User and Product Manual Instructions

This manual serves as a comprehensive guide for operating, maintaining, and potentially improving the Equi cycle. Whether you're a client looking to enhance the prototype, troubleshoot issues, or a different team aiming to create a sturdier version, this document is designed to be easily comprehensible even for non-engineers. We've prioritized clarity by incorporating plenty of images and diagrams to facilitate understanding. Think of this manual as your sole resource for all things Equi cycle – from initial setup to ongoing maintenance. Should you need to introduce a new feature, rest assured, we'll provide you with the necessary knowledge and guidance.

GNG5140

Design Project User and Product Manual

THE EQUIBIKE

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1. Introduction

The User and Product Manual (UPM) for the Equibike serves as a crucial guide for both wheelchair users and their assistants, ensuring the effective and safe utilization of this transportation prototype. Beginning with an introduction emphasizing the importance of following instructions for safety, the manual provides a detailed description of the Equibike's design and features, highlighting its role in facilitating wheelchair transportation. Safety guidelines are meticulously outlined, covering loading procedures, wheelchair securing, and safe handling during transit. Operating instructions offer step-by-step guidance for both the wheelchair user and the assistant, detailing loading processes, carriage securing, and transportation initiation. Maintenance and care instructions are provided for the upkeep of the Equibike, including routine tasks and troubleshooting tips. In case of emergencies, users are equipped with procedures to respond effectively, ensuring the well-being of all involved. Contact information for technical support or inquiries is included, ensuring users have access to assistance when needed. Through comprehensive understanding and adherence to the UPM, both users and assistants can guarantee the safe and efficient use of the Equibike, fostering a reliable and satisfying transportation experience.

2. Overview

Our product endeavors to make the joys of cycling accessible to individuals with physical limitations who may otherwise be unable to partake in this rewarding experience. By alleviating the concerns associated with traditional bicycle riding, our solution offers a safe, user-friendly, and durable alternative. Designed with the user's comfort and convenience in mind, our product empowers individuals with physical limitations to embrace the exhilaration of cycling without the need to focus on maneuvering the bicycle itself.

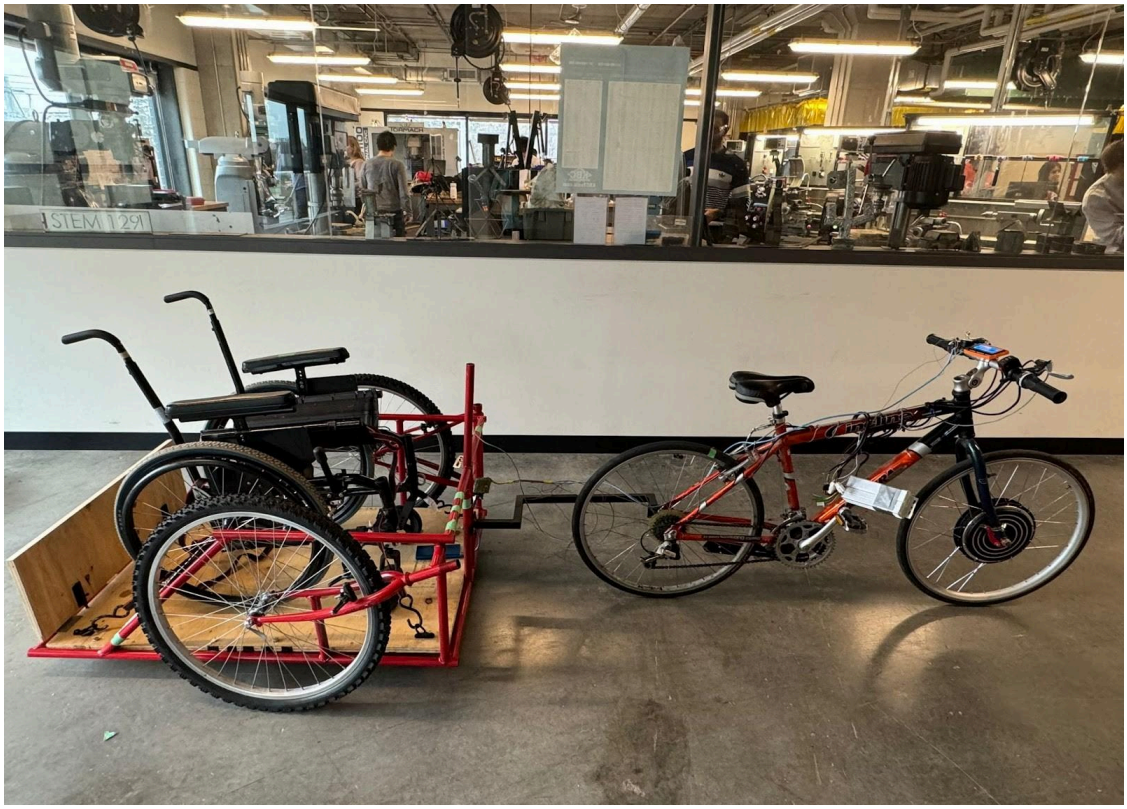

Figure 1. The Equicycle

Utilizing our product is a straightforward process: the user effortlessly rolls onto the platform and is securely fastened with straps for stability. The

assistant then attaches the platform to the bicycle and ensures it is properly secured, after which they are ready to embark on their journey. Constructed initially with hollow steel tubing, wooden platforms, and bicycle wheels, our prototype evolves into its final iteration featuring hollow steel tubing, a steel platform, and two premium-quality wheels. One additional safety feature added is the integration of electronic communication and indication systems for safe riding on the roads. Engineered for use on light terrain, particularly cycling trails with minimal obstacles, our product's design prioritizes maneuverability and ease of use, enhancing the overall cycling experience for individuals with physical limitations. Absence of safety systems and measures which is of utmost importance while riding on the streets and lack of forms of communication between user and driver. Two extra safety systems are implemented, Safety system- Controls for the turn lights located on the ends of cart and brake switch for enabling the brake lights when needed and Communication system- A simple communication system using LCD and push buttons for communication between the user and driver. Implementation of a safety system which comprises turn and brake lights. Implementation of a communication system which enables the user to communicate with the driver. Developing highly efficient working and easy to handle safety and communication systems. Development of the electronics from scratch using already available components at minimal and zero costs. Minimal investment of money and a cost-effective system.

Usage of discarded ethernet cables for wire connections minimizing costs and taking a step towards sustainability. Easy and cheap replacement of faulty components. The following is the architecture of the electronic system: A microcontroller is connected to the safety system and the COM system, The safety system comprises of the turn lights, brake lights and

switches, The COM system comprises of LCD display and push buttons, The controller is powered by an external power source of 5V.

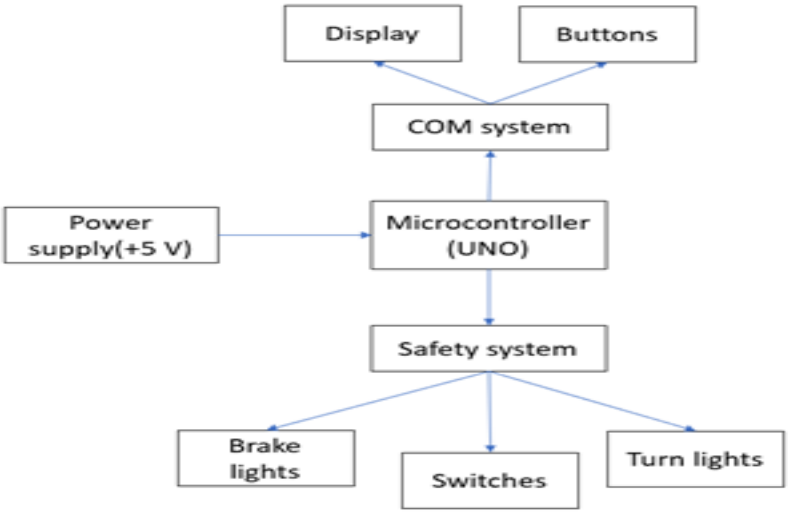

Figure 2. Electronic Workflow

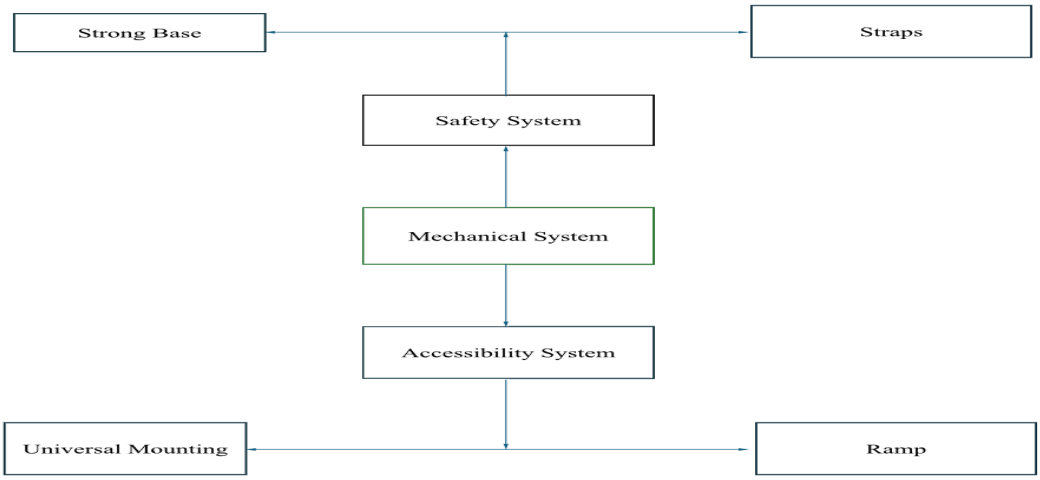

Figure 3. Mechanical Workflow

2.1. Conventions

- Ensure means to check condition(s) or make certain that (something) shall occur.
- Do not/don't mean not to do.

2.2. Cautions & Warnings

- Do not allow persons under 18 to operate the product
- Do not operate when under the influence of drugs or alcohol
- Always wear safety riding equipment
- Ensure the ramp is firmly locked
- Ensure that all straps are secured before usage
- Ensure that the attachment to the bicycle is secure before usage
- Ensure that the brakes are in working order.
- Ensure electronics are Safely Mounted
- Ensure that power source is less than 5V

3. Getting started

3.1. System Initialization

- Mechanical System
    - Check all the components of the carriage are firmly tightened
    - Check all the components of the Bike are firmly tightened
    - Mount the mount on the carriage at specific height as per the size of the bike
    - Tighten the nut and bolts for firm connection of mount and carriage
    - Connect the mount to the axle of the bike and fix the bolt firmly
    - Lower the ramp and move the wheelchair on the carriage
    - Position the wheelchair properly and secure it with straps
    - Raise the Ramp and fix it in vertical position using toggle clamp

Figure 4. Ramp Down

Figure 5. Ramp Up

Figure 6. Full Assembly

- Electrical System
    - Attach the mount to the required height at the front of the carriage using the details provided.
    - Un-bolt the ramp at the back of the carriage and lay the ramp on the floor.
    - Roll the wheelchair user onto the carriage and using the straps and hooks provided, strap the user to secure them on the floor of the carriage.
    - Close the ramp and re-bolt it to the floor.
    - Remove the end-nut from the left side of the bike.
    - Insert the mount flange into the rear axle.
    - Re-bolt the end-nut tightly.
    - All the electrical systems will be pre-assembled on the vehicle. If the user wishes to switch to another cycle, then remove the LCD and the switches from the casing and transfer the system along with the wires onto another bike.
    - The microcontroller stays on the carriage and if a replacement of the power source is needed just unplug the cable connected to the Arduino.

Figure 7. Communication System

Figure 8. Indication System

3.2. Set-up Considerations

Please ensure that any wheelchair utilized adheres to the 150kg weight limit, accounting for both the wheelchair itself and its user. Bikes within the rear wheel size range of 24 in to 29in are suitable for use. Prior to operation, verify that the electronic components are powered on correctly. Below is a block diagram providing an overview and concise explanation of both the Mechanical and Electronic Systems.

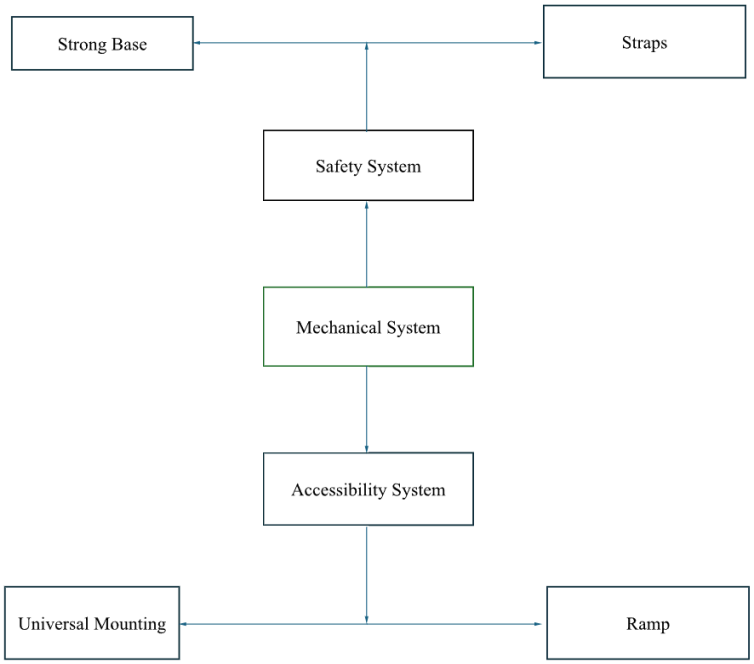

Figure 9. Mechanical System

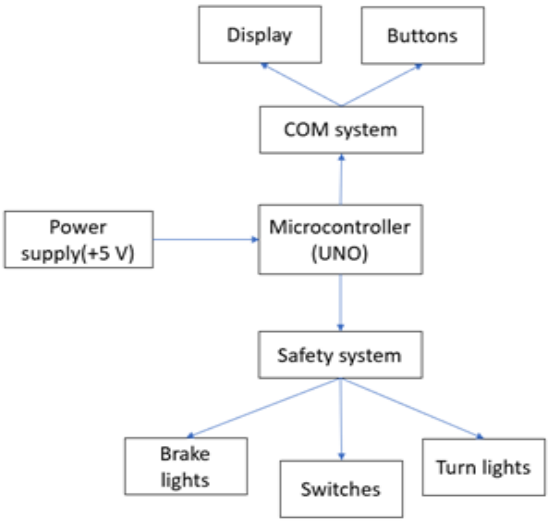

Figure 10. Electronic System

3.3. User Access Considerations

There are two different users of the product. The first user will be the bike rider and the second user will be the wheelchair user. The bike rider will be the one who rolls wheelchair users onto the carriage and straps them in place. The rider has to first assemble the bike and carriage together and check if they are firmly attached together. The rider has to check if the wheelchair is mounted properly.

3.4. Accessing the System

Ensure all the wirings are not getting crisscrossed and getting in contact with the chain or pedals. The power source must be plugged into the Arduino using the mentioned Arduino cable to turn on the system. Ensure the source such as a power bank has

enough charge to power the system. Ensure that all the tires of the carriage and the bike are adequately filled with air. Attach the mount to the front of the carriage and the rear of the bike securely. See to it that the wheelchair user is strapped in correctly.

3.5. System Organization & Navigation

The LCD comprising the COM system and the switches panel are located at the front of the bike handle and the brake switch is attached to the brakes present on the right side of the bike. LED strips are present on the rear end of the carriage on either end. The push buttons panel for the COM system is present in the carriage's front end above the microcontroller and power source equipment.

3.6. Exiting the System

- Remove the end-nut
- Remove the flange from the rear axle of the bike.
- Re-attach the end-nut to the bike.
- Un-bolt the ramp from the floor and lay the ramp flat on the floor.
- Un strap the user from the 4 straps and roll them off the carriage using the ramp.
- Re-bolt the ramp in its upright state.
- Remove the nuts and bolts from the mount and separate the mount from the carriage.

- Store the mount safely for future use.
- Unplug the power source from the Arduino.

4. Using the System

4.1. Electrical System

4.1.1. Safety System-

- The features are- Turn lights and brakes
- Description-
    - Slider switches- There are two slider switches at the front on one side of the bike handle. The two switches are positioned in such a way that the left switch is at the top and the right switch is below.
    - Brake switch- There is a brake switch attached to the one end of the right brake at the front.
    - LED strips- There are two LED strips at the back of the carriage which function as both brake lights (red luminance) and turn lights (yellow luminance).
- Usage-
    - Slider switches and brake switch- When we slide the switch from one end to the other, say for example the top switch (left indicator), the LED strip on the left starts blinking and to turn off the lights slide the

same back again to its original position. The same procedure applies for the left switch. When the right-side brakes are pressed the switch which was initially pressed gets released and both the rear end strips glow red turning on the brake lights.

4.1.2. COM System

- The features are- - LCD and buttons
- Description-
    - LCD- There is an LCD at the front in the middle of the bike handle which displays messages on the screen. The messages are displayed only when the buttons are pressed.
    - Push buttons panel- The push buttons panel is located at the carriage s front and firmly held in place with the help of a casing.
- Usage-
    - There are four push buttons which convey basic messages as a form of communication to the driver. When one of the buttons is firmly pressed messages are instantly displayed on the LCD.

4.2. Mechanical System

4.2.1. Mount Sub-system

- Description-

- The mount subsystem consists of the mount which is a piece made from steel square pipes and steel plates welded together to form a solid piece which joins the carriage and the bike with each other enabling the bike to pull the carriage and the wheelchair user sitting inside it.

- Usage-
  - The mount comes with 2 pairs of nuts, washers and bolts. Insert 2 bolts and the washers through the larger of the plates and slip the bolts through the holes provided in the frame of the carriage and tighten them using the nuts provided using a wrench.

Figure 11. Mount manufacturing

4.2.2. Strapping system

- To secure the wheelchair on the platform, the Husky 1-inch x 12-feet Ratchet Tie-Down straps were used with a working load limit of 500 lbs.
- https://www.homedepot.ca/product/husky-1-inch-x-12-ft-ratchet-tie-down-4-pack-/1001031415

Figure 12. strap

- Take a pair of straps and secure their hook ends on the left and right anchors for the front wheels and rear wheels of the wheelchair accordingly. The straps should pass through the lowest points of the wheels to provide the tightest fit possible. If the gaps in the wheels are too small to fit the ratchet end of the strap, pass the hook part of the strap from the inner side of the wheel in the direction of the anchor to be used or secure the straps over the metal frame of the wheelchair.

- Steps for Strapping
    - To secure straps in a tight position follow these steps.
    - Thread the webbing into the slotted spool
    - Adjust the webbing length
    - Lift and lower the ratchet handle to tighten the straps to the desired degree of tightness. At that moment, the wheels should be firmly held on the floor of the trailer.
    - Lock the ratchet.

Figure 13. Strapping Step 1

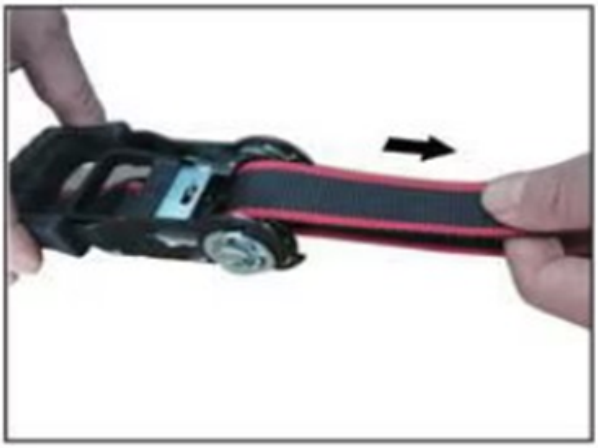

Figure14. Strapping Step 2

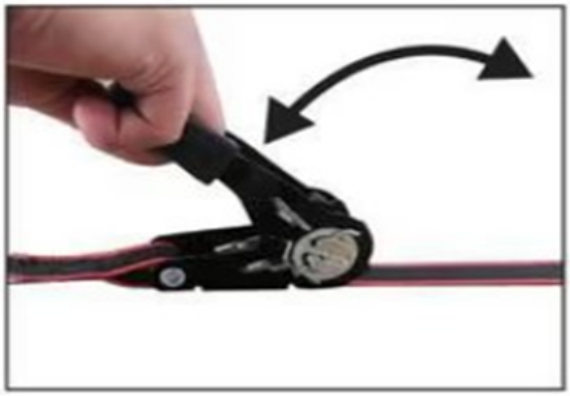

Figure 15. Strapping Step 3

Figure 16. Strapping Step 4

- Steps for Unstrapping
    - The system can be released after the bike with the trailer comes to a full stop and the user wants to unmount the wheelchair from the trailer. To release the straps, one should follow these steps:
    - Pull back on release tab
    - Unlock the ratchet
    - Pull out the webbing

Figure 17. Unstrapping Step 1

Figure 18. Unstrapping Step 2

Figure 19. Unstrapping Step 3

5. Troubleshooting & Support

5.1. Error Messages or Behavior

- At times, too much webbing can be wound on the spool of the ratchet that might lead to the webbing to be stuck. Try to avoid the situation by adjusting the webbing to a tight position before tightening it with the ratchet. If excess amount was still wound and the webbing got stuck in the ratchet, bring the ratchet to an unlocked position and gradually free the excess amount of the webbing on the spool, then pull it out of the ratchet.

5.2. Maintenance

- Air must be regularly filled in the two tires on the carriage. The user must also ensure that all the wires in the electrical system are operating properly.

5.3. Support

5.3.1. Electrical Support

- If there are any issues and support is needed regarding the electrical system then contact Raghav Kaushik at rvaga070@uottawa.ca. If any components are found to have stopped working then contact the Makerspace Lab located at STEM, UOttawa for help regarding resources and support. Issues may include disconnection of wires, Arduino issues, faulty components, power issues, etc.

5.3.2. Mechanical Support

- If there is any issue regarding the mount or the floor or the ramp, immediately notify Gaurang Lele at glele049@uottawa.ca. Issues may include cracks in the wooden floor and ramp, cracks in the mount and carriage welds, paint peeling off the mount and the carriage, bending of mount flanges, etc.

6. Product Documentation

6.1. Mount

- The mount was designed taking into consideration that a maximum load of 1500N would be exerted in the longitudinal direction (tension-compression) along the length of the mount. Another design consideration was the bending force that will act primarily on the flanges with a load of 800N.

6.1.1. Design Iterations

- Several design iterations of the mount were tested based on different use cases. Earlier versions of the mount included 2 arms from the bike to the carriage for added stability. It was later found that commonly used bikes have space to attach the flange of the mount on only one side of the rear axle and hence, the design was changed to a single sided design.

6.1.2. BOM (Bill of Materials)

Item	Quantity	Need	Cost	Link
1/4th inch thick steel plate	2	To attach the square rods to the bike and the carriage.	8$	https://quote.metalpros.com/?search=&shape=SHEET%2F%20PLATE&size=0.250&material=HOT%20ROLLED%20STEEL&grade=

1in x 1in cold-rolled steel square hollow pipes with 0.065in thickness	1 x 4in 1 x 19in 1 x 5in 1 x 8in	To create the attachment.	19.14$	https://quote.metalpros.com/?search=&shape=RECT%2F%20SQUARE%20TUBE&size=1.000x1.000x0.065&material=HOT%20ROLLED%20STEEL

6.1.3. Equipment list

- MIG Welding available at STM 129 (Brunsfield Centre)

6.1.4. Instructions

- The mount system consists of 4 1in x 1in cold-rolled steel square hollow pipes that were welded together in a particular pattern. 2 1/4th in thick hot-rolled steel plates were attached to the ends of the pipes to connect them to the carriage and the bike.
- Acquire the pipes and plates of the required lengths, widths and thicknesses.

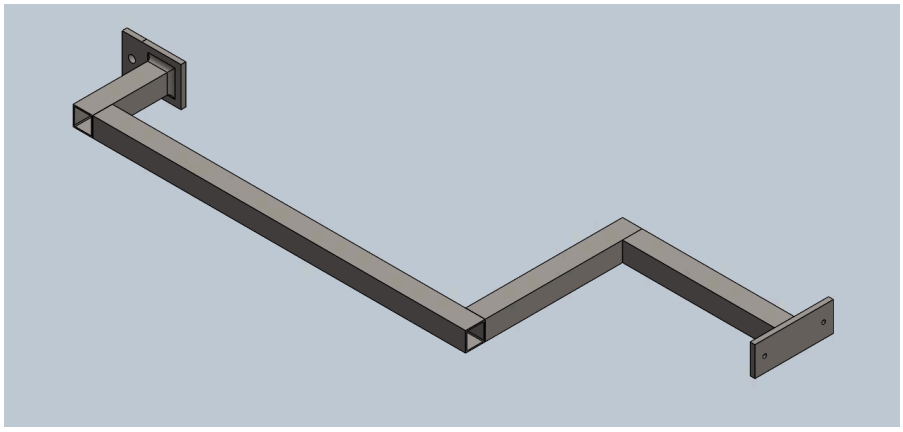

Figure 20. CAD Drawing of the Mount

- Clean the plates with soap water to remove the oil film present on the metal.
- Mark the plates at the points at which the pipes will be welded onto them.
- Lay the pipes on the floor as they are supposed to be welded to check their orientation.

Figure 21. Layout of the Pipes

- Weld the pipes perpendicular to each other.

- Drill 2 holes in one of the plates 3in apart from each other using a 3/8 in drill bit.
- Drill 1 hole in the other plate 1/2in from one of the sides using a 5/8 in drill bit. `
- Weld both the plates on either side of the pipes.

Figure 22. Pipes after welding

- Sand the welds and surfaces of the plates and pipes to create a smooth surface.
- Paint the mount black to avoid rusting.

Figure 23. Mount after Painting

6.2. **Electronics**

- The electrical subsystem was designed taking into consideration the dimensions of the PCBs for the system and the length of the wires needed for connections from the bike to the carriage. The wire lengths considered were long enough to be compatible with any other bike or carriage of similar dimensions. The power rating for firing up the systems were calculated to be not more than 5V DC and a maximum current of 40mA. The LED strips and LCD used were rated at 5V which were powered by the Arduino pins.

6.2.1. Design Iterations

- Many circuit designs were done initially in tinker cad and on the breadboard. There were many problems with the initial designs regarding the components, connections and pins. Few components were replaced, and some additional components were added where changes in the connection were also done and the finalized design consisted of slider switches, contact switch and LED strips for the safety system and push buttons for the COM system.

6.2.2. Bill of Materials (BOM)

Component	Quantity	Cost	Need
Arduino UNO	1	$10	Brain

M2M jumpers	10-20	$3	testing
M2F jumpers	10	$3	testing
LED STRIPs	2	$10	Safety System
Slider Switches	2	$1	Safety System
Contact Switch	1	$1	Safety System
LCD	1	$5	COM System
Voltage Source	5 V	depends	Power source for the Arduino and components
PCBs	3-4	$2	For final assembly
single-strand wires	10-30	$5	For connections
Buttons	5-10	$2	COM System

6.2.3. Equipment List

- Components and soldering stations are present at Richard Labbe Makerspace, STEM, uOttawa.

6.2.4. Instructions

- The safety system consisted of LED strips, slider switches and contact switch while the COM system consisted of an LCD and push buttons.
- Make a list of the components using the BOM above and collect the components from the place mentioned above.

- Finalize the list of components needed for the final prototype.
- Assemble the components comprising the safety system on the breadboard initially and write code for that system in the Arduino IDE.
- Next assemble the components comprising the COM system on a breadboard, write the respective code and test.
- Integrate both the systems on the breadboard.

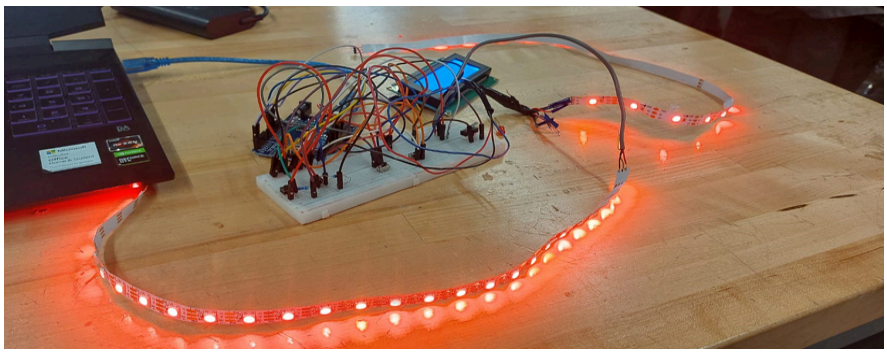

Figure 24. Electronics on Breadboard

- Once working successfully take the components and solder them on the PCBs. One PCB houses the Arduino, one for the slider switches and the third for the push buttons panel.
- The switches and LCD are placed at the front on the bike handle and connected with the Arduino located on the carriage.
- Use a power source like a power bank to plug into the Arduino.

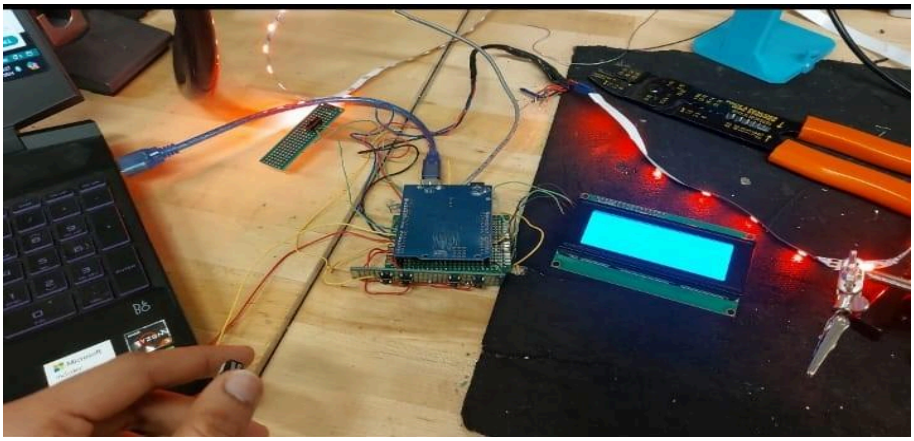

Figure 25. Electronics Soldered to PCB

6.3. Strap

6.3.1. Bill of Materials

Item	Quantity	Need	Cost	Link
Husky 1-inch x 12-feet Ratchet Tie-Down straps	1 pack (4 pairs)	For securing the wheelchair on the wooden platform.	$19.98/each	https://www.homedepot.ca/product/husky-1-inch-x-12-ft-ratchet-tie-down-4-pack-/1001031415
Husky Black Anchor Points	1 pack (4 anchors)	For attaching the straps to the wooden floor base.	$9.44/each	https://www.homedepot.ca/product/husky-light-duty-black-anchor-points-4-pack-/1001580425
Exterior Black Hex Lag Bolt	8 bolts	To secure anchoring system on the platform.	$0.41/each	https://www.homedepot.ca/product/paulin-1-4-20x2-exterior-black-hex-lag-bolt/1001613147

Exterior Black Hex Nut	8 nuts	For securing anchoring on the platform.	$0.14/each	https://www.homedepot.ca/product/paulin-1-4-20-exterior-black-hex-nut/1001613140
Exterior Black Flat Washer	8 washers	To prevent damage to the wooden floor base from overtightening the nuts.	$0.14/each	https://www.homedepot.ca/product/paulin-1-4in-exterior-black-flat-washers/1001613141

6.3.2. Equipment list

- Husky heavy duty straps, 1 package (2 pairs used)
- Husky anchors, 1 package
- 8 1/4 x 2 inch black bolts
- 8 ¼ black nuts
- 8 ¼ black washers
- Wrench to tighten the nuts.
- Drill with ¼ inch bit for wood

6.3.3. Instructions

- Drill 8 holes in the corners of floorboard of the trailer with the ¼ bit size for the wood
- Attach the anchors on the floorboard with the help of bolts, nuts and washers (the bolt goes through the whole, then on the other side it is secured with the washer and the nut)

- Make sure to tighten the nuts well with the wrench before using the straps so that the anchors would be attached firmly to the floor board !
- Now the anchoring system is ready to be used with the straps.

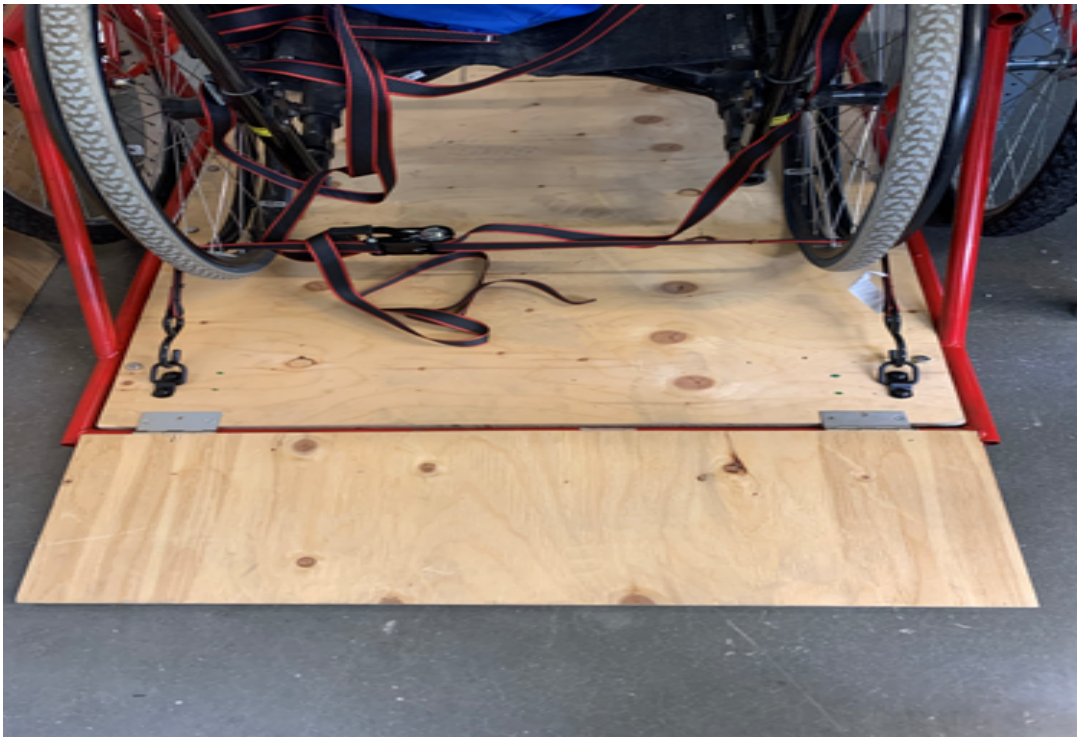

Figure 26. Straps Mounted in the Carriage

6.4. Testing & Validation

6.4.1. Mount Testing

- The mount testing consisted of two types of testing. The final prototype design was tested first in Ansys to check its structural integrity. The second round of testing was performed after the manufacturing and installation of the mount was completed. The mount was connected to the bike

and the carriage was tested with a person sitting in the wheelchair to simulate actual workload. The mount was successful in both the tests that were conducted, and it was concluded that the mount works like it is intended too.

6.4.2. Electrical systems test

- The electrical test consisted of two tests. Breadboard testing where both the system was tested out individually and then the two systems were integrated and tested out. Once the first test was successful in the second testing the two systems were soldered onto PCBs and then placed on the bike for final testing where both the systems were checked to see if all the components were functioning well as per the final requirements.

6.4.3. Strapping subsystem testing

- The straps are rated with a working load limit of 500 lbs and break strength of 1500 lbs per strap. The testing was conducted for 5 laps approximately 200 meters each with the wheelchair secured with help of straps on the platform. The user of the chair weighed approximately 70 kgs. During the ride the wheelchair remained very securely and firmly attached on the trailer platform.

7. Conclusions

In summary, we successfully developed an inclusive bicycle, the Equibike, designed to enable a wheelchair user to engage in physical activity alongside a person on a standard bicycle. Our initial design involved mounting the frame at the front, but we later redesigned it to be easily detachable and detachable at the rear of the bicycle.

We conducted simulations with various materials and concluded that wood was the most cost-effective option for the trailer. The attachment underwent several iterations before we decided on a one-sided system. This design was chosen for its simplicity in manufacturing, ease of attachment for the user, and cost-effectiveness. For the electrical system, we developed a signaling, braking, and communication system between the cyclist and the wheelchair user. This was achieved by repurposing electronics from the makerspace and utilizing old ethernet and phone wires.

Feedback from potential users suggested improvements to the communication system to facilitate a walkie-talkie style conversation between the cyclist and the wheelchair user. Additionally, it was recommended that we modify the attachment system to connect to the bicycle seat instead of the axle, to prevent potential damage.

7.1. Lessons learnt

- Our Engineering Design team, like many before us, faced challenges with clear and timely communication, exacerbated by language barriers due to our diverse backgrounds. We suggest future teams hold biweekly phone meetings for concise and timely discussions.
- Time management was another hurdle. Mid-semester, we lost access to our project management software, Wrike, complicating our cooperation. Keeping the software updated was also difficult. We advise future teams to use easily accessible and long-term free software, like a mobile app for quick status updates.
- Finally, effective teamwork is crucial. Knowing each member's strengths and weaknesses allows for efficient task allocation. We recommend open communication within the team to understand everyone's skills for optimal performance.

7.2. Future work recommendations

- We have several recommendations for future work on the system.
- For the attachment system between the bike and the trailer, we would recommend improving its strength and durability. Moreover, we would recommend moving the location of the attachment such that it clamps onto the seat.

- We would recommend improving the stability and maneuverability of the trailer. Adding some means of shock absorption, and improving the quality of the welds would be key to this.
- We would recommend changing the floor and ramp materials to be more durable and moisture resistant. A material other than wood may be a good idea, such as plastic or expanded metal. Alternatively, sealing the wood via an oil-based paint or using sealant may be appropriate.
- Keep in mind the life cycle analysis of the product when making design decisions for materials. Everything, even steel, degrades eventually. For this design to be viable in practical applications, considering waste in the manufacturing process, and material degradation during use would be key.
- Perform a risk analysis. The product needs to be safe to use in practical scenarios, like on the road. What happens during a collision? Can anything be done to mitigate injury?
- Talk to users. User centric design can help make a product that people actually want to use. Keep in mind that you don't want to overemphasize existing needs so much that you overlook future requirements for an innovative design decision.
- Improve the communication system: While we moved the wheelchair user to the back to reduce cost and to

allow the trailer to be easily removable, we noted that a front mounted design does allow the biker to more easily communicate with the wheelchair user. Disabled users can often be socially isolated due to societal stigmas, so having an opportunity to socialize with the biker is a key feature for the wheelchair user. Making the communication system bidirectional would help make the equibike much more fun to use.

- Changing the signal system on the bike: we would recommend changing the system so that it uses a single slide switch with three positions, one for indicating turning left, one for neutral (indicating nothing), and one for indicating turning right. Most motorcycles have a similar system. If it's affordable, it would be nice if the switch turned itself automatically after the user has traveled a certain distance.
- Rather than just a simple LCD, it may make more sense to create an app on the user's phone to relay communication between the user and the bike. This has the benefit of reducing the cost, while allowing for other applications to easily run, like an online mapping service.
- It would be nice to reduce the number of wires between the trailer and the bike. This would help avoid hampering the bikers ability to peddle while biking and make the link between the bike and trailer more visually appealing. In addition, it would reduce the complexity of removing the electronic system from the bike.

8. Bibliography