

Open Mobility

*A Modular Manual Wheelchair Designed for
Local Repair and Global Access*

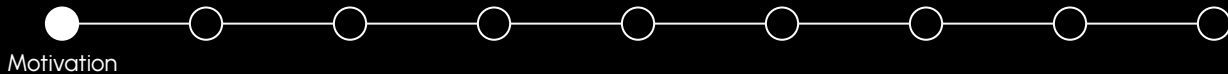
Student Team Members: Michael Cerny, Anna Morrison, Aydan Kloiber, Aidan Lareau,
Christopher Shih, Daniela Broad.



Faculty Advisor: Professor Jack Price

All models/renderers by Christopher Shih unless otherwise stated. External assets obtained from grabcad.com and mcmaster.com and used with permission.

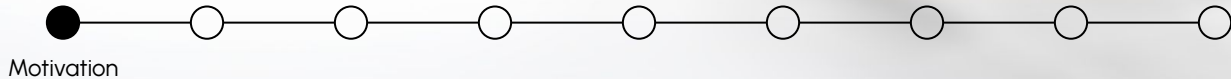
Develop an open-source, modular wheelchair, using bicycle parts and basic hardware, that can be built, adjusted, and repaired locally.



Modular

/ 'mä-jə-lər / adjective

- 1: of, relating to, or based on a module or a modulus.
- 2: constructed with standardized units or dimensions for **flexibility** and **variety in use**.



We are in a **Global** Wheelchair Crisis

Wheelchairs are essential for basic independence.

- 80 million people worldwide need wheelchairs [1].
 - Only 5-35% of those people have access to one, with low-income countries disproportionately affected [2].

Wheelchairs can be a significant economic burden.

- \$100 to \$2000+ [3]
- Over half of surveyed users experienced component failure in a 6-month period. [4]

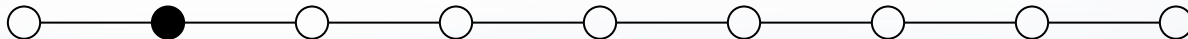


[1] World Health Organization, International Society for Prosthetics and Orthotics, and International Society of Wheelchair Professionals, Eds., Wheelchair provision guidelines. Geneva: World Health Organization, 2023.

[2] W. Zhang, A. H. Eide, W. Pryor, C. Khasnabis, and J. Borg, "Measuring Self-Reported Access to Assistive Technology Using the WHO Rapid Assistive Technology Assessment (rATA) Questionnaire: Protocol for a Multi-Country Study," *Int. J. Environ. Res. Public Health*, vol. 18, no. 24, p. 13336, Dec. 2021, doi: 10.3390/ijerph182413336.

[3] "How Much Does A Wheelchair Cost?," *BraunAbility*. Accessed May 21, 2025. [Online]. Available: <https://www.braunability.com/us/en/blog/accessibility-living/how-much-does-a-wheelchair-cost.html>

[4] L. A. Worobey et al., "Wheelchair Repairs: Delays, Causes, and Associated Outcomes," *Arch. Phys. Med. Rehabil.*, vol. 106, no. 3, pp. 379-386, Mar. 2025, doi: 10.1016/j.apmr.2024.10.001.



Why Bicycles?

Designing a wheelchair from bicycle parts transforms maintenance from a specialized service to a local capability, empowering communities to pursue mobility independence.

1

Worldwide Availability

Bicycles and shops can be found worldwide [5]

2

Standardized Parts

Standardization of part fittings allows for ease of repair and modularity.

3

Repairability

Our wheelchair can be repaired wherever there is a bike shop.

4

Cost Efficiency

Bike parts are usually significantly cheaper than wheelchair parts [6]

[5] O. Oke, K. Bhalla, D. C. Love, and S. Siddiqui, "Tracking global bicycle ownership patterns," *Journal of Transport & Health*, vol. 2, no. 4, pp. 490–501, Dec. 2015, doi:<https://doi.org/10.1016/j.jth.2015.08.006>

[6] "SafariSeat." Accessed May 21, 2025. [Online]. Available: <https://trango.com/safari-seat/>



There are Existing **Open-Source** Solutions

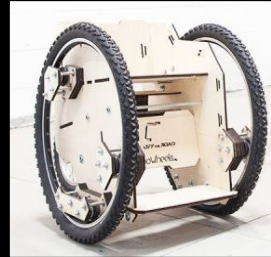
What have they accomplished, and what are they missing?

1: SafariSeat



All terrain chair for use in rural environments.
Open source, relying on bicycle parts and simple tools [6].
Lacks modularity

2: TooWheels



CAD-based, customizable design.
Fabricated with standard tubing and shop tools.
More focused on indoor, sporting use [7].

3: OSW



Variety of DIY, high-performance wheelchairs
Built with widely available materials and basic tools [8].
Limited scalability

[6] "SafariSeat." Accessed: May 21, 2025. [Online]. Available: <https://t.me/s/safariseat/>

[7] "toowheels." toowheels | la carrozzina sportiva che puoi costruirti da solo, 2025. <https://toowheels.org/>

[8] "Open Source Wheelchairs." Open Source Wheelchairs, 2024. <https://www.opensourcewheelchairs.org/open-source-wheelchairs> (accessed May 27, 2025).



Key Design Requirements

1

Modular design for assembly without the need for specialty tools

Reason: Ease of repair, maintenance, customization

Test: Perform assembly/disassembly tests using standard tools

2

Support user weight of up to 120kg with a 1.5x safety factor

Reason: Cover a broad user base, based on existing solutions [9]

Test: Perform SolidWorks simulations to evaluate deformation and yield. Include safety factor calculations

3

Mobility across various terrain types

Reason: Cover a broad range of environments (tile flooring, low-pile carpet, concrete, and cobblestones)

Test: Evaluate turning radius [10], propulsion effort, and time to complete a 10m course on the specified surfaces

[9] "Wheelchair Weight Limit," Redman Power Chair. Accessed: Jun. 16, 2025. [Online]. Available: <https://www.redmanpowerchair.com/do-wheelchairs-have-a-weight-limit/#~:text=Basic%20wheelchairs%20have%20weight%20limits.can%20find%20the%20right%20wheelchair>
[10] "ISO 7176-1:2014," ISO. Accessed: May 28, 2025. [Online]. Available: <https://www.iso.org/standard/56817.html>



Trade Studies for Design Direction

Design Direction	Cost Efficiency	Modularity	Component Availability	Ease of Assembly	Ease of Repairs	Durability	Total
Mount bicycle assembly to a frame built with regional materials.	3	4	5	5	5	4	4.3
Modular frame built with an axle for bicycle wheels imbedded into the frame.	4	5	5	3	4	3	4.2
Welded frame using bike tubing.	2	2	5	2	1	5	2.6
Weight	20%	25%	15%	10%	20%	10%	100%

Frame Material	Cost Efficiency	Strength	Material Availability	Ease of Assembly	Weight	Durability	Total
Wood	5	4	5	5	2	3	4
80/20 Aluminum	2	5	3	5	4	5	3.8
PVC	3	2	2	4	4	4	3.1
Weight	25%	20%	15%	10%	20%	10%	100%

[1] D. E. Kretschmann, "Mechanical Properties of Wood".

[2] "Overview of materials for High Carbon Steel." Accessed: Jun. 18, 2025. [Online]. Available:

https://www.matweb.com/search/datasheet_print.aspx?matguid=ee25302df4b34404b21ad67f8a83

[3] "PVC Properties." Vinidex Pty Ltd. Accessed: Jun. 18, 2025. [Online]. Available:

<https://www.vinidex.com.au/technical-resources/material-properties/pvc-properties/>

[4] "HPM® 80/20 AL| Hamilton Precision Metals." Accessed: Jun. 18, 2025. [Online]. Available:

<https://www.hpmetals.com/products/materials/nickel-strip-foil/www.hpmetals.com/products/materials/nickel-strip-foil/hpm-80-20-al>



Material Selection

What are the tradeoffs for using different frame materials?

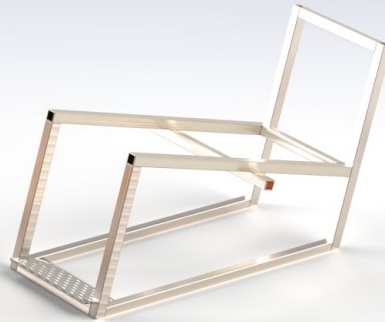
1: Wood

Pros: Available, low-cost, simple to install
Cons: Less strength and environmental resistance



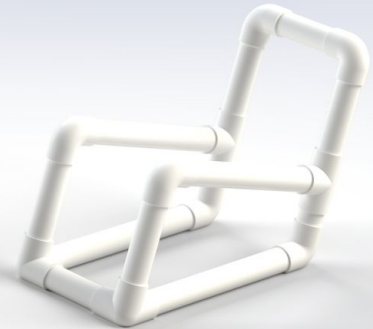
2: 80:20 Aluminum

Pros: High strength-weight ratio, durable
Cons: Less available, less cost-effective



3: PVC

Pros: Lightweight, simple to assemble, inert
Cons: Lower strength, poor heat performance



Propulsion Solution

How can we accommodate various degrees of mobility using modularity?

1: Pushrims

For maximum mobility



2: Levers

For assisted mobility



3: Handlebars

For full assistance



Design Implementation

1

Original CAD Model



2

Bike Parts



3

Rough Wood Frame



4

WIP Mounting Solution



Design Implementation, Cont.

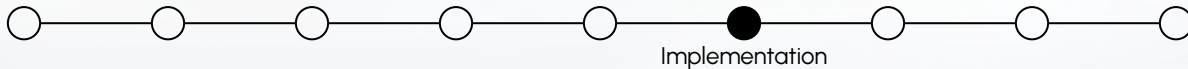
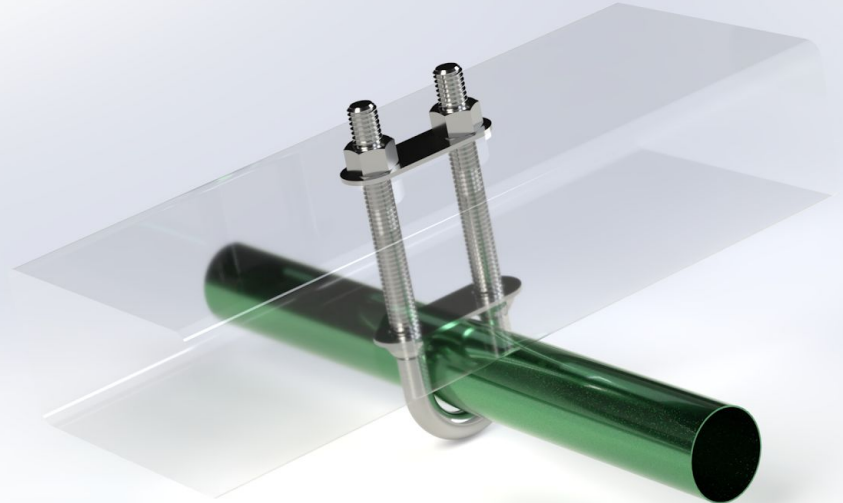
How can we attach our frame to bike parts without welding?

Design challenge: non-destructively integrating the wooden frame with metal bicycle components.

- Bike tubing is non-cylindrical and irregularly shaped.
- Significant slipping and rotation under load.

Our Solution: Structural struts run beneath the wooden frame, attaching at three strategic contact points. Rubber-lined U-bolts secure the contact.

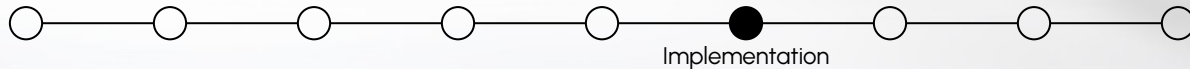
- Three points of contact resists both translation and rotation.
- Rubber lining conforms to irregular geometry



Further Implementation

Our build steps in the near future.

- 1: Receive materials and complete the first prototype frame (footrest, backrest, third U-bolt strut).
- 2: Attach front caster wheels, pushrims, brakes, and seat cushion.
- 3: Rebuild with what we've learned building the first prototype.
- 4: Test the final prototype and corresponding CAD model.



Testing Procedure

SolidWorks Simulation

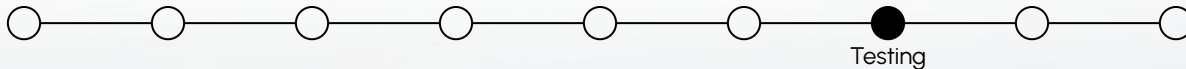
- **Static Load:** 1764 N (120 kg user × SF 1.5) applied to seat/backrest
 - Pass Criteria: Stress < yield strength, FOS ≥ 1.0, deflection ≤ 10 mm [16]
- **Fatigue Analysis:** 200,000 rolling + 6,666 curb drop cycles (ISO 7176) [17]
 - Pass Criteria: Predicted life > required cycles using S-N curve data
- **Anthropometric Variability:** Test at 5th, 50th, and 95th percentile adjustments
 - Pass Criteria: Safety maintained across all user configurations



[15] "Lode Esseda Wheelchair Ergometer | Cranlea" Accessed: Feb 16, 2026. [Online]. Available: <https://www.cranlea.co.uk/product/lode-esseda-wheelchair-ergometer/>

[16] "Wheelchair Weight Limit." Accessed: Jun 18, 2025. [Online]. Available: <https://www.redmanpowerchair.com/do-wheelchairs-have-a-weight-limit>

[17] "ISO 7176-1:2014." ISO. Accessed: May 28, 2025. [Online]. Available: <https://www.iso.org/standard/55617.html>



Physical and Functional Testing

Stability Testing

- 15° incline with 120 kg load, brakes engaged for 10 min [17]
- **Pass:** No tipping or sliding

Modularity Verification

- Independent tester can assemble with written instructions, without power tools
- **Pass:** Successful assembly without damage

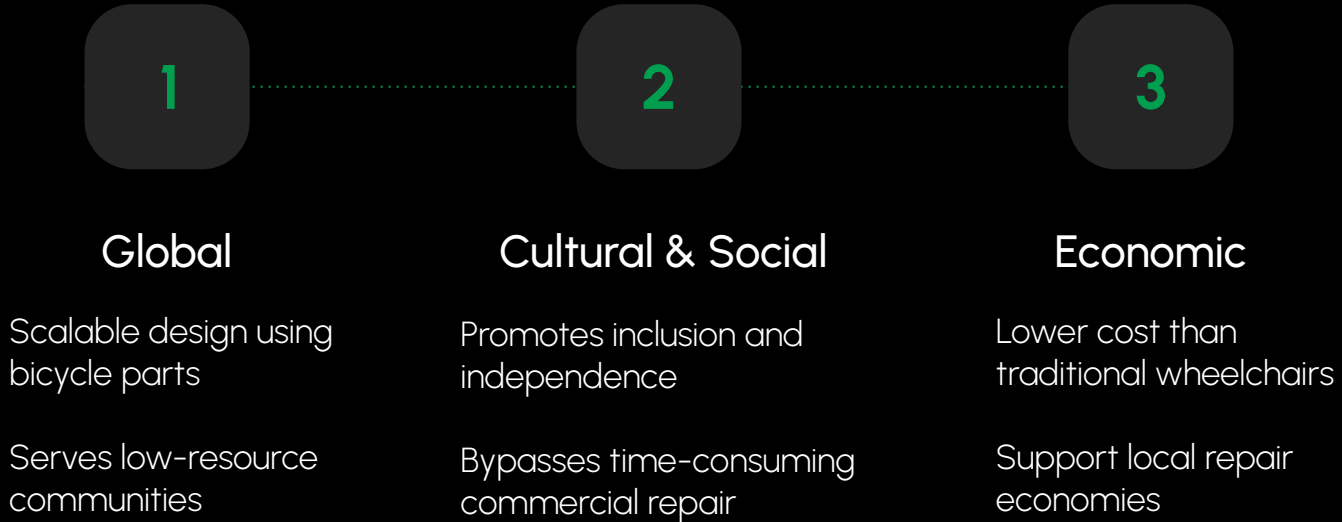
Environmental Resistance

- 15 min simulated rain exposure
- **Pass:** No swelling, corrosion, or joint degradation

Terrain Maneuverability

- Test surfaces: tile, carpet, concrete, compact dirt, cobblestone
- **Pass:** No immobilization or structural instability, intact turning radius

How Our Design Creates Change



What Should You Take Away?

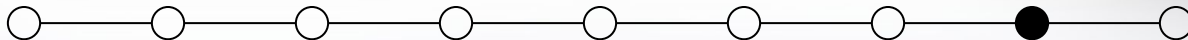
Current wheelchair options are limited worldwide.

- Not repairable by user
- Unaffordable prices

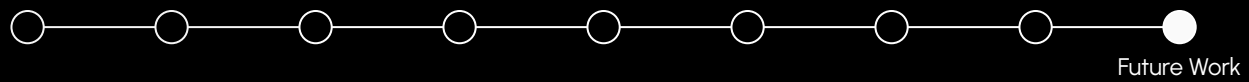
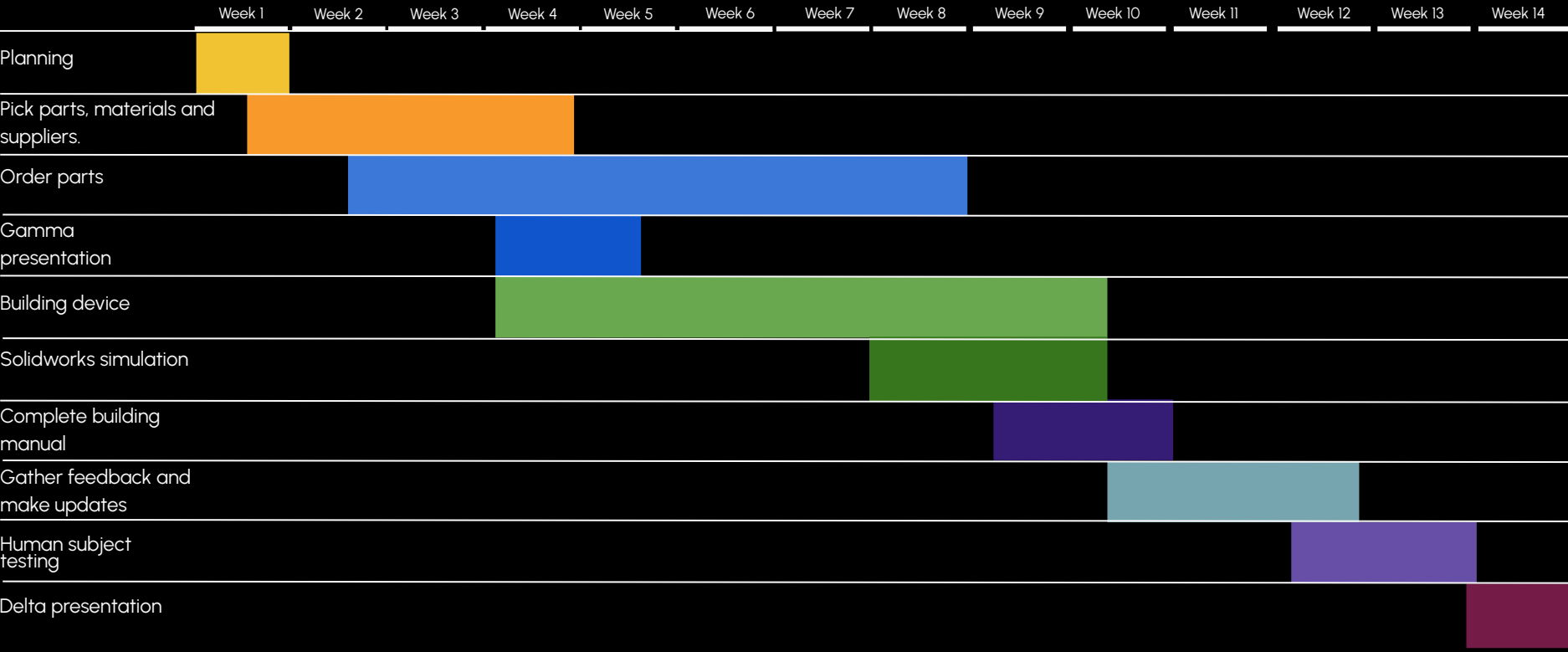
Individuals need individualized means of addressing mobility impairments.

- Bicycle shops and basic hardware stores are found worldwide.

Open-source, customizable instructions will allow communities to care for those in need, and enhance disabled individuals' community engagement.



Capstone 2 Timeline



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