



---

## Stair Chair

*Product Design Specifications (PDS)*

BME 200/300 Section 307

September 19, 2024

### **Client**

Mr. Daniel Kutschera

### **Advisor**

Dr. James Trevathan

### **Team**

Matt Sheridan	mjsheridan2@wisc.edu
Cody Kryzer	ckryzer@wisc.edu
Daniel Altschuler	daltschuler2@wisc.edu
Abi Conners	aconners2@wisc.edu
Luke Rosner	lrosner2@wisc.edu

## Function

The main function of this device is to transport non-weight-bearing patients both up and down an outdoor staircase consisting of 3 to 5 stairs. It should also allow for easy access into and out of the device for the patient. The device should be an inexpensive alternative to electric stair lift systems, as well as being resistant to conditions that come with Wisconsin winters. Additionally, the device should be light, but sturdy enough to withstand frequent use across eight to ten-week windows when patients are non-weight bearing.

## Client requirements

- The client requests a proof of concept for a mobile stair chair that non-weight bearing patients of his can use to travel up and down between 3 to 5 stairs
- The device should be free-standing to make the device accessible for patients that do not have sturdy rails leading up to their residences
- The device must be durable enough to withstand heavy use during eight to ten-week windows
- The device must be reusable once a patient no longer needs to use it to travel up and down stairs
- The chair must be able to swivel and support up to 140 kilograms
- Given the old age of some of the patients, the ratchet system should not require more mechanical power than an 80-year-old could output with one leg
- The chair must have a seat belt attachment to keep patients secure as they use the device

## Design requirements

### 1. Physical and Operational Characteristics

#### *a. Performance requirements*

The device will be used frequently during largely eight to ten-week spurts, but should also be able to withstand up to twenty-six weeks of frequent use for patients that remain non-weight-bearing for longer. The device should also be capable of holding up to 140 kg.

#### *b. Safety*

The chair should have an attached seat belt to keep patients from falling off during use. The device should also have stable legs that keep it from tipping over, as it will be a freestanding unit. A ratchet system will be used on the rails to prevent patients from accidentally sliding down five steps while attached to the device. The chair will also be able to be sanitized easily as it will be made from plastic. Given the originality of the idea, there are limited standards to be concerned with beyond [ISO 13485](#), the standard of quality for medical devices [1].

#### *c. Accuracy and Reliability*

The device should be able to ratchet up the stairs without enduring significant wear and tear that could render it unusable. The attached seat should swivel without much force, allowing a patient to twist the seat and get off of the chair once they have reached the top of the stairs.

#### *d. Life in Service*

The assisted stair chair is built with the assumption that it will be rented out by DME (durable medical equipment) rental companies. That being said, it will deteriorate from transport, installation, patient use, removal, and cleanings. Altogether the assisted stair chair can expect a lifetime of 5 years as compared with other DME [2].

#### *e. Shelf Life*

Due to the metal component of the assisted stair chair, the device should be stored in a dry, climate-controlled environment to prevent corrosion. Additionally, the device should be protected from high pH conditions, salt, and other corrosive materials.

#### *f. Operating Environment*

The assisted stair chair should be able to withstand routine weather conditions as well as tougher conditions. It should be able to withstand temperatures between -18°-52°C and should be able to function within the normal atmospheric pressure range between 751-767 mmHg [3]. Additionally, the assisted stair chair should be able to handle outdoor conditions such as dirt, snow, rain, humidity, and other common conditions.

#### *g. Ergonomics*

The stair chair should be accessible to a wide range of individuals, specifically those with limited strength in one leg. The force required to raise the chair should be feasible for all, meaning a force of 20 kg should be able to cause upward motion [4]. Additionally, the plate should be reachable for all users from a seated position, and getting onto and off of the chair should be seamless regardless of height.

#### *h. Size*

Staircases in Wisconsin must be at least 91.44 cm wide [5], so the stair chair should be able to accommodate staircases of that width and greater. This means that the product should be able to be installed and function within that 91.44 cm range without causing discomfort for the user. With a wider staircase, room should be made to the side of the product to allow for walking.

#### *i. Weight*

Because the individual will be propelling both themselves and the product up the staircase, the weight of the product should be minimized, with a maximum product weight being 30 kg. This maximum weight is adjustable if added weight allows for more mechanical advantage. An ideal weight is from 10-15 kg, and there is no concern with a minimum weight, as long as the product can withstand the performance requirements stated earlier. The track portion of the product does not have weight requirements.

#### *j. Materials*

The material for the chair portion should be a strong and durable yet relatively lightweight plastic, with metal included where needed to strengthen the product. The rails for the device will likely be made out of some aluminum alloy, given the material's high strength-to-weight ratio, excellent corrosion resistance, and high ductility that allows them to be shaped without damage to the material [6]. Additionally, a fabric cover could be included to keep the product out of the elements.

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

The finish on the product should be a texture that is not overly slippery to prevent injuries. As far as color, many stair lifts come in a cream, beige, or light gray color [7] to not draw attention to the product. A neutral color such as those will be the initial goal for the product but can be expanded on with additional time.

## **2. Production Characteristics**

### *a. Quantity*

Client is seeking a proof of concept item.

### *b. Target Product Cost*

Production cost will be determined once the feasibility of the product is determined through proof of concept.

## **3. Miscellaneous**

### *a. Standards and Specifications*

Standards are limited due to the novelty of the product. Related standards include:

- i. [ADA §405](#) - ADA Standards for ramps. [8]
- ii. [S. Hrg. 111-1138](#) - Hearing before the Senate Subcommittee on Employment and Workplace Safety of the Committee on Health, Education, Labor and Pensions - discusses patient lifting standards. [9]
- iii. [FDA CFR Title 21, Volume 8 §850.5150](#) - FDA standard on powered chair lifts. [10]
- iv. [ASME A18.1-2017](#) - American Society of Mechanical Engineers standard on safety for powered chair lifts. [11]
- v. [ISO 13485](#) - international standard on quality and safety of medical devices. [2]
- vi. [Premarket Notification 510\(k\)](#) - “A 510(K) is a premarket submission made to FDA to demonstrate that the device to be marketed is as safe and effective, that is, substantially equivalent, to a legally marketed device.” Premarket Notifications can only be used for Class I and II devices. There is no classification for our proposed device, however the powered chair lift is classified as a class II device. [12]

### *b. Customer*

The client intends to rent out the apparatus to patients at the Encompass Health Rehabilitation Hospital of Fitchburg. Patients are typically older people with short term mobility issues, most often with one usable leg.

### *c. Patient-related concerns*

Since the device is intended for short term use, comfort is not necessarily prioritized. Safety is important to address since patients are already dealing with injuries. The device should require little effort to use.

### *d. Competition*

Current solutions for ascending and descending stairs with a mobility issue include electric stair lifts, wheelchair lifts, wheelchair ramps, and elevators. The goal of this project is to provide a cheaper, temporary, and more practical

solution than these alternatives. Few stair assist devices exist that are portable, lightweight, and safe. One dubbed the “Step by Step” is another UW Madison BME design project that Daniel Kutschera was involved in [13].

## References

- [1] ISO, “ISO 13485 Medical devices,” ISO, 2016. <https://www.iso.org/iso-13485-medical-devices.html>
- [2] “Social Security Act §1834.” [https://www.ssa.gov/OP\\_Home/ssact/title18/1834.htm](https://www.ssa.gov/OP_Home/ssact/title18/1834.htm)
- [3] “Calibration & barometric pressure | Wisconsin DNR.” <https://dnr.wisconsin.gov/topic/labCert/BODCalibration2.html>
- [4] Diogo Luís Marques, Henrique Pereira Neiva, Daniel Almeida Marinho, Ivan Miguel Pires, C. Nunes, and Mário Cardoso Marques, “Load-power relationship in older adults: The influence of maximal mean and peak power values and their associations with lower and upper-limb functional capacity,” *Frontiers in Physiology*, vol. 13, Sep. 2022, doi: <https://doi.org/10.3389/fphys.2022.1007772>.
- [5] “Wisconsin Legislature: SPS 321.04(2)(d),” [docs.legis.wisconsin.gov](https://docs.legis.wisconsin.gov). [https://docs.legis.wisconsin.gov/code/admin\\_code/sps/safety\\_and\\_buildings\\_and\\_environment/320\\_325/321/ii/04/2/d](https://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/320_325/321/ii/04/2/d)
- [6] “Aluminum Alloy: Definition, Characteristics, Types, Properties, and Applications,” [www.xometry.com](http://www.xometry.com). <https://www.xometry.com/resources/materials/what-is-aluminum-alloy/#:~:text=Aluminum%20alloy%20has%20a%20high>
- [7] “Stairlift Features,” Silver Cross, Jun. 13, 2024. <https://silvercross.com/stair-lifts/stair-lift-features/#:~:text=Seat%20styles%20and%20colors> (accessed Sep. 18, 2024).
- [8] “U.S. Access Board - Chapter 4: Ramps and Curb Ramps,” [www.access-board.gov](http://www.access-board.gov). <https://www.access-board.gov/ada/guides/chapter-4-ramps-and-curb-ramps/>
- [9] “- SAFE PATIENT HANDLING AND LIFTING STANDARDS FOR A SAFER AMERICAN WORKFORCE,” [www.govinfo.gov](http://www.govinfo.gov). <https://www.govinfo.gov/content/pkg/CHRG-111shrg76035/html/CHRG-111shrg76035.htm>
- [10] “CFR - Code of Federal Regulations Title 21,” [www.accessdata.fda.gov](http://www.accessdata.fda.gov). <https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=890.5150>
- [11] “A18.1 Safety Standard for Platform Lifts & Stairway Chairlifts - ASME,” [www.asme.org](http://www.asme.org). <https://www.asme.org/codes-standards/find-codes-standards/a18-1-safety-standard-platform-lifts-stairway-chairlifts>
- [12] FDA, “Premarket Notification 510(k),” FDA, Nov. 30, 2021. <https://www.fda.gov/medical-devices/premarket-submissions-selecting-and-preparing-correct-submission/premarket-notification-510k>
- [13] “Step by Step: A comprehensive approach to stair climbing assistance,” Wisc.edu, 2023. [https://bmedesign.engr.wisc.edu/projects/f23/stair\\_assist\\_bench](https://bmedesign.engr.wisc.edu/projects/f23/stair_assist_bench) (accessed Sep. 18, 2024).