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LOW-INTERFERENCE WHEELCHAIR FOOTREST

BME 200/300 - Preliminary Report

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Abstract

Wheelchairs are one of the most commonly used assistive devices worldwide. There are many customizable aspects of the wheelchair, including the seat, controls, and the footrests. However, there are currently no forests on the market which adapt to the varying levels of mobility in wheelchair users. Current models include rigid bars that hang down from the seat and connect to footplates near the ground or rigid bars that hang down from the seat and connect to a bar spanning the length of the wheelchair, allowing for a limited range of motion. In addition current wheelchair models are heavy and bulky. The team has been tasked with creating a footrest that has low-interference and that allows wheelchair users to live more independent lives, while still being cost effective. This includes a footrest that originates from the castors, and is able to be folded up in order to move out of the way. However, when extended, it is able to support the full force of the individual's legs. As it is made out of a light, durable material and is comparatively small to current models- the model is more accessible to everyone, while still being functional. To ensure the group delivers a satisfactory device, testing will be conducted on the durability during static and dynamic movements, and client evaluations will occur many times over the fabrication process. With the team’s efforts, a more inclusive footrest design will allow more individuals to complete activities of daily living independently.

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I. Introduction

Motivation

Wheelchairs are one of the most common assistive devices worldwide, with approximately 131 million people worldwide reporting using a wheelchair [1]. Many wheelchairs in today's society are able to be customized to fit the users needs; with adjustments able to be made to the frames, controls, cushions, and head arrays [2]. Another customizable aspect of wheelchairs includes the footrests, which traditionally consist of a bar that connects foot plates to the base of the wheelchair seat. Footrests are vital to maintain stability, comfort and safety of wheelchair users. If a desired footrest can not be achieved or maintained, the patient may be negatively affected [3]. Current wheelchair models do not account for varying levels of mobility among patients, with many being difficult to remove when not in use or too heavy to use [4]. Ideally a wheelchair footrest should be able to adapt to a person's mobility and range of motion, while still being durable, lightweight, and easy to use.

Existing Devices and Current Methods

While there are many different types of wheelchairs on the market, there are two major categories of foot support. The most common category is a footrest. A wheelchair footrest generally consists of a footrest hanger and footplate. Footrest hangers attach to either side of the seat and are often made of aluminum alloys or other lightweight but durable materials. Additionally, the footrest hanger is often designed to be adjustable in order to accommodate different leg lengths among wheelchair users. The footplate is a small plastic or metal piece fixed at a 90° to the end of the footrest hanger. Footplates are often made to swing-away, in line with the footrest hanger, in order to make transitions in and out of the wheelchair less cumbersome. There are several different types of footplates on the market, including individual standard footplates and rigid wheelchair footrests. Standard footplates consist of two separate components designed to rest both feet separately while rigid wheelchair footrests consist of a single platform designed for both feet to rest beside each other [5]. The other type of foot support available are legrests. Legrests are not as widespread as footrests and are most common on tilting wheelchairs where they are able to move with the chair to provide leg support in both seated and reclining positions. Legrests generally consist of the same components as a footrest with the addition of a calf-support pad perpendicular to the footrest hanger [6]. Due to its additional components, legrests are often heavy and bulky, making them less than ideal for users with limited mobility who require a lightweight design. It is also difficult to set the footplate to a comfortable position when the leg rest is adjusted. [7].

There are many wheelchair footrests and leg rests on the market currently. Both Drive Medical [8] and Invacare Corporation [9] offer traditional wheelchair footrest designs with a removable footrest hanger and footplate. In addition, the Drive Medical model includes a heel strap for increased foot support. The inclusion of a foot strap on footplates adds significant support without the addition of substantial weight and may be ideal for users who reposition often. The footplates for both of these designs are 7” x 6” and swing upwards 90° to create foot space when needed. Both Drive Medical [8] and Invacare Corporations [9] also offer legrest designs which feature calf pads. These calf pads are fixed rigidly on the footrest hanger and may not be adjusted, but the length of the hangers themselves can be altered accordingly. Most wheelchair companies offer a variety of footrests designed specifically for their type of chair, but a majority of designs model closely to the ones described above. Prices for wheelchair foot supports generally start at $40 and range upwards of $300, with some exceptions [10].

Existing designs include large and bulky components which might be difficult for users with mobility issues to attach and remove independently. If a new wheelchair footrest can be designed that allows for a greater accessibility, gives users increased range of motion, and maximized ease of use while still being lightweight and cost effective, wheelchair users would be allowed increased independence in their daily lives.

Problem Statement

There are currently no wheelchairs on the market which allows those who are not paralyzed to perform helpful movements, such as opening doors with their feet or being able to pick up objects from the floor. In addition, current footrest models are heavy, bulky, and not easily able to be removed and stored when not in use. While footrests are crucial for support if the wheelchair tilts or reclines, it is imperative to design a wheelchair footrest that allows for more foot mobility- should the user require it- and for easier storage of said footrests. The updated footrests should be able to adapt to a person’s abilities, should be easily able to remove and store them when not in use, and be lighter and less bulky, while still providing the benefits of a footrest when necessary.

II. Background

Relevant Biology and Physiology

There are many different conditions that require the use of wheelchairs; including quadriplegia, paraplegia, cerebral palsy, and various neuromuscular disorders. All of these conditions result in different levels of mobility, strength, and range of motion [3]. The broad goal of this project is to design footrests that are able to adapt to differing levels of mobility in wheelchair users.

Proper leg and foot support is immensely important to the comfort of wheelchair users as long term use of improper foot or leg rests can lead to lower back pain and excess pressure on the user's thighs and buttocks area. Wheelchair footrests also offer posture support and play a significant role in supporting appropriate pelvic and lower limb positioning. Proper posture should compliment the natural 'S' shape curve of one's spine and is maintained when weight is distributed equally across both hips and both feet are flat on a solid surface [11]. The support of footrests on wheelchairs allows for proper seated positioning which contributes to an equal distribution of weight below the torso, increased blood flow, and eased pressure in the legs, hip joints, muscles, and lower back regions [12].

Proper footrest position is also important in order to prevent accidental injury. A study done by San Francisco State University's School of Engineering investigated the types of injuries sustained by wheelchair users over a 5 year period. In the 253 incidents over the 5 year period, 33 % were component failures, which included faulty footrests. In addition, 42% were tips and falls, which included footrests mishaps. Reported injury types included cuts and bruises, fractures, head injuries, muscle and tendon injuries, and 13 unspecified injuries. Results from the experiment show correlation with powered wheelchairs and sideways falls [3].

Client Information

The client, Mr. Dan Dorszynski, is a resident of the Madison, Wisconsin area who is looking for improvements to his wheelchair's footrest design. He requires the team to manufacture a footrest that allows him more mobility and also is easier to handle when not in use.

Design Specifications

This design is built specifically for our client, but there is potential for an expanded customer base for those in wheelchairs with foot mobility. The client's requirements include the footrest having the ability to be stored on the wheelchair itself or be easily removable from the wheelchair, have a combined weight of 3-4 lbs, and the ability to move with the wheelchair. The footrest should have an equivalent lifespan of a typical wheelchair base (4-5 years) [13]. Additionally, the wheelchair should hinder the user's foot and leg from sliding backwards into the base of the wheelchair to ensure the safety and comfort of the client. The device should be able to support the force of the clients feet when in use. The footrest must not hinder the user's transfer onto or off of the wheelchair. Finally, the footrests should allow for foot movement from the client when in use, and should not interfere with any leg or foot movement that the client wishes to perform.

III. Preliminary Designs

Fold-Up Footrest

The Fold-Up Footrest footrest design consists of two separate footrest pieces that will support one foot each. The footrest pieces attach to the right and left castors on the base of the wheelchair. An attachment device secures the footrest to the castors. The attachment devices are molded to fit tightly around the top of the castors and strap around the bottom of the castors to ensure the stability of the footrest. A hinge connects the attachment device to the footplate portion of the design. The hinge locks at 90 degrees, which ensures the footplate will remain parallel to the ground while in use. When the footrest is not in use, the footplates are able to fold back up 90 degrees to be stored next to the castors. This allows the client to remove the footrest and easily store it on the wheelchair while the wheelchair is in use.

The design features two separate footrest pieces to ensure that the client is able to easily fold up the footrests when not in use. Because the footrests do not take up the entire space between castors, the client is able to move his foot off the footrest and out of the way to allow enough room for the footrest to fold up. Additionally, the footrest attaches to the base of the wheelchair which allows the client to utilize the up and down movement of the wheelchair seat to get their feet on and off of the footrests. The compact design of the foot plate allows the footrest to be stored next to the castors without interfering with the wheelchair components, the movement of the client, or the client's transfer on and off the wheelchair.

Figure 1: Fold-Up Footrest Design Drawing

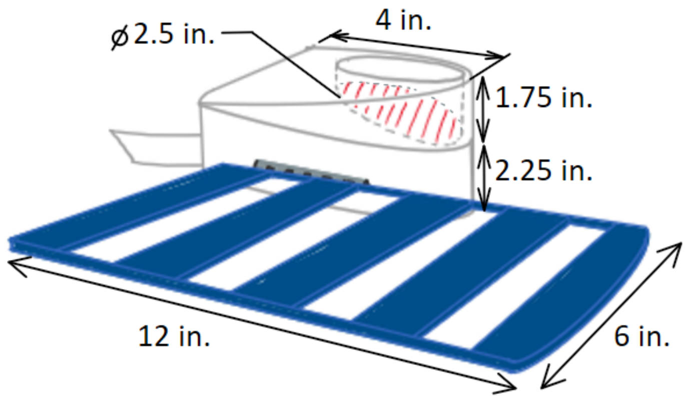


Figure 2: Fold-Up Footrest Design Dimensions

Folding Mesh Footrest

The Folding Mesh Footrest design consists of one foot piece that will support both feet. The frame of this footrest is made from a metal material and the footplate is made from a mesh material. The back portion of the footrest attaches to the base of the wheelchair. The foot piece portion connects to the back section of the footrest by hinges. The hinges lock at 90 degrees, ensuring the foot piece will only fold down 90 degrees to remain parallel with the ground when in use. When not in use, the foot plate folds back up 90 degrees and stores on the base of the wheelchair, behind the client's legs.

This design also attaches to the base of the wheelchair. Again, this allows the client to utilize the movement of the wheelchair seat to get their feet on and off of the footrests. The footrest is made from a mesh material to ensure the footrest is lightweight and compact and allows for storage on the wheelchair. Additionally, the footrest is able to be completely removed from the wheelchair base. The client is then able to remove the mesh portion from the frame if they wish to clean it.

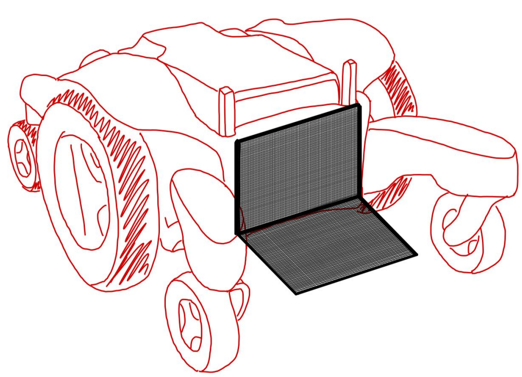


Figure 3: Folding Mesh Footrest Design Drawing

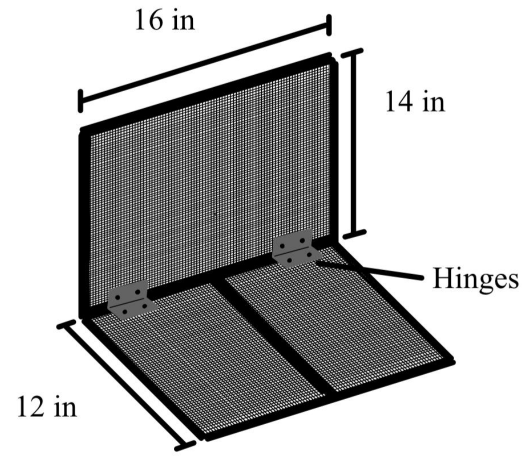


Figure 4: Folding Mesh Footrest Design Dimensions

Airplane Armrest Footrest

The Airplane Armrest Footrest is stored underneath the armrest and flips around to fold down and to the side when in use, similar movement to an airplane tray table. The storage box is made from a plastic material and the footrest components are made from a plastic material with metal supports. This ensures that the footrest is strong enough to support the client's feet but also light enough that our client is able to fold the footrest down and back up into the storage box. When not in use, the footrest folds back up and is stored in the storage box that is located on the right side of the wheelchair. The client transfers on and off the wheelchair from the left, so installing the storage box on the right side of the wheelchair ensures the footrest will not restrict the client's transfers.

The seat of the client's wheelchair is able to move up and down as well as tilt back and forward. This design attaches to the seat of the wheelchair, so it will move up and down and tilt with the seat. This ensures that the client's feet will be supported by the armrest no matter the position the seat is in.

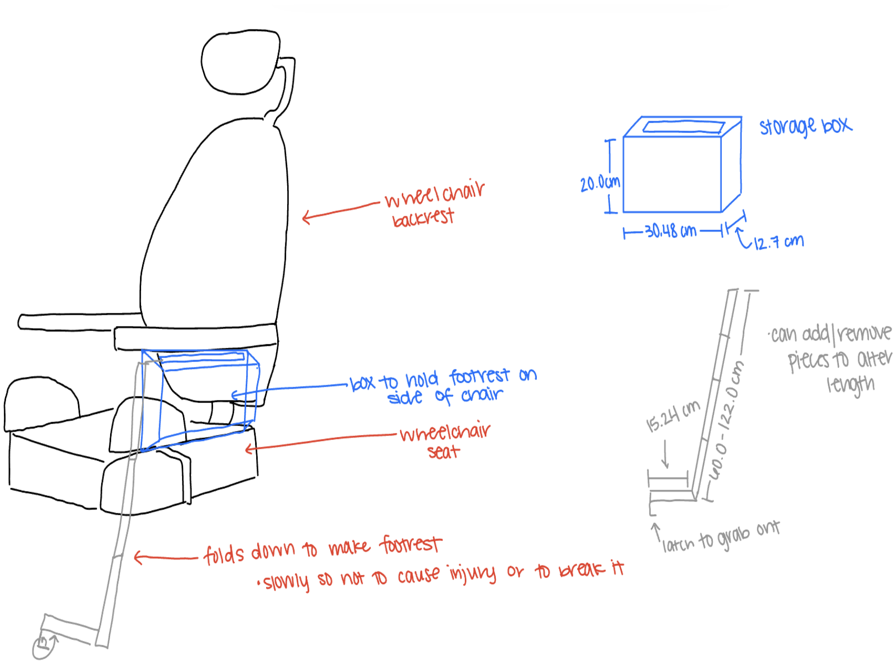


Figure 4: Airplane Armrest Footrest Design Drawing

IV. Preliminary Design Evaluation

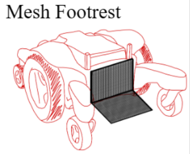
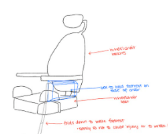
Design Matrix

The design matrix is a tool employed by the design team to evaluate preliminary designs in terms of important selected criteria. The criteria chosen by the design team was evaluated based on the client's requirements, what was most readily accomplishable in a semester, and by the amount of background knowledge that the design team has.

The criteria includes 7 categories, where each category has a specific percentage in which they contribute to the total point system. First category is ease of use, weighted 25 percent which is the highest. Ease of use is extremely important since the design needs to be easy and simple to function for the client since they have limited mobility. Next is storage, weighted 20%. This category assesses how well the design is able to be low interference. The ideal design needs to be stored discreetly on the wheelchair, so it can be spatially low interference. The storage aspect must also not interfere with the other functionalities of the wheelchair. Next is weight, weighted 15%. A lightweight footrest design is lacking in competing designs. The weight category assesses how well the design satisfies the outlined maximum weight of 4 pounds, to accommodate the clients needs. Next is size, weighted 10%. Size has a similar assessment to storage. This category assesses if the design has a good balance between being small enough to be low interference spatially, and an appropriate size to fit the client's feet. Next ease of fabrication, weighted 10%, assesses how easy the design is to fabricate. Next durability, weighted 10%, assesses how well the design can withstand day to day usage and potential weather elements. The footrest is desired to have the same lifespan as the wheelchair, which is about 5 years. Finally cost comes in last, weighted 5%, which assesses how expensive the design is. Higher the scores reflect a less expensive cost. This category is rated lower since the client's needs come first.

The matrix results applied the discussed criteria. For ease of use, The Fold-Up Footrest design and Folding Mesh Footrest scored full points since both have simple operations of flipping up 90 degrees for the optimal storage position. The storage category awarded full points to the Fold-Up Footrest since it proves to maximize low interference and does not crowd the front area or other functions of the wheelchair. The weight category awarded full points to the Folding Mesh Footrest since the footplate being made of mesh fabric will be extremely lightweight. The ease of fabrication category awarded full points to the Folding Mesh Footrest since it does not require complex mechanical procedures. The durability category awarded full points to the Fold-Up Footrest, since the sturdy foot plates made of either plastic or aluminum and hinge reinforcements, will withstand constant forces and weather. Finally cost awarded full points to the Folding Mesh Footrest since the use of mesh fabric minimizes the cost of the entire design.

Table 1: *Design Matrix. Evaluation of feasible design ideas amongst different criteria. Highlighted areas indicate the highest score per category. Scores out of 5.*

	Design 1: Fold-Up Footrest 	Design 2: Folding Mesh Footrest 	Design 3: Airplane Armrest 
Ease of use (25)	5/5	5/5	2/5
Storage (20)	5/5	4/5	3/5
Weight (15)	4/5	5/5	2/5
Size (15)	5/5	5/5	3/5
Ease of Fabrication (10)	4/5	5/5	1/5
Durability (10)	5/5	3/5	3/5
Cost (5)	3/5	5/5	2/5
Total (100)	93	92	47

Proposed Final Design

According to the design matrix, the team decided to go with a modified version of Design 1: The 'Fold-up Footrest'. In particular, its simple design allows for the most ease of use and greater potential for the use of lightweight durable materials. Several aspects of the design allow for the best storage capabilities. The fold-up aspect allows the device to be out of the way when not in use, but remain on the wheelchair. This eliminates the need for the user to do excess work. The design is also relatively confined to the castor region of the wheelchair and is therefore not a large hindrance to other wheelchair functions, both when in use and not in use. Compared to other designs, this one is slightly more difficult to manufacture. The modified design requires either a mold or a complete model of the castor in order to adequately create a casing to fit around them. However, the stability the design offers as a result outweighs this disadvantage, and the process for manufacturing this is nonetheless achievable. Design 2 did offer very similar advantages and was lower in cost, but its durability and storage disadvantages outweigh the disadvantages of Design 1. Design 3 did not perform high in any category.

V. Fabrication/Development Process

Materials

At this point in the design process, the material selection has not been finalized. The final design will potentially be composed of Aluminum Alloy 6601-T6 and or a plastic such as polycarbonate. Both fit many of the outlined criteria.

AA6601-T6 allows for design flexibility since it is highly weldable. It is also relatively lightweight with a density of 2.70 g/cm^3 [14] while also providing a high strength-to-weight ratio which means weight reduction won't compromise the structure's integrity. The high strength and durability of the material can be stated from the fact it can withstand a tensile stress of 276 MPa [14]. The material is also corrosion resistant [15] and can be reliable against a variety of weather conditions. This meets the criteria of longevity where it can last as long as the wheelchair, which is about 5 years [13].

Polycarbonate also allows for design flexibility since it is moldable and has a mold temperature of 90-320 degrees Fahrenheit [16]. Polycarbonate is extremely lightweight with an average density of 1.20 g/cm^3 [16] while also providing a fair strength-to-weight ratio however it doesn't nearly compare to the strength of AA6601-T6. The strength and durability of polycarbonate is stated from the fact that it can withstand an average tensile stress of 64.2 MPa [16]. Polycarbonate has no risk of corrosion and can prove steady in terms of weather conditions. This meets the criteria of longevity in which it can last as long as the wheelchair, which is about 5 years [13].

Methods

Since the castors and the existing holes are the focal points of attachment, a mold will be taken for fabrication. A potential and likely method of approach is constructing a CAD design of the castors with the negative holes to then 3D print. This 3D print model can be used as a mold to construct the cap piece of the design that will be inserted into the castors. For the other components, a 90-degree hinge can be purchased to satisfy the design's function of rotating a total of 90 degrees. The hinge will be reinforced via screws, which will also attach the footrest plate to the cap. The actual footrest plate can be purchased to eliminate the need to fabricate. However, if no appropriate products on the market exist that fit the weight, size, and material criteria, then fabricating one would be necessary.

Testing

A variety of testing methods are outlined for execution. The final design must be tested to fit and function on the client's wheelchair base. The design is made to attach to the castors in which existing holes on the castors provide the intended attachment method. The design must fit these existing holes snuggly for maximum support and stability. This testing will ensure the manufactured measurements were correct. The overall function of the design can be tested by ensuring that the footplate can rotate down to the desired position and angle. Additionally, it must be verified that the footrest design does not hinder any functions of the client's electric wheelchair. For example, the design must not touch or invade the function of the nearby wheels. Quality assurance testing must also be conducted. Verification and validation of the structure integrity can be done by applying similar compressive and tensile forces to the extent the client will apply on the footrest design. Before physically testing such, the maximum allowed force can be calculated. For either material, the maximum force can be calculated by using the maximum tensile stress and multiplying it by the measured cross-sectional area of the material that is perpendicular to the anticipated force. The anticipated forces applied can be verified as allowable by comparing this number to the calculated maximum. The anticipated load must meet the requirement of being within an allowable factor of safety, in which the ratio between the maximum load and anticipated load falls within 1.25-4.

VI. Results

We will analyze our results by using multiple forms of distribution, such as statistical significance and percent error, specifically regarding tensile strength and factor of safety measurements and calculations. We have yet to collect this data and will update this section once we have done so. If the design proves to handle the appropriate weight and not hinder wheelchair usage, we will move forward with the design. However if the foot plate portion breaks or deforms due to weight applied, we will reevaluate the chosen material. If the attachment device or hinge fails, it is likely an issue of mechanical support, so we will evaluate and adjust for this if the issue arises. Many of our tests also rely on user feedback, so if we find the footrests to be a major hindrance in any way or not significantly more useful then previous designs, we will use that feedback to improve the design and retest.

VII. Discussion

This product is designed around a specific model of a wheelchair, so it would only be useful for clients with a Quickie Power wheelchair. However, competing footrests often restrict leg movement and are not able to be removed while the wheelchair is in use. There is a possibility of clientele that would benefit from a wheelchair footrest that is removable and allows for leg movement and allows feet to reach the ground.

Throughout the group's testing and research, some of the main ethical considerations are that the final product must be safe to use and does not inhibit any functions of the wheelchair. The product should not affect the movement of the wheelchair by restricting the movement of the front wheels. Additionally, the product should not permanently alter or damage the wheelchair by putting more force on the castors then they are able to support. The product should not affect the client's transfer on and off of the wheelchair. Throughout the testing process, the group will ensure the product is able to support the force of the client's feet. The footrest must support this weight without the foot plate moving past the 90 degree angle the hinge locks in. If the foot plate were to move down past the 90 degree angle, the footrest could restrict the movement of the wheels that are located below the castors. These wheels spin 360 degrees and are responsible for turning the wheelchair, so it is essential that our footrest not inhibit their motion. Through testing, if the group finds that the footrest is unable to support the weight, extra supports will be added to the foot plate. This could include support bars underneath the foot plate, extra hinges, or a larger attachment device that covers a larger portion of the castors.

Possible sources of error could arise from inaccurate measurements of the force of the client's feet that will be applied to the footrest. The force of the client's feet onto the footrest changes depending on the angle of the client's legs or if they are leaning forward or backward. Additionally, the client could lean to one side or the other, which would put additional pressure on one of the footrests. This could make it difficult to find an exact number for the weight the footrest must support.

VIII. Conclusions

Current footrests available to wheelchair users do not allow for users to perform useful movements, such as picking up objects from the floor or opening doors with their feet. The available footrests are also bulky, heavy, and difficult to remove from the wheelchair. Though footrests are important for support of feet and legs when in use, and this function should not be inhibited, these footrests should allow for more mobility of the user. The updated footrests should adapt to the abilities and mobilities of the user, should be easily removable and storable on the wheelchair when not in use, and should be lightweight and less bulky. However, it is imperative that the footrests still provide the main functions and benefits of a typical footrest of a wheelchair when necessary.

The final design consists of two footrest pieces that will connect to the caster wheels on the base of the wheelchair. These two footrests will support one foot each. An attachment device will be used to secure the footrests to the caster wheels. A hinge attached to the attachment device will lock the footrests at 90 degrees, parallel to the ground, when in use. When the footrests are not in use, they will fold up 90 degrees to the side, and will be stored in this position. This will keep the footrests out of the way of the user, but easily accessible on the wheelchair. The team developed three different design ideas, and determined the chosen final design based on weighted scores in various design criteria. These criteria were chosen based on the clients requirements for the device. Thus, the team worked to create a final design that incorporated all the criteria the client desired, and that improved on current wheelchair footrest devices.

If the time were to do this portion of the project again, there would be greater emphasis on design metters where the team members discussed the specifics of each design. This includes the mechanisms for each device's storage, and the mechanism for stability when the device is in use. Additionally, the team would have asked the client questions about his mobility earlier on in the process, making it easier to understand the importance of different aspects of the design, such as the storage of the device.

In the future, the team will need to develop the specifics of the footrest, and fabricate the device. This will include determining a final attachment piece to secure the device to the casters, and determining how to keep the footrest in place when in storage mode. Once the prototype is fabricated, the group will perform various testing procedures to ensure that the device is functioning properly. Once the testing phase is complete, the team will determine if any revisions need to be made to the final design, and then move on to final testing. Once the final testing is complete, any final changes necessary will be made.

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X. Appendix

A. Product Design Specification (PDS)

Function:

There are currently no wheelchairs on the market which allows those who are not paralyzed to perform helpful movements, such as opening doors with their feet or being able to pick up objects from the floor. In addition, current footrest models are heavy, bulky, and not easily able to be removed and stored when not in use. While footrests are crucial for support if the wheelchair tilts or reclines, it is imperative to design a wheelchair footrest that allows for more foot mobility- should the user require it- and for easier storage of said footrests. The updated footrests should be able to adapt to a person's abilities, should be easily able to remove and store them when not in use, and be lighter and less bulky, while still providing the benefits of a footrest when necessary.

Client requirements:

I. Combined weight between 3-4 lbs
II. Ability to fold footrest up or be able to easily remove and store them
III. If removable, a place to store them so they are accessible but not a hindrance
IV. Ability to move with wheelchair (i.e. move with the rest of the chair when chair tilts backwards)
V. Have calf support

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements*:

I. The wheelchair footrests must have an equivalent lifespan of wheelchair base (between 4-5 years [1]). Production cost should not exceed $200 to maintain reproducibility and combined weight may not exceed 4 lbs. The footrests should also be able to be stored on the wheelchair.

b. *Safety*:

I. Any materials used to construct wheelchair footrests must not include sharp edges.

II. Footrests should hinder the user's foot and leg from sliding backwards into the base of the wheelchair as to ensure comfort and safety.

III. Footrest accessories must be removable or swing away in order to clear a path and avoid accidents when the user transfers into/out of the wheelchair seat.

c. *Accuracy and Reliability*:

I. The footrest must be able to connect to the base of the wheelchair safely and securely every time it is attached.

d. *Life in Service*:

I. Footrest should have the same lifespan as a typical wheelchair base, which is an average of 4-5 years [1].

e. *Shelf Life*:

I. The footrest must be able to last as long as the client will be using the specific wheelchair that the footrest will attach to, 5 years. [2]

f. *Operating Environment*:

I. The footrest must be able to operate both indoor and outdoors. The footrest should be able to withstand all weather conditions.

II. The footrest must also be able to support the force of the client's feet. The force that the client can exert on the footrest will be determined at a subsequent meeting.

g. *Ergonomics*:

I. The footrest must be able to support the client's feet while also not restricting leg movement or the client's ability to put their feet on the ground.

h. *Size*:

I. The footrest, if two separate pieces, should accommodate wider than the shoe's width, but can be shorter while supporting the majority of the foot's length. The size of the footrest should accommodate a variety of sizes and can be based on average shoe sizes. Based on the average men's shoe being a 10.5 with measurements of 11.645 by 4.25 inches [3], the footrest's dimensions can be around 7 by 5 inches.

II. The footrest, if one piece, should accommodate for a shoulder width apart orientation of feet.

i. *Weight*:

I. The weight of the entire design should be a maximum of 3-4 lbs, per client's request.

j. *Materials*:

I. The footrest design should be constructed of a durable long lasting material that is able to withstand stress causing forces, and a variety of weather conditions. Potential materials include Aluminum Alloy (7075-T6 or 6061-T6), stainless steel, plastic, or polyvinyl chloride (PVC).

k. *Aesthetics*, *Appearance, and Finish:*

I. The final configuration of the footrest can not impede any other relevant functions of the wheelchair or user safety

II. The aesthetics and appearance aspects of the product are not relevant to the final design so long as they meet the other requirements detailed in this document.

2. Production Characteristics

a. *Quantity*:

I. The client requires a single prototype to be used as an attachment to his current wheelchair. With successful creation of one prototype, more could be created for a larger population.

b. *Target Product Cost*:

I. The target cost of the product provided by the client is within $200.

3. Miscellaneous

a. *Standards and Specifications*

I. ISO 7176: This standard states testing guidelines for various mechanical components off the wheelchair. Parts 1 and 2 [4][5] refer to static and dynamic stability of the wheelchair movement. Other parts refer to wheelchair dimensions, maneuvering space, durability, etc. Since the apparatus would affect the physical properties of the wheelchair itself, these are important to note.

b. *Customer*:

I. The customer for this product is the client Mr. Dan Dorszynski. He dislikes the current footrest options that restrict his ability to use his feet for small everyday actions, such as opening a door. We are currently discussing which specific aspects of the footrest he finds restricting and what aspects he can overcome.

II. While this product is being designed with a specific customer in mind, if similar frustrations are faced by other wheelchair users with degrees of mobility, the final product could potentially be utilized in other similar situations.

c. *Patient-related concerns*:

I. The final product is one such that it may require some modification or attachment to the clients wheelchair. As the wheelchair is a necessary component of the clients everyday life, it is essential that any building, testing, and final product allow all other functions of the wheelchair to remain intact.

d. *Competition*:

I. There are many other wheelchair footrests on the market today with varying design elements. These include, but are not limited to, models from Drive Medical [3], Invacare Corporation [6], Comfort Company [7], and Therafin Corporation [8].

II. Prices generally start at $40 and range upwards of $300 [9].

References

any quantitative information without references came directly from the client, Mr. Dan Dorszynski

[1] Ngamwongsa-Nguan, Panya & Arayawichanon, Preeda & Manimmanakorn, Nuttaset. (2017). Manual Wheelchair Longevity and Related Factors among Spinal Cord Lesion Patients. Asia-Pacific Journal of Science and Technology. 22. 1-6.

[2] Quickie Q700 M / Q700 M HD - Sunrise Medical, www.sunrisemedical.com/getattachment/f2db9ac9-1c2b-4dcc-903e-cafdbacb5111/Quickie-Q700-M-Owner-s-Manual.aspx. (Accessed 22 Sept. 2023).

[3] "Brannock Device® Foot-Measuring Device User Guide" by The Brannock Device Co., Inc.

[4] ISO. (2014). Wheelchairs — Part 1: Determination of static stability. https://cdn.standards.iteh.ai/samples/56817/abc81b2284d1465f91679e4588c269be/ISO-7176-1-2014.pdf

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[6] "Invacare Footrest Assembly," Quickie Wheelchairs. https://www.quickie-wheelchairs.com/Wheelchair-Parts-Accessories/Assorted-Wheelchair-Parts/Footrests-Legrests/Invacare-Footrest-Assembly-3-1-8-Pin-Spacing-Pair/24518p (accessed Sep. 20, 2023).

[7] "Comfort Calf Protector," Quickie Wheelchairs. https://www.quickie-wheelchairs.com/Wheelchair-Positioning/Lower-Extremity/Comfort-Calf-Protector/27557p (accessed Sep. 20, 2023).

[8] "Ankle Supports - Velcro Closures' Quickie Wheelchairs. Ankle Supports - Velcro Closures | Lower Extremity (quickie-wheelchairs.com) (accessed Sep. 20, 2023).

[9] "Drive Medical Swing Away Footrests," Vitality Medical. https://www.vitalitymedical.com/wheelchair-swing-away-footrests-stds3j24sf.html (accessed Sep. 20, 2023).

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[11] J. R. Davis, *Corrosion of Aluminum and Aluminum Alloys*. Materials Park: ASM International, 1999.

[12] Overview of materials for polycarbonate, molded, https://www.matweb.com/search/DataSheet.aspx?MatGUID=84b257896b674f93a39596d00d999d77 (accessed Sept. 20, 2023).

B. Expenses and Purchases

The team has not yet made any purchases.

C. Testing Protocols

Force Exerted Through User's Foot

1. Have the user sit with feet flat on the ground
2. Place a scale beneath one foot
3. Record the reading on the scale
4. Repeat on the other foot
5. Average results and use value for testing photo plate

Durability with Static Weight

1. Note the initial vertical starting position of the footplate
2. With the foot rest attached to the provided wheelchair base, place a weight on the platform equivalent to that found in 'Force Exerted Through User's Foot'
3. The footrest should be able to hold the weight for at least 5 minutes
4. Record any temporary and/or permanent deformations–check every minute and final position.

Durability with Dynamic Movement.

1. Connect the footrest to the user's wheelchair.
2. With footrest flipped up, ensure the attachment device does not hinder movement of castor wheels–use observations and user evaluation to determine the results of this.
3. Have them first simply place feet on footrests at a comfortable sitting position–ensure stability.
4. Once set, have the user move around in the wheelchair. Observe any difficulties with or deformations after use.