety for the client. The ProBasics wheelchair is also very affordable at $369.00, which may be less than the amount it would take to build a custom frame. This wheelchair frame also has another advantage over a custom-built one in that it is guaranteed to be safe and secure while a custom-built wheelchair frame would involve plenty of welding and therefore plenty of places for the wheelchair to be weakened. Overall the ProBasics wheelchair provides a very solid yet affordable template for the custom beach wheelchair.

There are still modifications that need to be made to fit the client’s requests. The tires on the ProBasics need to be modified. The ProBasics wheelchair is set up to be a standard wheelchair with wheels meant for solid surfaces. To be suitable for the client’s needs, the wheels will be replaced with inflatable polyurethane tires. This will be simple if polyurethane tires can be found that have the same bolt diameter as the replaced wheelchair tires. If not, the wheelchair frame will need to be modified to match the diameter of the hole in the polyurethane tires. As in Alternative Design 1, the front polyurethane tires will be smaller than the rear ones.

The ProBasics wheelchair is completely padded but it is not properly set up to support the client's needs. It does not offer restraints or enough back, neck and head support for the client. To fix this problem, the ProBasics wheelchair will need to be modified to fit the tumbleforms chair provided by the client. The wheelchair will be modified by adding large Velcro strips to the wheelchair and adding corresponding Velcro strips to the back of the tumbleforms chair. This will give the client all the support of the tumbleforms chair but also allow it to be removable to preserve the folding ability and easy transportation and storage of the chair.

The ProBasics wheelchair is lacking functional handles. The client is not able to power the chair and relies completely upon another person pushing it. The reclining back support will have two aluminum handles coming off the back. The handles will have a small notch cut into them to allow for a backpack to hook over them without falling off. The end of the handles will be angled downwards to allow for easy pushing of the chair. The end of the aluminum handles will be covered with rubber grips. The handles will feature a quick release pin to allow them to fold close to the back support for easy storage and transportation.

The original brake on the ProBasics wheelchair was designed for the street wheels. The brake must be modified to work with the inflatable polyurethane tires. A small brake will be attached to the bottom aluminum tubing. The brake will pivot on the tube which will allow it to swing towards and away from the rear tire. The brake will consist of a small aluminum arm with a rubber pad at each end. When the arm is pushed towards the wheel, the rubber grip will contact the wheel and will ensure that the tire does not rotate and the whole wheelchair stays in place. This is a crucial safety feature.
Alternative Design 3

This design proposes that the two rear tires of the wheelchair be much larger than the front two. All tires are inflatable and constructed from polyurethane. Most of the client’s weight will be positioned over the back wheels so it makes sense for those to be larger as they will better distribute the load. The seat used will be provided by the client’s family. The provided seat, tumbleforms chair, is specially tailored to the client’s support needs. The tumbleforms chair is padded and assures proper alignment for the client’s scoliotic spine. The tumbleforms chair includes a full body harness which is enough to secure the client into the wheelchair. The tumbleforms chair is attached to the beach wheelchair by two large Velcro strips located on the back of the chair and their corresponding parts on the wheelchair frame. The back support portion of the frame will have neck and head pads to help support the client’s head and provide additional comfort. The pads will be made from vinyl-covered foam. The back support will initially be set at a 90 degree angle with the seat.

To allow the chair to recline, but have the seat and back remain at a 90-degree angle, the entire seat will pivot on an arc that is locked in place by a set of two pins. This allows many degrees of adjustability while remaining compatible with the tumbleforms chair, which is always at a 90-degree angle.

The seat support will be constructed from a flat aluminum panel. The plate will be supported underneath by crossing aluminum tubing.

The back support will have two aluminum handles coming off the back. The handles will have a small notch cut into them to allow for a backpack to hook over them without falling off. The end of the handles will be angled downwards to allow for easy pushing of the chair. The end of the aluminum handles will be covered with rubber grips. The handles will feature a quick release pin to allow them to fold close to the back support for easy storage and transportation.

The leg support will consist of two aluminum tubes linked by an aluminum footplate at the bottom. A vinyl-covered foam pad will run between the aluminum tubes and will provide structural support along with comfort for the client. The top of the leg support will be linked to the seat support by means of an

Figure 8. Tilt-n-space wheelchair design
aluminum tube. The leg support will slide in and out of the seat support to allow it to be lengthened as the client grows.

The front tires will be significantly smaller than the rear tires. The steering will be done through the smaller, more agile front tires while the much larger rear tires will be used for load distribution. The front tires will have be connected to the bottom support by the means of a swivel joint. An aluminum tube will connect each side of the tire to the swivel. The swivel joint allows for maximum maneuverability in any direction and will provide a small turning radius. A small brake will be attached to the bottom aluminum tubing. The brake will pivot on the tube which will allow it to swing towards and away from the rear tire. The brake will consist of a small aluminum arm with a rubber pad at each end. When the arm is pushed towards the wheel, the rubber grip will contact the wheel and will ensure that the tire does not rotate and the whole wheelchair stays in place. This is a crucial safety feature. The back tires will be fixed to the back end of the bottom support and will be locked into a single point, unable to turn or maneuver.

2.1 Optimal Design

2.1.1 Objective

The purpose of this project is to design a beach wheelchair for use by Jack Davies, a 12 year-old boy with Cerebral Palsy. Cerebral Palsy (CP) is a disease that affects the neurological system. Usually diagnosed during very early childhood, the disease permanently affects muscular movement. Though there are varying degrees of debilitation resulting from Cerebral Palsy, Jack’s condition requires the use of a wheelchair pushed from behind in order for him to be mobile. Jack’s family spends time every summer in the beaches of Rhode Island. The wheelchair that Jack uses daily is not suitable for sandy terrain, which makes it very difficult for his parents to transport him around the beach. The beach wheelchair will offer the mobility Jack enjoys in his regular wheelchair, but will provide him access to the beach and allow his parents to easily transport him over the sandy terrain.

The overall purpose of this design project is to create a beach wheelchair for Jack that will offer him the security, support and comfort of his daily wheelchair, but allow him to be easily transported around sandy terrain. The current system of transportation for Jack on the beach involves using a tow cart not designed to transport children. Our aim, therefore, is to provide him with a very safe and comfortable wheelchair that will allow his parents to easily push their son across the sand. The wheelchair will have features like his normal wheelchair, including reclining ability, a platform to attach his current cushioning system (tumbleforms chair), neck and back supports, and a place for a feeding tube apparatus to hang. Additionally, the wheelchair will have large, rounded wheels that will travel well over sandy terrain.

The current chair that Jack uses is a “tilt-in-space” system that treats the seat and backrest as one unit, allowing them to recline and remain at a 90-degree angle. The beach wheelchair will also be able to recline at multiple angles. However, the “tilt-n-space” wheelchair simply reclines from the top half of the frame whereas the entirety of the beach wheelchair will lean back to recline. One of the main differences between the chairs will be the wheels. The tires on Jack’s current chair are not suitable for use in sandy terrain, as they do not offer enough area to disperse the weight of the chair and rider. Our beach wheelchair design will feature large polyurethane tires to ensure the wheelchair can travel easily across sandy terrain. Another big difference in design will be the ability to condense our chair a little for transportation purposes. The large rear tires are removable which allows the beach wheelchair to fold to a degree when those are removed. It is not completely foldable but can be reduced in size.

The main addition that our beach wheelchair will feature is the ability to adapt to Jack as he grows. This will be done using a couple of different methods. Firstly, the frame will be built large enough
to support Jack even at his full height. Velcro straps will be used to attach the tumbleforms chair to the wheelchair meaning the tumbleforms chair can be swapped out with larger ones as Jack’s height and weight increases.

### 2.1.2 Subunits

The beach wheelchair is based off a transport wheelchair frame. However there were many modifications that had to be made to turn the transport wheelchair into a functional beach wheelchair. These modifications can be individually analyzed by breaking the beach wheelchair into subunits. Each of these subunits was designed specifically to interact with the other subunits to create a fully operational final design. The following section describes each subunit in terms of its structure, function and significance. Figure 9 gives a CAD model of the overall beach wheelchair optimal design.

![Portable Beach Wheelchair schematic design](image)

**Figure 9. Portable Beach Wheelchair schematic design**
Frame

The entire design is based off an ultralight transport wheelchair made by Quickie. There are many modifications to make to the wheelchair but the majority of the aluminum frame is used as the base in the beach wheelchair.

Figure 10 shows a picture of the frame that is used for the beach wheelchair.

![Figure 10. Quickie ultralight folding wheelchair](image)

Seat

The frame of the portable beach wheelchair is unique, because it is going to allow for the attachment and removal of a cushion system that the Davies’ family currently owns. This cushion system, also known as a tumbleforms chair, is shown in Figure 3 and is tailored to Jack’s needs. The tumbleforms chair is padded and assures proper alignment for the client’s scoliotic spine, it also provides adequate support for his torso. The tumbleforms chair includes a full body harness which is enough to secure the client into the wheelchair. The tumbleforms chair will be secured to the wheelchair frame via large Velcro strips. This will allow the tumbleforms chair to be quickly removed to allow for more compact folding of the beach wheelchair. As Jack grows, he will require larger tumbleforms chairs. By simply adding Velcro strips to the back of the updated tumbleforms chair, it can be easily attached to the beach wheelchair ensuring that the wheelchair can still support Jack as he grows.

Tires

Polyurethane balloon tires from Wheeleez, Inc. will be used to enable the beach wheelchair to travel across the sand. Larger (49 cm diameter and 23 cm width) tires will be used for the rear of the wheelchair while smaller (24 cm diameter and 12.3 cm width) tires will be used for the front of the wheelchair. The polyurethane tires will be inflated at very low pressures (2-4 psi) to efficiently disperse the client’s force and allow the beach wheelchair to move easily across the top of the sand. Figures 11a and 11b show the two sizes of polyurethane balloon wheels that will be used.
**Axles**

Wheeleez, Inc. will provide axles with the larger polyurethane balloon tires. However, these axles will need to be cut down to the appropriate size. Holes will be cut into the end of each axle to allow for a quick release pin to be fitted on each end. The quick release pins will allow the large wheel tires to be removed easily to facilitate transportation of the beach wheelchair. Small aluminum spacers will be fabricated to insert on the axle to keep the polyurethane tire from rubbing on the side of the frame as it spins. Figure 12 shows the axle with the quick release pins.

**Brake**

The brake will be heavily based on the existing brake on the transport wheelchair. The current position of the brake must be moved to adjust for the difference in sizes of the transport wheelchair wheels versus the rear balloon tires. Also, since the balloon tires are so much wider than the original transport wheelchair wheels, the brake length must be extended to be efficient. The brake extension will be made out of steel. Figure 13 shows the modified brake.
**Casters**

Casters will only be needed for the front wheels. Wheeleez, Inc. will provide axles and casters with the smaller polyurethane tires that will be used on the front of the wheelchair. However, the casters they provide are not the correct size to directly attach to the wheelchair frame. A caster addition will be created and attached to the top of the factory caster via four provided bolts. This caster addition will have a hole with the correct diameter to fit the wheelchair frame as well as a brace to ensure the wheels do not wobble. Therefore the caster addition will act as a converter of sorts by allowing the factory caster to be connected to the transport wheelchair frame. The caster addition will be made out of aluminum. Figure 14 shows the modified caster.

![Figure 14. Modified caster](image)

**Rear Wheel Extensions**

Due to the large size of the front polyurethane balloon tires, the wheelchair would not sit flat if the rear balloon tires were attached using the location of the previous transport wheelchair wheels. Extensions will need to be made to allow the rear tires to be mounted in a location that balances the increased height from the front balloon tires. There will be an extension for each side. Each side will consist of two rectangular aluminum pieces. Each aluminum piece will have 5 holes drilled into it. Three of these holes will be mounted to the wheelchair frame while the other two will support the plate that will house the axle. Figure 15 shows the rear wheel extensions.
The reclining mechanism is one of the pieces that make this beach wheelchair unique. The reclining mechanism will allow the entire wheelchair to lean backwards in a reclined position. This means that this mechanism must be very strong but also highly adjustable to allow for multiple angles to recline to. It will be made out of hollow aluminum tubing, however the two different tubes of different widths will be used. The reclining mechanism will be attached to the wheelchair frame via two sets of aluminum plates. The reclining mechanism will be able to swing freely and the plates will have holes drilled in multiple locations so that the reclining mechanism can be locked into place at a variety of angles which allows for a greater range of overall angles for the wheelchair to recline to. Figure 16 shows the plates and the top of the reclining mechanism.
The reclining mechanism attaches to the wheelchair at two separate points using the aforementioned plates. At this point, the reclining mechanism is formed from 1” width hollow aluminum tubing. The tubing from either side is welded to a cross piece which has a singular piece of 1” tubing coming off the center. This piece has 6 holes drilled into the end of it. Inside of this piece slides a ¾” width piece of aluminum tubing. This tubing also has 6 holes drilled into its end. A locking pin can lock these two pieces together at any given hole on either piece. This variation in the length also contributes to the variety of angles that the beach wheelchair can recline to. Figure 17 shows the reclining mechanism but more specifically the locking pin and the length adjustable tubing.
At the base of the reclining mechanism there is a foot made from an aluminum plate. The plate will increase the wheelchair’s surface area contact with the ground thereby improving strength and stability as well as ensuring the reclining mechanism doesn’t simply plunge deeply into the sand. This plate is bolted to the end of the reclining mechanism and is allowed to swing freely. This allows it to swivel freely and adjust to any angle the chair reclines at. Figure 18 shows the aluminum foot.

All of these portions come together to form the full reclining mechanism which is shown in Figure 19.
2.2 Prototype

The prototype is very close to the optimal design. The transport wheelchair was made by Quickie and purchased used from NEAT marketplace. The frame of the wheelchair is made of aluminum. The purchased chair included front and rear wheels, brakes, arm rests, a fabric seat bottom and the actual frame. The frame was missing leg rests and a back. The front casters and wheels had to be removed along with the rear wheels as these were replaced with the polyurethane balloon tires.

The transport wheelchair had fabric to form the bottom portion of the seat. However the back portion of the seat was missing. Fabric was added to the back of the wheelchair to form the rest of the seat. The client had a tumbleforms chair that was specially tailored to his support needs. Velcro strips were added to the wheelchair fabric as well as the bottom and back of the tumbleforms chair. This allowed the tumbleforms chair to be attached to the wheelchair and provide the necessary support for the client.

The transport wheelchair was also missing any sort of leg supports. The leg supports were fabricated as a single piece from a length of fabric. The fabric leg rests provided more comfort than metal ones, added less weight to the wheelchair and made transporting chair easier.

Safety, comfort and efficiency were the main focuses when designing and fabricating the beach wheelchair.

2.2.1 Subunits

*Frame*

The frame that was used is the same one that was mentioned in the optimal design. The frame comes from an ultralight folding wheelchair made by Quickie. The entirety of the wheelchair was not needed for the frame of the beach wheelchair. The leg rests, rear wheels, rear axles, front wheels, casters and back rest were all removed to reach the stripped down frame used for the beach wheelchair. The stripped down wheelchair has dimensions 15” x 19” x 36” (l x w x h) and weighs approximately 15 pounds. Figure 20a shows the stripped down Quickie ultralight folding wheelchair.
Figure 20a. Stripped down Quickie ultralight folding wheelchair

The frame is very lightweight as it is constructed from aluminum. Figure 20b shows a picture of the completed beach wheelchair (minus the armrests and leg rests which are completed but not shown); note the stripped down Quickie wheelchair frame used as the basis of the beach wheelchair. Also, the tumbleforms chair is not displayed in the below figure.

Figure 20b. Beach wheelchair featuring stripped down Quickie ultralight folding wheelchair frame
**Seat**

The frame of the portable beach wheelchair is unique, because it allows for the attachment and removal of a cushion system that the Davies’ family currently owns. The seat is the same one that was mentioned in the optimal design section. This cushion system, also known as a tumbleforms chair, is shown in Figure 3 and is tailored to Jack’s needs. The tumbleforms chair is padded and assures proper alignment for the client’s scoliotic spine, it also provides adequate support for his torso. The tumbleforms chair includes a full body harness which is enough to secure the client into the wheelchair. The tumbleforms chair can be secured to the wheelchair frame via large Velcro strips. This allows the tumbleforms chair to be quickly removed to allow for more compact folding of the beach wheelchair. As Jack grows, he will require larger tumbleforms chairs. By simply adding Velcro strips to the back of the updated tumbleforms chair, it can be easily attached to the beach wheelchair ensuring that the wheelchair can still support Jack as he grows. Figure 21 shows the tumbleforms chair with the necessary Velcro to attach it to the wheelchair.

![Figure 21. Tumbleforms chair with Velcro strips](image)

**Tires**

Polyurethane balloon tires from Wheeleez, Inc. are used to enable the beach wheelchair to travel across the sand. Larger (49 cm diameter and 23 cm width) tires are used for the rear of the wheelchair while smaller (24 cm diameter and 12.3 cm width) tires are used for the front of the wheelchair. The polyurethane tires are inflated at very low pressures (2-4 psi) to efficiently disperse the client’s force and allow the beach wheelchair to move easily across the top of the sand. Figures 11a and 11b show the two sizes of polyurethane balloon wheels that will be used.

**Axles**

Wheeleez, Inc. provided axles with the larger polyurethane balloon tires. However, these axles were very long and needed to be cut down to the appropriate size. Holes are cut into the end of each axle to allow for a quick release pin to be fitted on each end. The quick release pins allow the large wheel tires to be removed easily to facilitate transportation of the beach wheelchair. Small aluminum spacers have been fabricated and inserted on the axle to keep the polyurethane tire from rubbing on
the side of the frame as it spins. Figure 22 shows the axle with the locking pins and the two spacers. Figure 23 shows the axle from both sides when it is attached to the wheelchair.

![Figure 22. Axle with locking pins and spacers](image)

_figure22_.

![Figure 23. Views of axle when attached to wheelchair](image)

_figure23_.

**Brake**

The brake is heavily based on the existing brake on the transport wheelchair. The original position of the brake has been moved to a new position to adjust for the difference in sizes of the transport wheelchair wheels versus the rear balloon tires. Also, since the balloon tires are so much wider than the original transport wheelchair wheels, the brake length has been extended to be efficient. The brake extension is made out of steel. Figure 24 shows the modified brake attached to the wheelchair. The extension can be clearly seen pressing up against the tire.
Casters

Casters were only needed for the front wheels. Wheeleez, Inc. provided axles and casters with the smaller polyurethane tires that are used on the front of the wheelchair. However, the casters they provided are not the correct size to directly attach to the wheelchair frame. A caster addition has been created and attached to the top of the factory caster via four provided bolts. This caster addition has a hole with the correct diameter to fit the wheelchair frame as well as a brace to ensure the wheels do not wobble. Therefore the caster addition acts as a converter of sorts by allowing the factory caster to be connected to the transport wheelchair frame. The caster addition is made out of aluminum. Figure 25 shows the caster modification attached to the wheelchair.
Rear Wheel Extensions

Due to the large size of the front polyurethane balloon tires, the wheelchair would not sit flat if the rear balloon tires were attached using the location of the previous transport wheelchair wheels. Extensions have been made to allow the rear tires to be mounted in a location that balances the increased height from the front balloon tires. There is an extension for each side. Each side consists of two rectangular aluminum pieces. Each aluminum piece has 5 holes drilled into it. Three of these holes are mounted to the wheelchair frame while the other two support the plate that will house the axle. Figure 26 shows the rear wheel extensions.
Reclining Mechanism

The reclining mechanism is one of the pieces that make this beach wheelchair unique. The reclining mechanism allows the entire wheelchair to lean backwards in a reclined position. This means that this mechanism is very strong but also highly adjustable to allow for multiple angles to recline to. It is made out of hollow aluminum tubing; however the two different tubes of different widths were used. The reclining mechanism is attached to the wheelchair frame via two sets of aluminum plates. The reclining mechanism can swing freely and the plates have holes drilled in multiple locations so that the reclining mechanism can be locked into place at a variety of angles which allows for a greater range of overall angles for the wheelchair to recline to. Figure 27 shows the plates and the top of the reclining mechanism.
The reclining mechanism attaches to the wheelchair at two separate points using the aforementioned plates. At this point, the reclining mechanism is formed from 1” width hollow aluminum tubing. The tubing from either side is welded to a cross piece which has a singular piece of 1” tubing coming off the center. This piece has 6 holes drilled into the end of it. Inside of this piece slides a ¾” width piece of aluminum tubing. This tubing also has 6 holes drilled into its end. A locking pin can lock these two pieces together at any given hole on either piece. This variation in the length also contributes to the variety of angles that the beach wheelchair can recline to. Figure 28 shows the reclining mechanism but more specifically the locking pin and the length adjustable tubing.

![Figure 28. Length adjustable section of reclining mechanism](image)

At the base of the reclining mechanism there is a foot made from an aluminum plate. The plate increases the wheelchair’s surface area contact with the ground thereby improving strength and stability as well as ensuring the reclining mechanism doesn’t simply plunge deeply into the sand. This plate is bolted to the end of the reclining mechanism and is allowed to swing freely. This allows it to swivel freely and adjust to any angle the chair reclines at. Figure 29 shows the aluminum foot.
All of these portions come together to form the full reclining mechanism which is shown in Figure 30.
Footrest

The challenge with the footrest was trying to make it flexible but also supportive. This need ultimately led to a footrest made of very dense fabric. The fabric was sewn into a double layer that dangles from the bottom frame of the wheelchair. The fabric footrest supports the feet above the front casters and also provides both comfort and support. Figure 31 shows the footrest.

Armrest

The original transport wheelchair came with armrests. We simply used these armrests as they are adjustable and were still properly located to be effective in our beach wheelchair design. Figure 32 shows one of the armrests.
3. Realistic Constraints

**Economic**

This design project had a specified budget that could not be exceeded. The budget was set to a sufficient value to create an efficient, safe and affordable product. The prime interest was fully fulfilling the client’s needs while limiting the cost as much as possible. An expanded budget would have allowed for the creation of a superior product by means of purchasing of higher quality materials. To minimize cost, the quality and cost of materials will be carefully balanced and any donations or reductions in price will be fully taken advantage of.

**Environmental**

The beach wheelchair has no electrical components and does not include batteries and will have little impact on the environment. The only environmental precaution that must be taken is ensuring that all unused metal is properly disposed of.

The beach wheelchair must be protected against the environment. Since it will be primarily used in the sand, it must be able to withstand the grit and roughness of the terrain meaning it should be scratchproof. The wheelchair will also be used in close proximity to the ocean so it must be able to withstand prolonged exposure to not only the salt in the wind off the ocean but also salt water itself. To do this, all components must be waterproof and all metal components will be covered in a rustproof spray to ensure the wheelchair does not rust or corrode. All components must have the ability to be easily cleaned without the danger of removing any of the waterproof or rustproof coating.

**Sustainability**

Since the wheelchair has no electrical components or batteries, it is fairly sustainable and does not require too much upkeep. The main thing would be ensuring that all pins still function properly and periodically checking the joints and welds to ensure that wheelchair frame remains safe in its most critical load bearing locations. The wheelchair should also be kept clean and the rustproof and waterproof coatings should also be checked periodically to ensure no portion is exposed to the highly damaging beach environment.

**Manufacturability**

Manufacturing this wheelchair on a large-scale basis might prove to be difficult. The majority of the wheelchair will be custom built from scratch and would therefore be difficult to replicate easily. All of the parts will be built from standard aluminum tubing and plating so the materials are fairly common but extensive customization is needed to correctly fabricate each part of the beach wheelchair. If the manufacturing plant had the ability to build automated devices calibrated to produce the unique parts on a large-scale basis. Only the CAD drawings would be needed to calibrate the machines to build each wheelchair part. The pins, rods, bolts and pads used on the wheelchair are all commercial parts that are readily available and would be easy to produce for large-scale manufacturing.
Health and Safety

By far the most important aspect of the beach wheelchair is safety. Jack is afflicted with cerebral palsy and scoliosis so this beach wheelchair must be equipped with special safety features that others might not need. Jack’s parents are providing a tumbleforms chair which comes equipped with a harness to properly secure Jack in the wheelchair. The frame of the wheelchair will be constructed of aluminum so it will be sturdy enough to support Jack’s weight and his increasing weight as he grows but also is light enough to allow for easy transportation of the chair. The lightweight design is also a safety feature because if for some reason, the wheelchair did tip over, it would not be heavy enough to cause significant damage to anyone (specifically Jack) it may fall on. The combined width of the polyurethane tires and the wheelchair frame is wide enough so that there is no danger of the wheelchair becoming unstable and tipping over. The adjustability of our beach wheelchair means that it will never be too small for Jack. If it was too small, there would be an increased likelihood that he could fall out due to poor fitting components. Since the wheelchair can adapt as he grows, him being too big for it will not be an issue.

Social

Every summer Jack’s family goes to the beaches in Rhode Island. Jack’s current wheelchair is not suitable for use on the sand and as a result, Jack cannot properly enjoy the beach with his family. This beach wheelchair will allow Jack to enjoy the beach with his family and not be restricted by the sandy terrain of the beach.

4. Safety Issues

Safety is a major concern in designing the Portable Beach Wheelchair. The biggest concern is the safety of the client. The chair must be strong enough to support the client’s growing body, and all parts of the chair must be weight bearing and supportive. Additionally, the chair must be able to keep the client safe and upright while it is traveling over uneven, sandy terrain. To ensure that this is possible, large, wide tires will be used to absorb some of the shock of the terrain. These tires are constructed of a very strong PVC rubber material. Additionally, the client will be using a strong harness to keep his torso from slipping out of the cushioning system. To give his parents the option of “parking” the wheelchair, a strong breaking system will be incorporated so that there is no chance of the chair rolling while unattended. These components are extremely important, and will ensure that the rider is safe and comfortable when using the Portable Beach Wheelchair.

5. Impact of Engineering Solutions

The overall goal of this project is to provide the client with a portable beach wheelchair that is low cost and can be used for many years. Because the chair is not going to be marketed with the intention of being sold, the global impact is negligible. If, however, the chair ever went to market, the standard of cost and sustainability of beach wheelchairs would be changed. Cost would be lowered and
sustainability would be improved, providing many more disabled people with the opportunity to enjoy the beach.

The environmental impact of the Portable Beach Wheelchair is small, but includes disrupting the sand where the chair rolls. This disruption will be minimal, and probably will not exceed the disruption caused by patrons who walk on the beach.

Socially, if a Portable Beach Wheelchair were to be marketed, it would be more common to see disabled individuals of all ages enjoying time on the beach. The gap between society and people with disabilities would become a little bit smaller, and the stigma associated with disabled individuals would decrease.

Globally, marketing a portable beach wheelchair that is low cost would increase society’s awareness of cerebral palsy and other disabilities, whether neurological or physical, closing the gap between disabled people and the able-bodied society. It may also open up more travel possibilities for those individuals who are disabled, allowing them to see parts of the world that they would otherwise be unable to visit. Overall, the chair offers the opportunity to improve the quality of life of many disabled individuals.

6. Life Long Learning

The design team gained a lot of new knowledge and many new skills while designing this project. When the project was first started, the team learned a lot about Cerebral Palsy. As our clients Jack and Matt exhibit, there are varying degrees of CP and every individual is affected differently. Jack lacks all motor control, and so he requires a wheelchair at all times, but his brother Matthew can use a walker to get himself around.

The project has also helped the team gain important insight into working with groups. The success of the project relies on the teamwork of the entire group, and the need to communicate is imperative. The team members have all learned to juggle multiple tasks, and to communicate with their teammates, as well as the client to achieve a product that is exactly what the client wants. These skills will translate well into many different work situations.

Understanding the functionality of typical beach wheelchairs was another important part of this project. The team examined many different types and designs to determine what would work the best for the client. They also learned how to adapt the various components to meet the needs of the client in terms of size and support level.

To create accurate drafts of the wheelchair design, the team had to learn to use a CAD program called SolidWorks. This extensive program is very detailed and is a professional program, used in many companies. Knowledge of this program will translate to any project that requires detailed 3D designs. Finally, in order to understand what is possibly to create the team had to understand all the components of the machine shop. To learn this, all members participated in a shop class that certified they were able to operate the machines and use all of the tools available to them.

7. Budget and Timeline

7.1 Budget

The team has been allotted a total budget of $2,800 to build both the wheelchair and the walker for the Davies family. Currently, it is estimated that $1,050 will be sufficient to purchase all components to create the wheelchair. Table 1 offers an overview of the breakdown of this budget.
### Table 1: Budget overview

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The frame is based off an existing transport wheelchair frame. Some aluminum tubing and fasteners were purchased to make the necessary modifications to the frame. The cost of the tires includes the cost of the “rims” and the axles. The cost from the machine shop is primarily due to the time Serge spent welding and the time that both Serge and Pete offered their guidance to us. The painting cost is the cost of the powder coating of the multiple components of the wheelchair that they did at CT Coating. The quick release pins are used on the reclining mechanism. Miscellaneous costs should be low, as very little additional materials will be necessary.

8. Team Members Contributions to the Project

**Team Member 1: Maya Alfonso**

For the duration of the project, Maya has been the contact to the Davies family. She spoke at length with Mr. and Mrs. Davies to comprehend exactly what they were looking for in the construction of this wheelchair. She has remained in contact with them for the duration of the project and has kept a running list of requirements of the projects.

Maya worked in depth with Kyle O’Brien to create a comprehensive optimal design that had all the components that the Davies were looking for. While Kyle created a Solidworks schematic of the chair, Maya researched the strength and feasibility of using various metals to construct the chair and ultimately wrote the optimal design report.

Maya and Kyle worked in conjunction to price out the parts and determine the cost of creating the chair. They chose the aluminum parts together and have been updating and finalizing the design together.

Maya and Kyle worked in conjunction to fabricate the wheelchair. Maya worked on the reclining mechanism, front casters, sewing and fabric work, rear axles and also handled all of the purchase orders and the financial aspect of the project. Maya was responsible for the sewing of the backrest and the footrest. She also worked on the disassembling and assembling of the beach wheelchair before and after painting.

**Team Member 2: Kyle O’Brien**

Kyle has spent the majority of his time designing the beach wheelchair in CAD. He first modeled the beach wheelchair from scratch, using a design created by both himself and Maya. Since then he has been researching commercially available wheelchairs to see if there are any available that could be
modified or used for parts. This involves comparing the commercially wheelchairs with our custom
design and seeing which components would mesh best to produce a fully functioning and safe beach
wheelchair. He will continue to modify the CAD drawings as updates to the design are made. He has
taken the shop safety class and will begin fabrication with Maya early next semester.

Maya and Kyle worked in conjunction to fabricate the wheelchair. Kyle spent most of his time on
the reclining mechanism, rear wheels, brakes, painting and reassembling and disassembling of the beach
wheelchair. Kyle was responsible for the final assembly, modification and cleaning of the beach
wheelchair. Kyle also worked to constantly update the CAD drawings and made sure they were kept
current with fabrication.

9. Conclusion

This project aims to create a portable beach wheelchair for Jack Davies, a 12-year-old boy with
Cerebral Palsy. The current design plans to use an aluminum frame because it is lightweight and easy to
work with, as well as easy to purchase. One of the more important parts of the design are the large
Polyurethane tires, which will be extremely wide to allow sufficient flotation over the sand. The chair
will feature a reclining mechanism for the client’s comfort on the beach. The cushioning system on the
chair will be an existent Tumbleforms cushion that the family already owns and transports to the beach,
which will make the chair even more portable.

10. References

Volk, Matthew (Ardmore, PA, US), Alderman, Holly (Bryn Mawr, PA, US),
Blumenthal, Karl-rainer (Glenside, PA, US), Cooperman, Benjamin (West
Conshohocken, PA, US), Henry, Dana (Media, PA, US), Herman, Lauren A. (Bala
Cynwyd, PA, US), Johnson, Vincent L. (Philadelphia, PA, US), Miller, Tara M.
(Melrose Park, PA, US), Peet, John S. (Wyndmoor, PA, US), Rouse, William E.
(Philadelphia, PA, US), Suway, Jeffrey (Rydal, PA, US), Zeglinski, John Z.
(Philadelphia, PA, US), Granger, Randy W. (Sumneytown, PA, US) 2005
Dignified broad footprint beach wheelchair United States William Penn
Charter School (Philadelphia, PA, US) 6869084

http://www.wheeleez.com/
http://www.neacare.com/
http://www.landeez.com/
http://www.mobility-usa.com/

11. Acknowledgements

The design team would like to thank Marek Wartenberg and Emily Jacobs for their continued
support and guidance throughout the design process, Serge and Pete from the University of Connecticut
Machine Shop for their careful instruction, and the Davies Family for their constant availability.
12. Appendix

12.1 Updated Specifications

**Physical:**
- **Type of Material:** Aluminum body and seat platform
  Polyurethane tires

**Mechanical:**
- **Size:** 36”x38”x52” (lxwxh)
- **Weight:** ~30 lbs
- **Turning Radius:** Rotate in place
- **Maximum Load:** 300 lbs
- **Special Features:** reclining frame, quick release tires

**Environmental:**
- **Storage Temperature:** Up to 110°F
- **Operating Temperature:** Up to 110°F
- **Operating Environment:** outdoors, wet/dry sandy terrain

**Safety:**
- **Constraints:** lap belt, arm and chest straps
### 12.2 PURCHASE ORDERS

**PURCHASE ORDER REQUISITION**  
**UCONN BME SENIOR DESIGN LAB**

**Instructions:** Students are to fill out boxed areas with white background  
Each Vendor will require a different purchase requisition

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Aurora, OH 44202-8087

**Phone:** (330) 995-5500

**Authorization:**

**Shipping**

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**Total:**

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- **Phone:** (707) 751-3999

**Authorization:**

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<table>
<thead>
<tr>
<th>Ship to:</th>
<th>University of Connecticut</th>
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<tbody>
<tr>
<td></td>
<td>Biomedical Engineering</td>
</tr>
<tr>
<td></td>
<td>U-2247, 260 Glenbrook Road</td>
</tr>
<tr>
<td></td>
<td>Storrs, CT 06269-2247</td>
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<table>
<thead>
<tr>
<th>Student Name:</th>
<th>Maya Alfonso</th>
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<tbody>
<tr>
<td>Total Expenses</td>
<td>$0.00</td>
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<th>Lab Admin only:</th>
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<tbody>
<tr>
<td>FRS #</td>
</tr>
<tr>
<td>Student Initial Budget</td>
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<tr>
<td>Student Current Budget</td>
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<table>
<thead>
<tr>
<th>Project Sponsor</th>
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<tbody>
<tr>
<td>Project Name:</td>
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<tr>
<td>Beach Wheelchair</td>
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<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
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<tr>
<td>Price Quote</td>
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<td>Shipping</td>
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<table>
<thead>
<tr>
<th>Vendor Accepts Purchase Orders?</th>
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<tbody>
<tr>
<td>Vendor:</td>
</tr>
<tr>
<td>Address:</td>
</tr>
<tr>
<td>Aurora, OH 44202-8087</td>
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<table>
<thead>
<tr>
<th>Phone:</th>
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<tbody>
<tr>
<td>(330) 995-5500</td>
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</table>

Authorization: