SECONDARY AIRLINE MOBILITY DEVICE

Preliminary Report - BME Design 200/300

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ABSTRACT

Airline travel is currently very challenging for individuals in wheelchairs. Due to size and security restrictions, multiple wheelchair transfers are required to move a traveler from their main wheelchair to their seat. When these transfers take place, disabled individuals risk being injured or embarrassed during the process. Current designs that work to eliminate or ease transfers are scarce or ineffective. Because of these difficulties in travel, our client, Dan Dorzynski, has tasked us with creating a design for a secondary mobility device to reduce the number of transfers required to board and exit a plane. Through team research and brainstorming, our team evaluated three preliminary designs that we narrowed down to one final design. Our preliminary design involves manufacturing a secondary device that will fit over our clients wheelchair, and have folding wheels to allow for use both with and without his primary wheelchair. Through our design, we will decrease the number of transfers experienced by our client by half, and improve his overall quality of airline travel.

I. INTRODUCTION

A. Motivation

Currently, airline travel for disabled passengers is stressful and difficult. To get onto the airplane the passenger must first be transferred into a aisle wheelchair. Transfers can be embarrassing for passenger, and dangerous, as they are commonly dropped by attendants who are not properly trained to help. Once on the plane, they are then transferred into their seat, with the same transfer risks as before. This process must happen again when the plane lands. There is also a risk of the passenger's own wheelchair being damaged during the flight or put on the wrong plane. Because of these reasons, many people who use wheelchairs avoid airline travel altogether.

B. Existing Devices

There are several aisle chairs currently in use for airlines. These devices are expensive and require multiple transfers of the users. One such device can be seen in Figure 1. This is the Aislemaster Unfoldable Boarding Wheelchair. This device ranges in width from 13 inches to 16 inches thus meeting airline aisle width specifications. This device contains hinging armrests to allow for easy transfer of passengers. This device meets safety requirements by including two shoulder straps. This device is fairly expensive as it costs $2,650. This device can hold up to 400 pounds of weight, and it weighs 40 pounds [1].

Figure 1: Aislemaster Unfoldable Boarding Wheelchair. The above design is a rigid chair that the client must be transferred to.

Another such device can be seen in Figure 2. This device is known as the TravelAide & RescueMate Transfer Chair [1]. This device also contains two shoulder straps to meet safety requirements. This device is also fairly narrow as it is 16 inches wide. It is lighter than the Aislemaster Unfoldable Boarding Wheelchair as it weighs 36 pounds, however it holds significantly less weight as it can only hold 300 pounds. This device also contains movable armrest to allow easy passenger transfer. This device is also expensive as it costs $2400.98 [1].

Figure 2: TravelAide & RescueMate Transfer Chair. This is rigid chair design that would require transfers of the user.

The third aisle wheelchair researched is the Aislemaster TransportMate Compact Wheelchair seen in Figure 3. This device differs from the others as it can fold for easy compact storage. This device is 16 inches in width so will fit most airplane aisles. This device is very light for a wheelchair. It only weighs 16.7 pounds. This device can hold 300 pounds. Like the other wheelchairs, this device is very expensive with a price of $2100 [1].

Figure 3: Aislemaster TransportMate Compact Wheelchair. This a foldable chair design that would allow for easy storage of the aisle chair.

The Eagle Lift is a device currently employed by Air New Zealand at five regional airports [2]. It consists of a mechanical hoist and a fabric sling that can be used to transfer passengers from wheel chairs directly to their seats. It can lift up to 200 kilograms, and has many features that increase its stability and ease of use for the airline workers. Some of its disadvantages include that it can't be used in flight, and it can only transfer passengers onto one side of the aisle in the plane.

Figure 4: EagleLift. This design incorporates a hammock like design to lift the user into the chair in an easier manner.

These designs are all good, but they have issues. Many of these designs are bulky so they can not be stored for use in flight. These devices all involve multiple transfer from primary device to secondary device to aisle chair. Ideally, our designs would be able to be used in flight and would have less transfers.

C. Problem Statement

Currently, airplane travel for handicapped passengers is a very difficult and arduous process. This process involves multiple wheelchair transfers which are lengthy and difficult. The transfers include the lifting of the passenger from their wheelchair to a small, specially designed aisle wheelchair and another transfer from the aisle chair to the passenger's seat. These two transfers pose opportunities for untrained staff to drop the passengers leading to potential injury and embarrassment. The current procedures in place are so inefficient and tedious that many wheelchair-bound people refrain from flying at all. This device will work to eliminate one of the two transfers that are currently required when moving a handicapped passenger from the jetway, through the aisle, and to their seat and will promote a healthier flying environment for those who require wheelchairs.

II. BACKGROUND

A. Background Research

Our background research included research on the current systems, similar devices, and FAA restrictions on our device. The current system of transferring a wheelchair user to an airplane seat includes two transfers. The first transfer occurs between the user's wheelchair and an airplane accessible aisle chair, and the second one occurs between the aisle chair and the airplane seat. Our goal is to eliminate the first transfer, so we further researched devices that could accomplish that. After looking into airplane transfer devices from multiple airline companies, we concluded that our device would have to be a chair variation or a lift [3]. We ruled out doing a lift because of the difficulty in fabrication and high cost.

After eliminating the lift design, we decided to make a variation of an aisle chair with the intention of eliminating a transfer. We researched FAA restrictions on personal airplane transfer chairs and concluded that our device must be less than 15 inches wide, and the device can't be sat on during the flight [4,5,6]. This narrowed our scope to strictly eliminating the first transfer from the user's wheelchair to the airplane chair. Further research revealed that most airlines allow stowable chairs and transfer devices to be stowed the plane during the flight, so our client

could use the chair mid flight [7]. We also concluded that a foldable or easily stowable chair would be beneficial to the airline as well as our client.

B. Client Information

Dan Dorszynski is in the computer graphics service business. Mr. Dorszynski has muscular dystrophy and is confined to a wheelchair. He travels about 3-4 times a year, and has experienced many problems at the airport because of wheelchair accessibility on airplanes. He has asked us to build a secondary mobility device that can be used on airplanes to make travelling easier and more accessible for people with wheelchairs.

C. Design Specifications

The design must limit the number of transfers to two or less, and also be easily stored. Our design will have proper safety restraints and supports to withstand a weight of 300 lb. The design will be able to fit down most airplane aisles, requiring it to be between 20 and 25 inches in width and 18 to 21 inches in height. The design will not have a battery so that it can be stored on board the airplane.

III. PRELIMINARY DESIGNS

A. Design 1: Compact Scissor Lift

Our first design would consist of a cushioned chair that is attached to a scissor lift mechanism beneath it. When collapsed down, this entire device would ideally sit in the cushion space of the client's current wheelchair, without changing the height at which he is seated. Once at the gate, this device would be lifted with the client in the chair and placed on the ground, where a worker would use a crank mechanism to raise the client to a height just above the height of the airline seats.

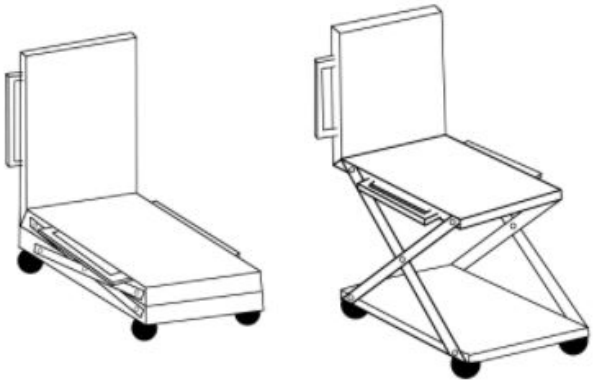

Figure 4: Compact Scissor Lift. The left shows the scissor lift in the collapsed position, which would sit on the client's chair. Once placed on the ground, the lift would be raised where it could then function as an aisle chair and be brought down the aisle

B. Design 2: Two Piece Scissor Lift

Our second design would be very similar to the compact scissor lift in function, however in this design the chair portion and structural scissor lift portion would be completely detachable. The chair portion would sit on top of the client's current wheelchair, while the structure would be collapsed and placed in the back of the wheelchair. Once at the gate, the structural portion would be brought around, expanded, and the client, while sitting on the secondary chair, be lifted on top of the scissor lift. These two portions would have a mechanical attachment point. This two-piece design would prevent an airline worker from having to crank up the full weight of the client, however, this also creates the hazard of a lifting transfer that requires attaching mechanical pieces.

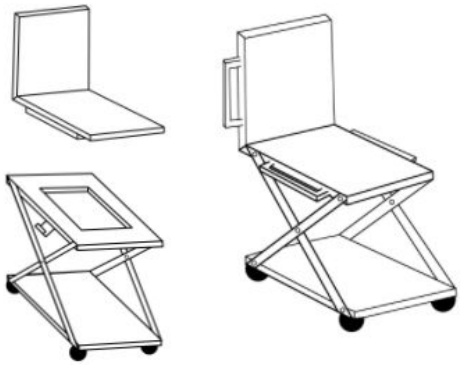

Figure 5: Two-Piece Scissor Lift. The left image shows how the chair portion and structural scissor lift portion would be detachable, and the right image when attached, which would function in the same way as Design 1.

C. Design 3: Rigid Chair with Folding Back Wheels

This design would consist of a rigid chair structure with back wheels that fold toward the front of the device and sit in a grove underneath the main seat. This would allow for the secondary chair to be pushed off of/pulled back onto the current wheelchair, ideally with minimal effort. Tracks would be build onto the current wheelchair to assist in this process, and fold-in bracing structures would also be built into the legs of the secondary chair. This device would completely eliminate two transfers in the onboarding/offboarding process, and the client would essentially be able to sit in the same chair all the way through the airport until he needs to be moved to his actual seat on the airplane.

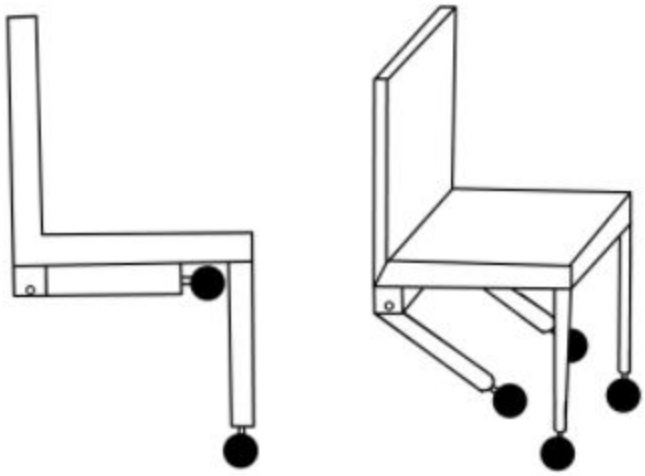

Figure 6: Foldable Rear Wheels. The left image displays how the chair would fit over the client's current wheelchair, while the right image shows how the back legs would swing down and lock into place after pushing it forward, off of the current chair.

D. Design 4: Eagle Lift Variations

The Eagle Lift is a design used by New Zealand airlines. It has a sling that fits over the passenger's wheelchair and eliminates the need for attendants to transfer the passenger. The

device takes the passenger directly from the wheelchair into their seat. We had several designs that mimicked this device, however it required an over-arching device that would be too large and too difficult to fabricate.

Figure 7: Eagle lift. A device used by New Zealand airlines to transfer disabled passengers. It has a sling where the passenger sits and an arch to move the sling down the aisle.

IV. PRELIMINARY DESIGN EVALUATION

A. Design Matrix

	Design 1 (Scissor Lift One Piece)		Design 2 (Scissor Lift Two Piece)		Design 3 (Folding Rear Wheels)	
Strength (25)	20	4/5	20	4/5	10	2/5
Size (10)	6	3/5	8	4/5	4	2/5
Cost (15)	9	3/5	9	3/5	12	4/5
Stowability (5)	4	4/5	5	5/5	2	2/5
Comfort (10)	4	2/5	6	3/5	8	4/5
Ease of Use (15)	9	3/5	9	3/5	15	5/5
Manufacturability (20)	18	2/5	18	2/5	16	4/5
Total (100)	64		65		67	

Table 1: Design Matrix. Each design idea was rated based on weighted criteria for the project. The Folding Rear Wheels Design scored highest based off of these criteria.

B. Summary of Design Matrix

The three designs we evaluated as part of our design matrix were the one piece scissor lift, the two piece scissor lift, and the folding rear wheel designs. The eagle lift inspired design was not included in our design matrix because it was determined to be unrealistic to fabricate and overly bulky.

The criteria and weightings of the criteria are listed on the left side of the design matrix. These were developed through meeting with our client, as well as our own design and manufacturing concerns. Our most important criteria were strength and manufacturability.

C. Proposed Final Design

Our final design is the rigid chair with folding rear wheels. This design minimizes the risk of the client being dropped during a transfer, and is the simplest design to manufacture. The rigid chair uses the least material as well, keeping costs low. The main problem we predict to face with this design is stability, and making sure the chair is stable with the folding rear legs. Also, unlike the scissor lift designs, this design is not foldable and compact, making it more difficult to store.

V. REFERENCES

[1] (2012, June 29) *Aircraft Boarding Equipment* [Online] Available: https://www.faa.gov/documentlibrary/media/advisory_circular/150_5220_21c.pdf

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[6] American Institute for Research (1987 March 9) *Guidelines for Aircraft Boarding Chairs* [Online] Available: https://ntl.bts.gov/DOCS/T10.html

[7] FAA (2017, July 25). *Pack Safe*. [Online] Available: https://www.faa.gov/about/initiatives/hazmat_safety/

VI. APPENDIX

Product Design Specifications Document:

Secondary Mobility Device for Airline Travel

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Date of most recent update: October 9, 2017

Function:

Currently, airplane travel for disabled passengers is a very difficult and arduous process, involving multiple wheelchair transfers, the assistance of untrained airline workers, and multiple times and sites of possible injury or embarrassment. The current procedures in place are so inefficient and tedious that many wheelchair-bound people refrain from flying at all. This procedure involves the lifting of the passenger from their wheelchair to a small, specially designed aisle wheelchair, and then another transfer from the aisle chair to the passenger's seat. This device will work to eliminate one of the two transfers that are currently required when moving a disabled passenger from the jetway, through the aisle, and to their seat.

Client requirements:

- Minimize number of transfers during boarding process (or identify other places to simplify disabled travel process in general throughout the entire airport ie. security checkpoint)
- Minimize the number of airline workers/outside help involved during transfers
- Some level of foldability/stowability for when device is not in use

Design requirements:

- Must keep within current FAA and U.S Access Board Guidelines for Aircraft Boarding Chairs (detailed below in Standards and Specifications section)
- Proper safety belts/harness must be in place
- Chair height should be approximately equivalent to height of airline seats

1. Physical and Operational Characteristics

a. Performance requirements:

Our device needs to be able to effectively roll and withstand the 250lbs weight of our client for up to multiple hours at a time. The device should be able to conveniently fold or condense to be stowed in a reasonable manner. This device will be used approximately three to four times a year, the approximate number of times the client flies per year.

b. Safety:

The structure of our device must be able to withstand a load of 300 lbs.t. It must have a factor of safety of 3.0 as well [8]. Safety straps will be necessary to hold the traveler in place in case of any accidental incorrect movements. The client prefers a lap belt to other types of straps.

c. Accuracy and Reliability:

It is critical that our design preform consistent with the needs of our client. Failure to consistently support upwards of 250 pounds and maintain our clients stability could result in undue attention to our client, and could injure him as well. This performance includes supporting his weight, maintaining its' balance, and allowing for easy transfers. The device must allow for an easy safe transfer during every use as well to prevent potential injury to the client.

d. Life in Service:

Our secondary device should maintain mechanical stability, and be able to traverse a variety of surfaces for extended length and time durations for as long as the client needs to use the device. This will typically include attaching it to his regular chair at home, traveling to the airport with it, and moving all the way to the gate with it where it will then detach and act separately from the primary wheelchair. The time used will vary depending on his distance traveled from home to the airport of departure and from the airport of arrival to his destination. This should be able to support our client for several hours.

e. Shelf Life:

The secondary device should maintain its' ability to withstand our client's weight over long periods without use. It should require minimal to no maintenance during periods without use. Ideally our device would be ready for use whenever our client requires it.

f. Operating Environment:

The secondary device should be able to support upwards of 250 pounds. It should be available for use predominantly in an indoor environment, while also having the ability to be used in the

outdoors as necessary. This requires it to maintain its stability when exposed to snow and rain, in addition to operating between the temperatures of 0 and 100 degrees fahrenheit. It should be able to move our client effectively on a variety of flooring surfaces including wood, tile, concrete, and carpeting.

g. Ergonomics:

It is important that the secondary device be comfortable for our our client to use over extended durations of travel. This comfort factor can include the use of similar seat padding, and a similar seat height to that of the client's wheelchair for comfort and to make transfers as easy as possible. The padding should be around 2 inches thick and the seat height should be between 18 and 21 inches [6]. The device should also incorporate at least 1 strap for our clients stability while being moved.

h. Size:

Based on the nature of our device, size is an important restriction. The design must be able to transit a variety of plane aisles. This requires that the device have a maximum width of 15 inches from the floor to a height of 25 inches, and a maximum width of 20 inches from 25 inches in height and taller. If we choose to make the device compact enough to be a carry on it should be able to compress down to be smaller than 9"x22"x14" [2] , [3].

i. Weight:

There are no restrictions on weight, as long as the device can be easily pushed or pulled by an adult of average strength with a passenger. The device also has to be light enough to be folded and stowed for when the device is not in use. However, the overall weight should be minimized in accordance with airline boarding chair regulations [8].

j. Materials:

Any materials may be used as long as the parts comply with FAA guidelines. The FAA currently prohibits assistive devices wheelchair devices that do not compress and that rely on batteries from being carry ons [7]. This device must comply with these regulations. We may try to make a device with no metal so the client can easily pass through security, but we are more likely going to use metal parts for a secondary wheelchair.

k. Aesthetics, Appearance, and Finish:

As of now the primary concern is constructing a device that fits the functional requirements. Aesthetics and appearance are less crucial as long as the device works. However, our client mentioned his favorite color is green and he likes the color of his current black wheelchair.

2. Production Characteristics

a. Quantity:

We are designing one unit for the client

b. Target Product Cost:

Our client gave us a relative budget of $500, but he mentioned that if we have a major breakthrough he would not mind us going over. The cost of a current airplane transfer chairs retail for anywhere from $86 to over $2000, so $500 should suffice.

3. Miscellaneous

a. Standards and Specifications:

FAA Operational Standards for Aircraft Boarding Chairs:

- Support passenger weighing 328 kg
- Equipped with braking level that stops all forward and backward movement
- Follow U.S Access Board Guidelines for Aircraft Boarding Chairs

U.S Access Board Guidelines for Aircraft Boarding Chairs:

- Seat height should match aircraft seat height, 43-48 cm
- Restraints securely support the torso, pelvis, knees and feet
- Footrests adjustable 41 to 74 cm from front of seat

b. Customer:

The customer's main concern is the transfers between wheelchairs, and would like us to focus on this issue to minimize transfers and the dangers that go along with them. Ideally, the client would like a device that goes over his existing wheelchair, which would reduce the number of transfers to two. If possible, he would like to a device that uses no metal, so that he can pass through metal detectors at security instead of being patted down. The very basics of what the customer wants is a device he owns that can be used on airplanes.

c. Patient-related concerns:

The device will be able to be cleaned easily, however does not need to be cleaned between uses.

d. Competition:

- The Karman Healthcare Airplane Aisle Chair sells for around $2,000. It is designed with detachable wheels that are 61 cm in diameter. When these wheels are detached, the width of the chair decreases to 35.5 cm. Smaller wheels attached to bottom of wheelchair are utilized when larger wheels are detached [1].
- The Columbia Medical Aislemaster Unfoldable Boarding Chair costs around $2,500. It has a width of 33 cm and features padded seat, backrest and headrest, as well as flip-up armrests for ease of transfer [4].
- The Columbia Medical Aislemaster TransportMate Compact Wheelchair was originally designed for an on-flight wheelchair under the 1986 Air Carrier Access Act. It collapses compactly to a height of 18 cm from an unfolded height of 85 cm. It has a width of 41 cm including the wheels [5].

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