GNG5140

Inclusive Bike – Revised Prototype Analysis and Test Results

Submitted by

[INCLUSIVE BIKE TEAM]

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University of Ottawa

Abstract

This document outlines our first attempt at prototyping and testing our final product. The prototypes in this document are a combination of simulated and concrete products. The global solution that we have come up with is described in detail using a block diagram. Moreover, the various prototypes are outlined in detail. Each subsystem's prototype will be documented in detail using sketches, diagrams, and pictures. When testing is possible, the tests completed for these systems are described and the results of these tests are provided. Moreover, a bill of materials outlining the costs of components that will be purchased is provided.

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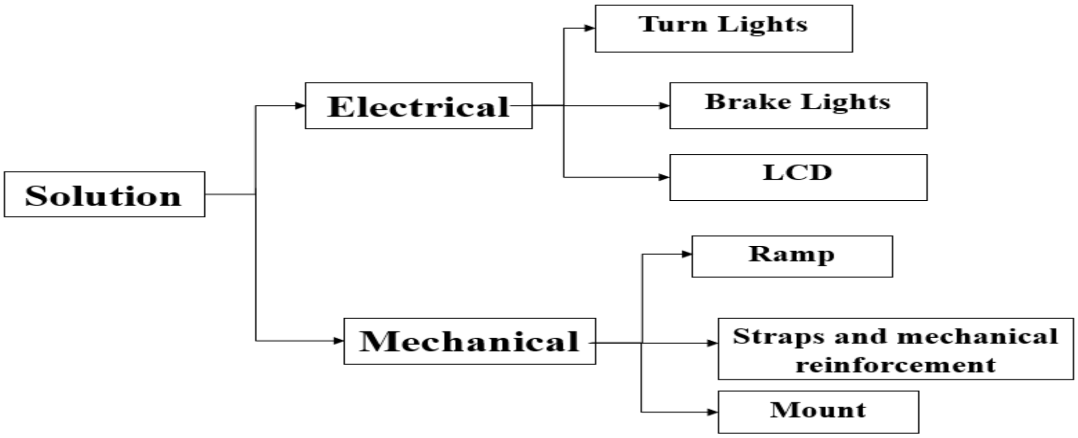
List of Acronyms

Acronym	Definition
BOM	Bill of Materials
GPS	Global Positioning System
FOS	Factor of Safety

1 Introduction

This document outlines the initial prototyping of the final product. It serves as a record of why decisions were made early in the design process and outlines the design in its early stages. It exists so that future engineers working on the project may understand why one decision was made over another, and what issues became apparent in the early stages of designing the project. The main purpose of this project is to create an inclusive bike that is significantly cheaper than current existing solutions, while also being easy to use and about as durable as competing products. Note that subsystems are often discussed and tested as separate entities in this deliverable; in a future deliverable the system will be shown as a whole.



2 Global Solution

Figure 1 – Inclusive Bike chart

As shown in Figure 1, there are two main subsystems in our solution: the electrical system and the mechanical system. The mechanical features include a system to hold the wheelchair securely to the floor and a ramp designed to hold the weight of the user without bending too much (up to 150kg). This ramp is designed to allow the user to get on and off the trailer hassle-free. Additionally, a mounting system is included to link the trailer and the bike. From the electrical perspective, the design includes a brake light that illuminates when the driver activates the bike's braking mechanism. Blinking signal lights are also incorporated for when the driver intends to turn. Moreover, an LCD display allows the rider to communicate with the driver of the bike. The rider may do so by using the 4 buttons present with the rider.

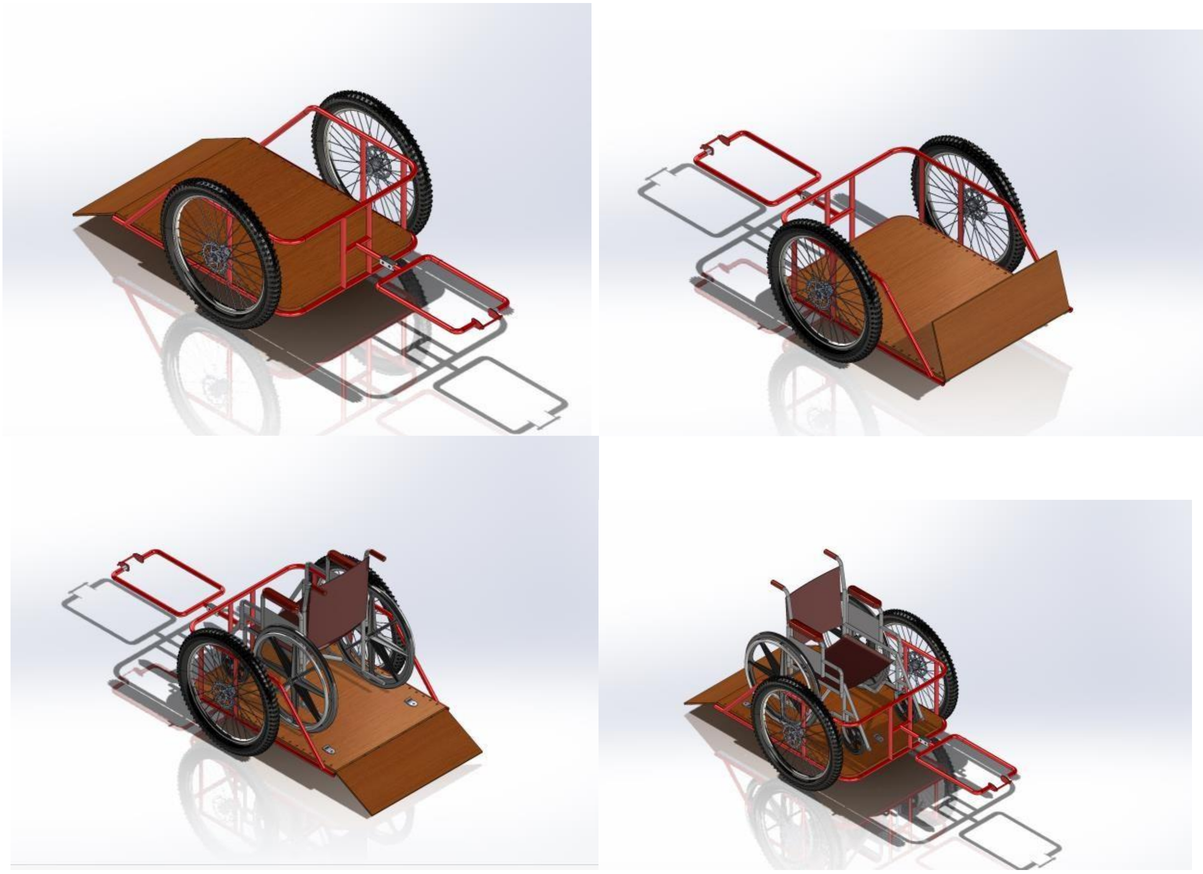


Figure 2 –Visualization of the final product. Electronics are not depicted.

Shown in the figure above is a visualization of the final product. Note that the straps and electronics are not depicted; the combination of each subsystem into a usable product will be shown in a future deliverable and is not the subject of this deliverable.

3 Prototype, Test, and Bill of Materials

This section documents the initial prototype for subsystem of the protype. The prototyping is broken down into 5 sections: (1) the brake lights and blinkers, (2) the mount system, (3) the floor and ramp, and (4) the straps. Lastly the bill of materials for all components is provided.

3.1 The Display, Brake Lights, and Blinkers

3.1.1 Documentation of Brake Lights and Blinkers

Listed below are the purposes of each component tested in this section.

1. In regards to the previous prototype where we demonstrated blinkers using just a single led strip, a lot of new changes have been introduced in the current prototype.
2. For instanc two LED strips (WS2812B) for the blinkers which is controlled using two slider switches instead of a single button used earlier that functions as per the final requirements.
3. Finaly assembly of LCD on breadboard for communication with the driver using push buttons meeting the communication requirements.
4. Integration of the two LED strips which function as both blinkers and brake lights and LCD (communication) and carried out successful testing on breadboard.
5. In the previous prototypes for basic testing we had used individual LED strip and LED for the blinkers, and brake lights.

The diagram of these components is shown in the figure below.

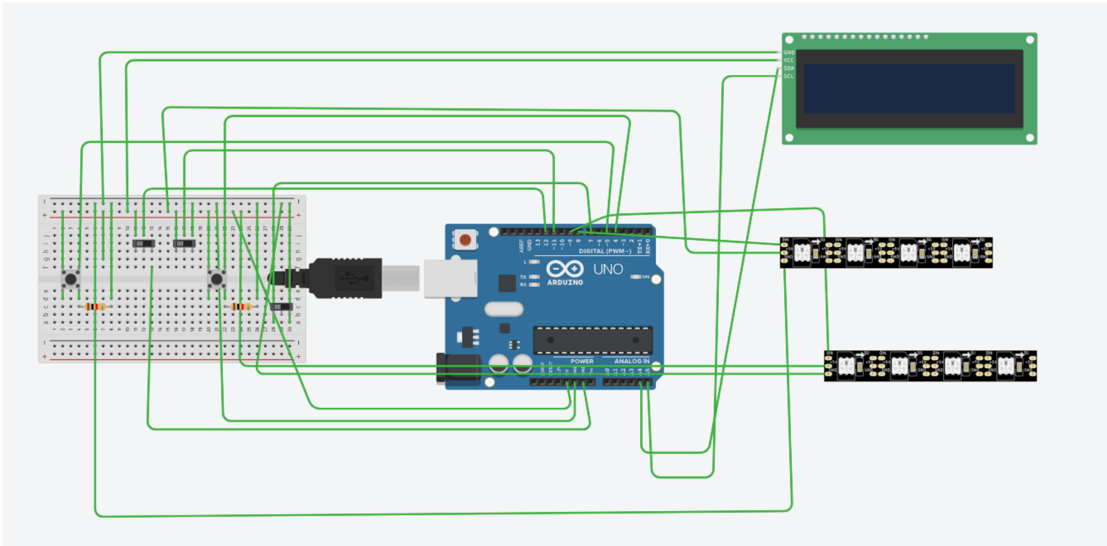
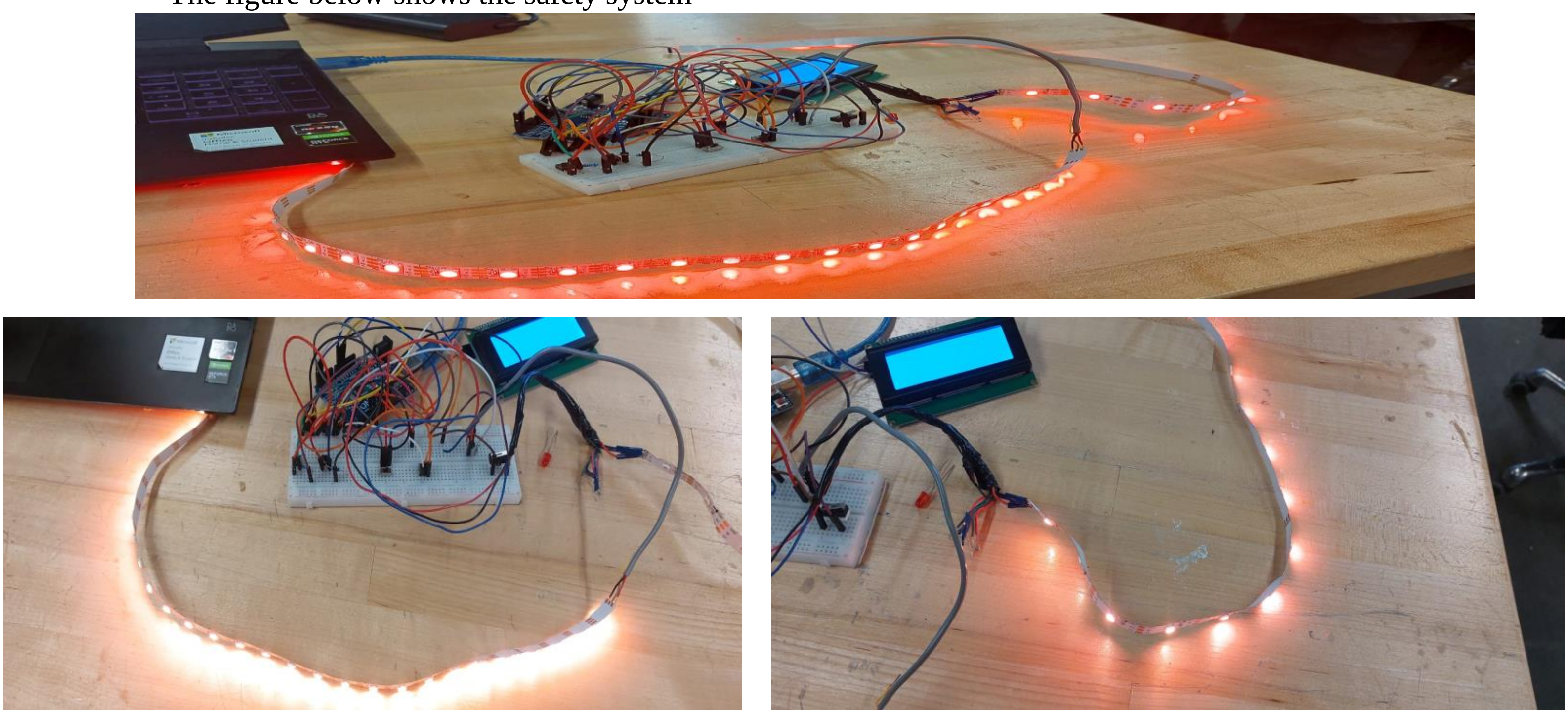


Figure 3 – Electronics of the display

3.1.2 Testing of the Safety system- Blinkers aka brakelights

The figure below shows the safety system



3.1.3 Testing of the Safety system- Blinkers aka brakelights

Table 1 – Tests Results for LCD, Break Lights, and Blinkers

Components-Category(Purpose)	Expected	Actual results
Blinkers (LEDs)- Safety	Blink when turning with high brightness so that it is visible to others	Matches the expectations 100%.
Slider switches(control)-Safety	When pressed turn on blinkers while taking turns and turn off when not needed.	Meeting the mentioned expectations
Red LED(Brake light)- Safety	When brakes are pressed backligh should glow	Both the blinker LED strips function as brake lights as well on breadboard when the brake switch is pressed
LCD- Communication	Show basic messages which the rider wants to convey to the driver and clear messages when the control is changed.	Tested out for all the message signals by pressing the control buttons under all conditions on the breadboard.

3.1.3 Electrical System- Future work before final prototype-

1. Design of Protoboard circuit and soldering of all the components on individual PCBs.
2. Initial testing of all the components and systems soldered on the PCBs to ensure there is no change in the previously recorded test results.
3. Design and manufacturing of the casings for the safety and communication systems.
4. Assembly of the different complete boards on the bike and run the wiring between the various PCBs and systems.

3.2 The Floor and Ramp

3.2.1 Documentation of Floor and Ramp

We have outsourced the materials required for the components and subsystems asssembly in our inclusive bike. The components are hinge, ramp, base and a mount for connecting the bike with the carriage. These components are shown in the figures below.

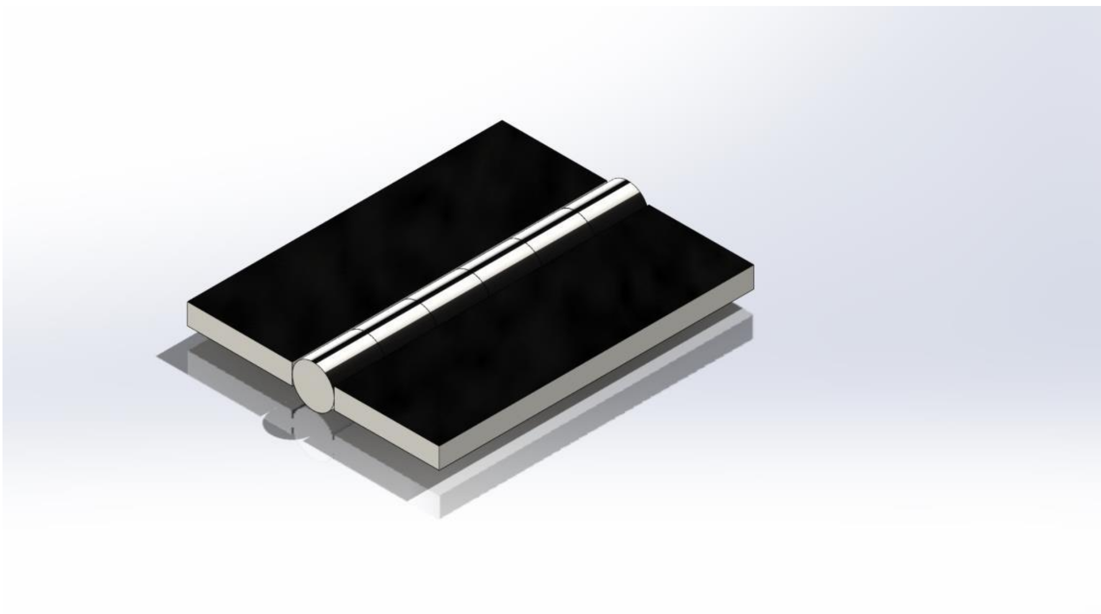


Figure 8 – Isometric View of Hinge

Figure 9 –Top and side view of Hinge

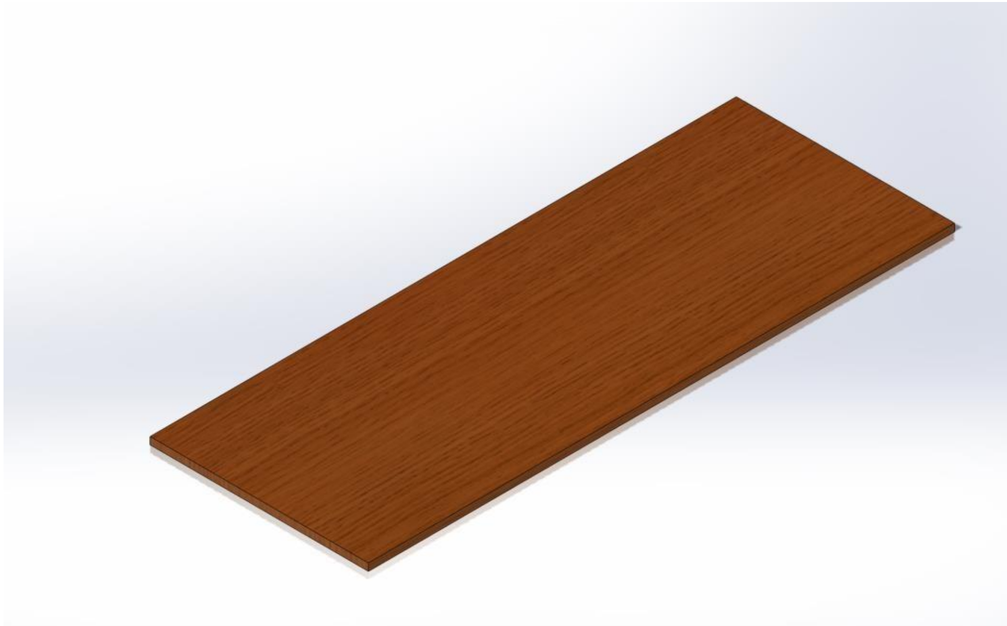


Figure 10 –Isometric View of Ramp

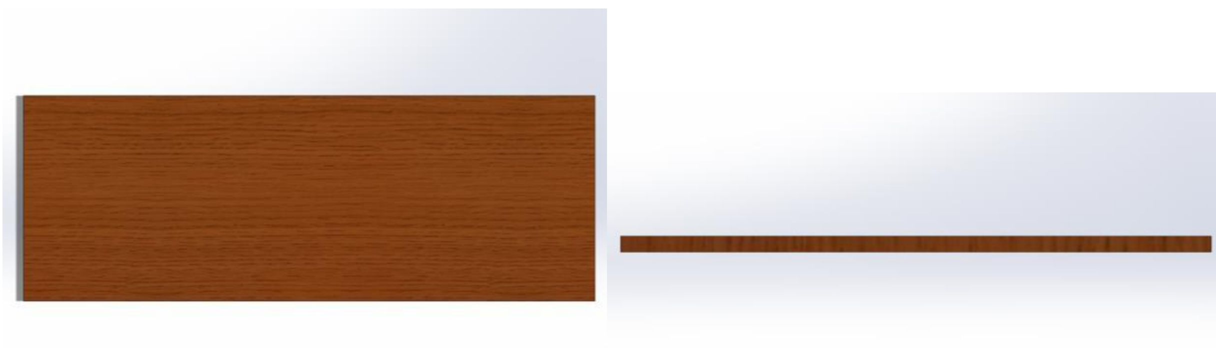


Figure 11 –Top and side view of Ramp

Figure 12 – Isometric View of Floor

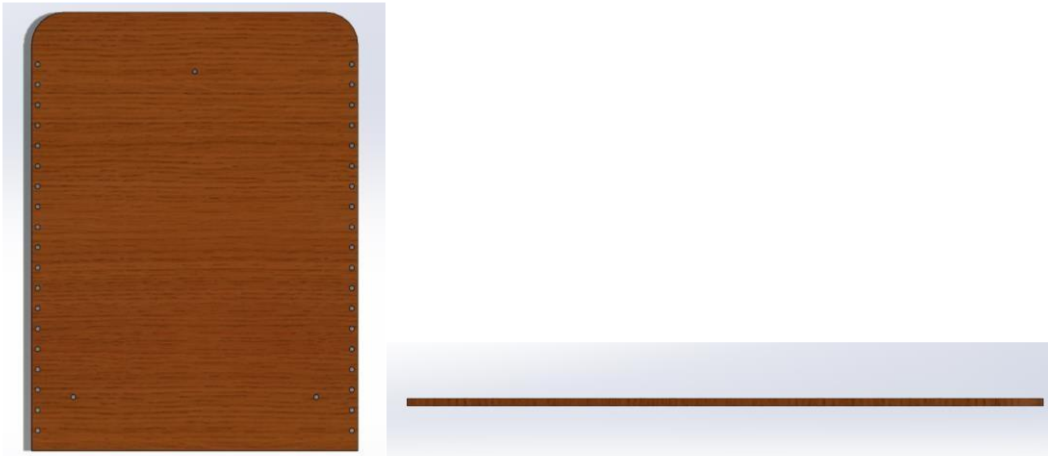


Figure 13 –Top and side view of Floor

The dimensions of the components shown above are given in the table below.

Table 3 – Dimensions of Components

Hinge	LxBxH: 30x24x2 mm
Ramp	LxBxH: 805.5x300x10 mm
Floor	LxBxH: 1077.7x805.52x15 mm

3.2.1 Testing the Floor and the Ramp

In this section the deformation, equivalent stress, and factor of safety are simulated and the results are shown. The results were used to determine the exact size, shape and dimensions of the components. First, the hinge was tested. Static Structural Testing was conducted on the hinge with a maximum load of 1200 N at the point of connection between the base and ramp . The total deformation, equivalent stress and FOS have been pictured below. The load was spread over a 10s time.

The results of the completed tests are shown below.

3.2.1.1 Maximum Deformation: 0.0014mm

3.2.1.2 Maximum Equivalent Stress: 45.39MPa

3.2.1.3 Minimum FOS: 1.9

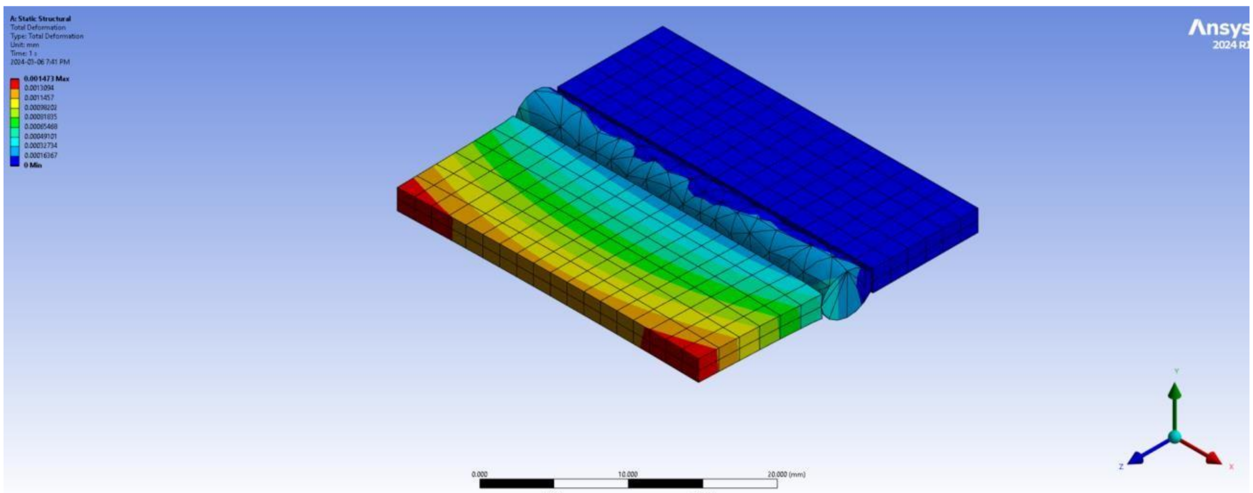


Figure 14 – Total Deformation

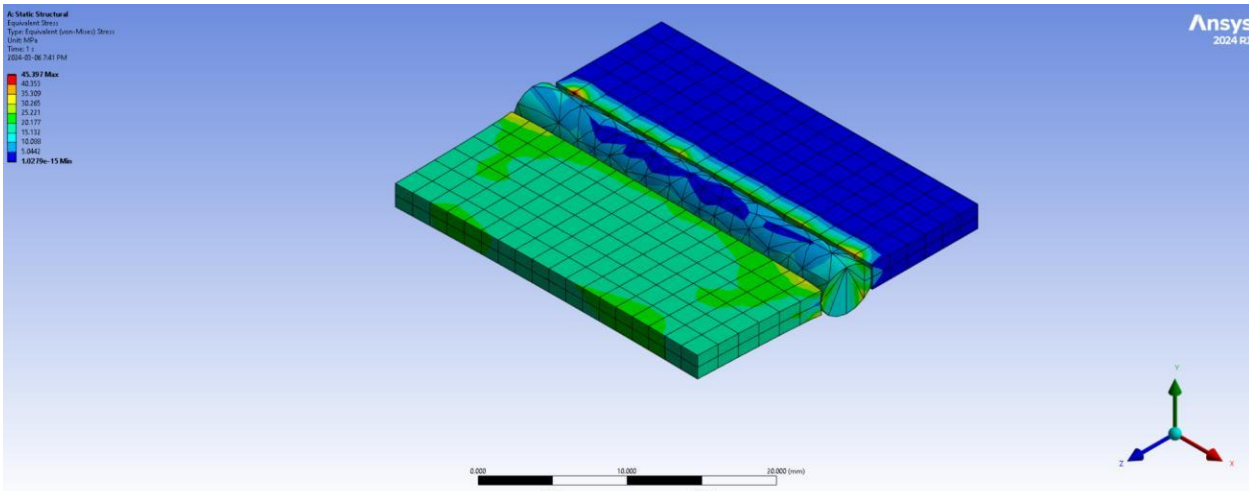


Figure 15 – Equivalent Stress

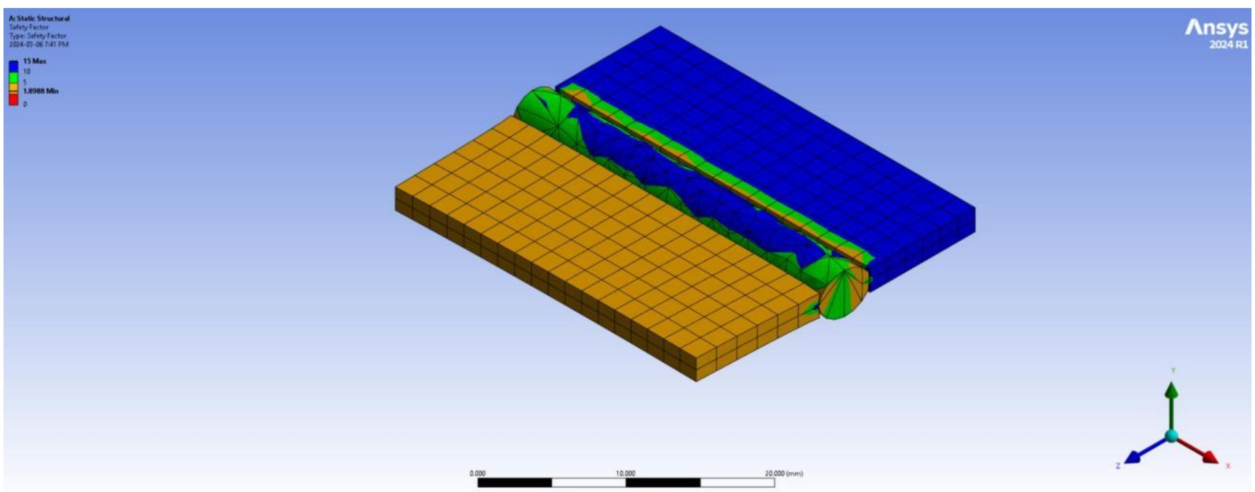


Figure 16 – Factor of Safety

Static Structural Testing was conducted on the ramp with a maximum load of 1200 N on the face of the ramp . The total deformation, equivalent stress and FOS have been pictured below. The load was spread over a 10s time.

The following are the results of the tests in the figures below:

3.2.1.4 Maximum Deformation: 0.44mm

3.2.1.5 Maximum Equivalent Stress: 60.57MPa

3.2.1.6 Minimum FOS: 1.42

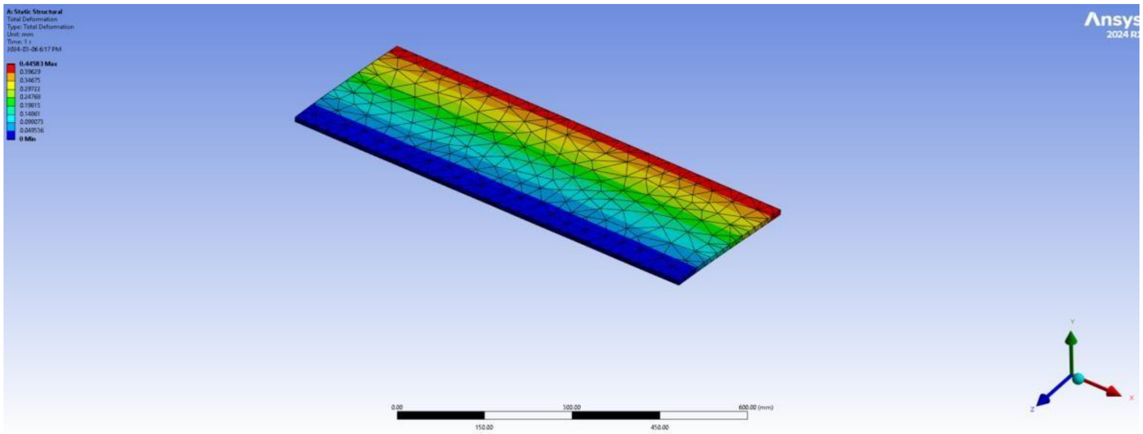


Figure 17 – Total Deformation of Ramp

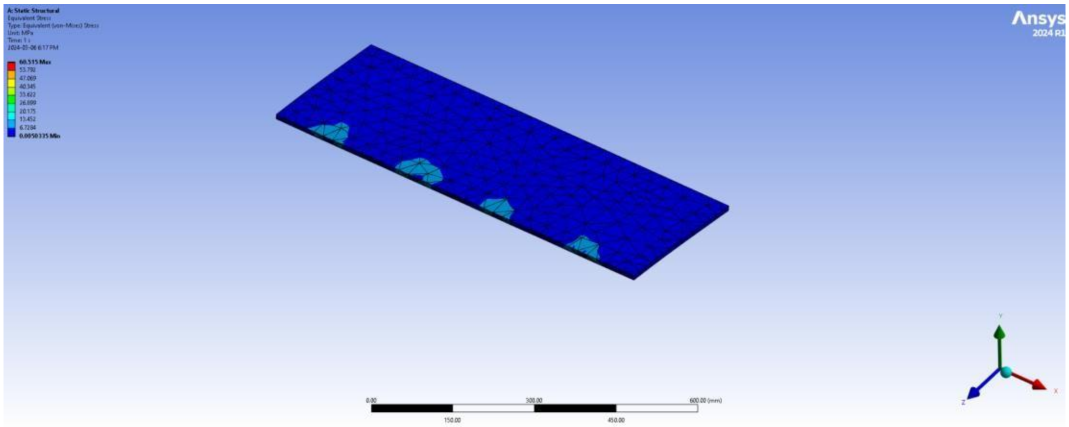


Figure 18 – Equivalent Stress of Ramp

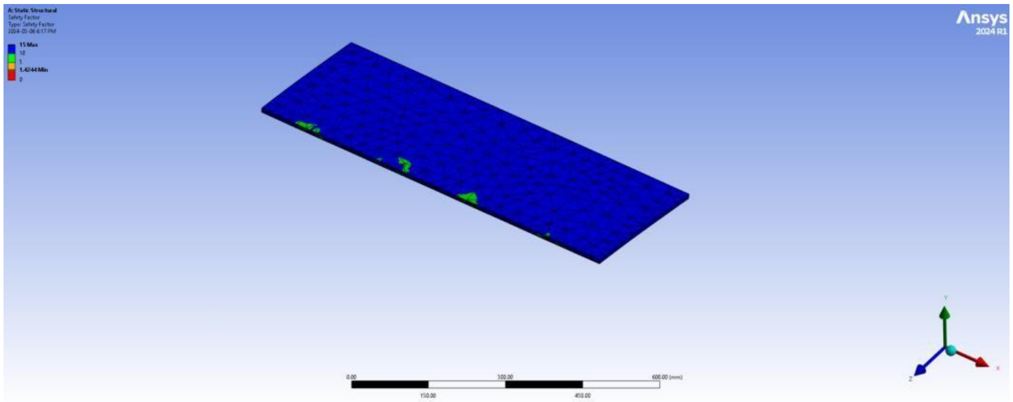


Figure 19 – Factor of Safety of Ramp

Static Structural Testing was conducted on the floor with a maximum load of 2205 N on the face of the floor . The total deformation, equivalent stress and FOS have been pictured below. The load was spread over a 10s time.

The results from the images shown below are as follows.

3.2.1.7 Maximum Deformation: 0.09mm

3.2.1.8 Maximum Equivalent Stress: 24.21MPa

3.2.1.9 Minimum FOS: 3.5

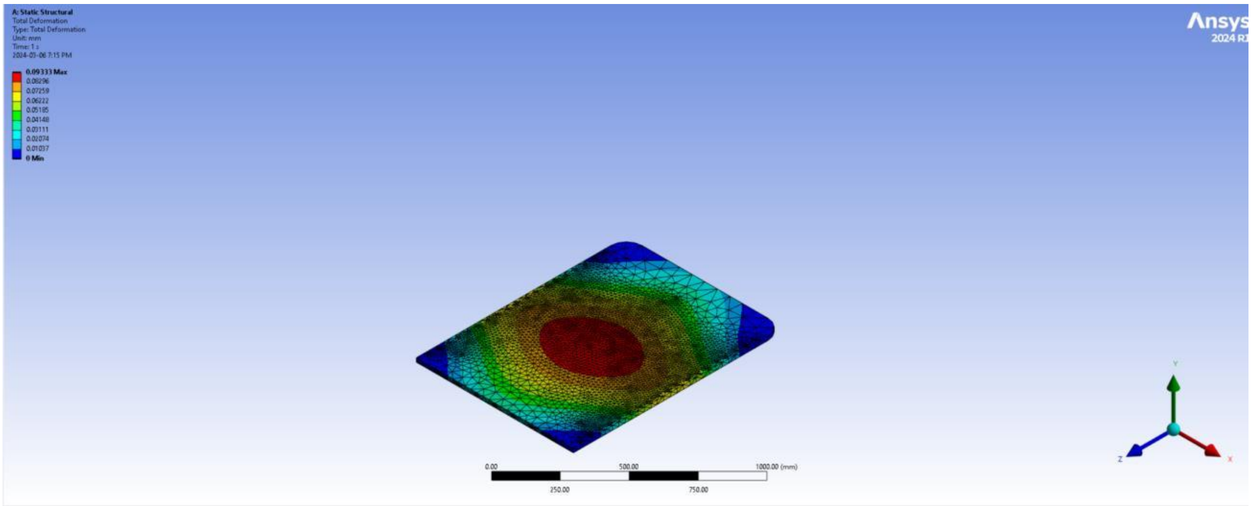


Figure 20 - Total Deformation

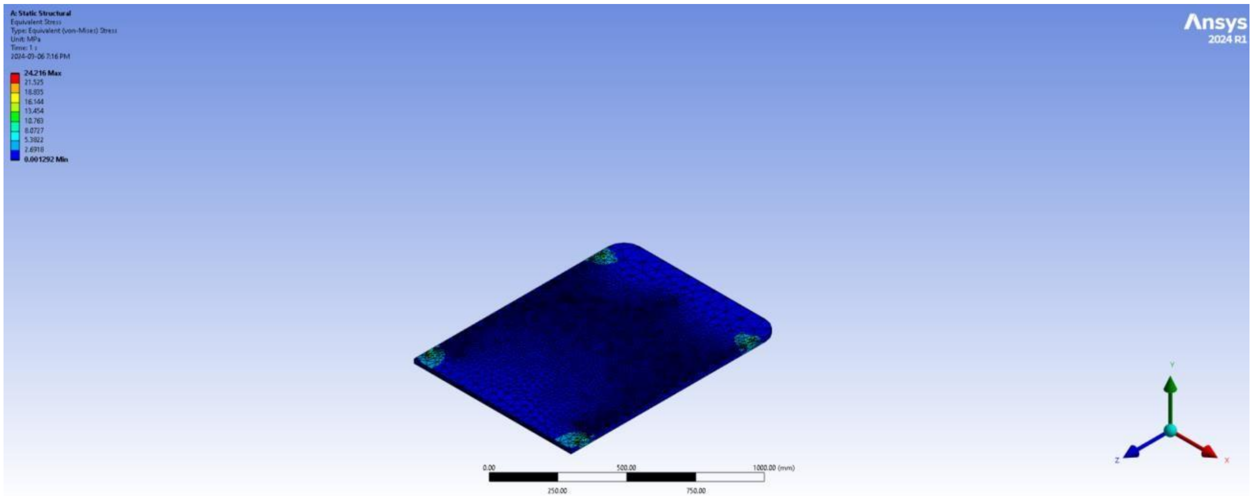


Figure 21 – Equivalent Stress

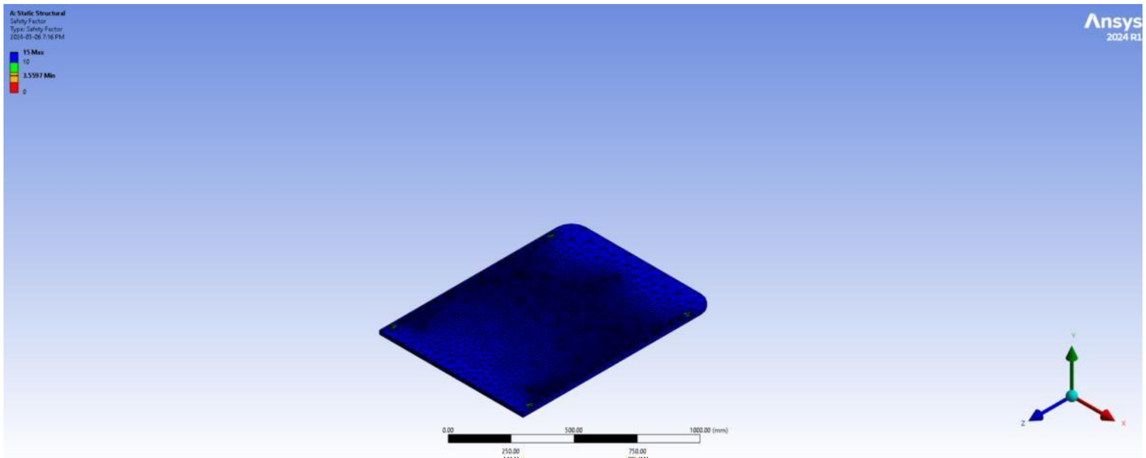


Figure 22 – Factor of Safety

3.3 Mount

The rear mount subsystem consists of 2 flanges which will be installed onto the rear axle of the bike. The flanges have a hole in them through which the rear axle will be passed. These flanges are then welded to pipes which wrap around the rear wheel of the bike. Another pipe is welded perpendicular to the wrap around pipe with holes made for bolts to be inserted through.

The maximum deformation is under limits at 0.227mm. The Maximum Equivalent Stress and the Factor of Safety (FOS) figures are dangerously close to failure and hence will be reviewed in the future. The end pipe where the force has been tested on will be covered by a square steel element protruding from the carriage. Two bolts of 12mm will be inserted into the holes to secure the linkage. Hence, the safety concerns are lowered when considering the above use case.

3.3.1 Documentation of Mount Design

The dimensions of the prototype are as follows:

3.3.1.1 Rear Axle: Dia. 9mm

3.3.1.2 Flange: Hole Dia. 9mm, Length: 75mm, Height: 40mm, Thickness: 3mm

3.3.1.3 Secondary Flange: Hole Dia. 9mm, Length: 3in, Height: 1in, Thickness 3mm

3.3.1.4 Square Pipes: 1in x 0.065in thickness

3.3.1.5 End Flange: 3in x 1.5in x 3mm

3.3.1.6 Total length of all pipes: 851mm

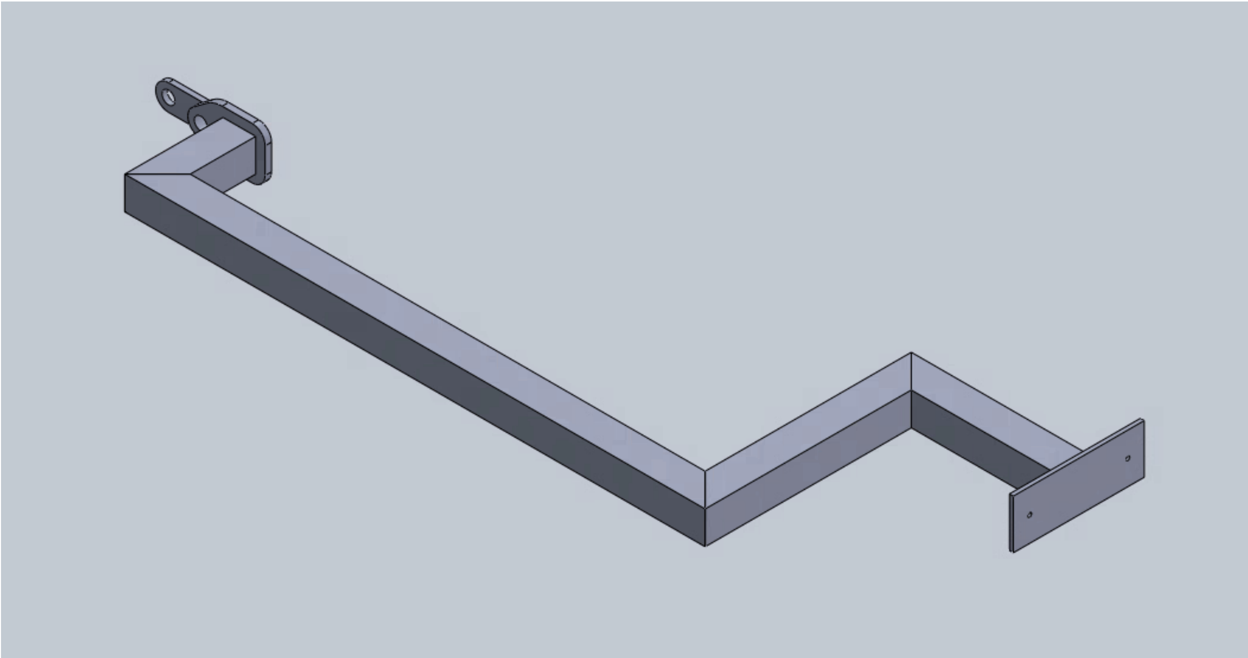


Figure 23 – Welded Component Isometric View

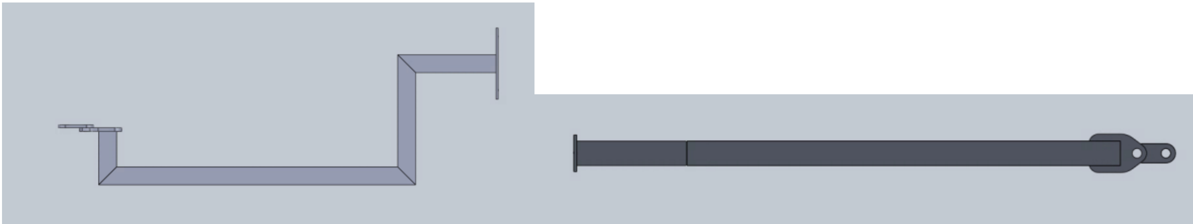


Figure 24 – Welded Component of Mounting Top View and Mounting Side View

3.3.2 Prototype Testing

Static Structural Testing was conducted on the Mount with a maximum load of 1000 N at the point of connection with the rest of the carriage. The total deformation, equivalent stress and factor of safety have been pictured below.

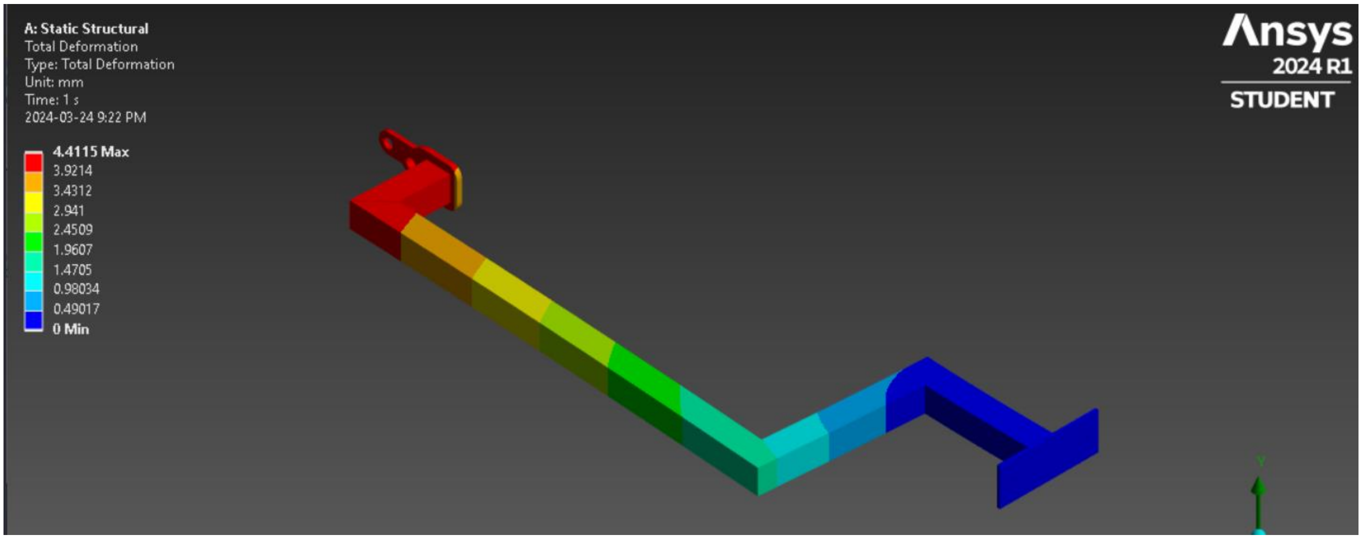


Figure 27 – Total Deformation

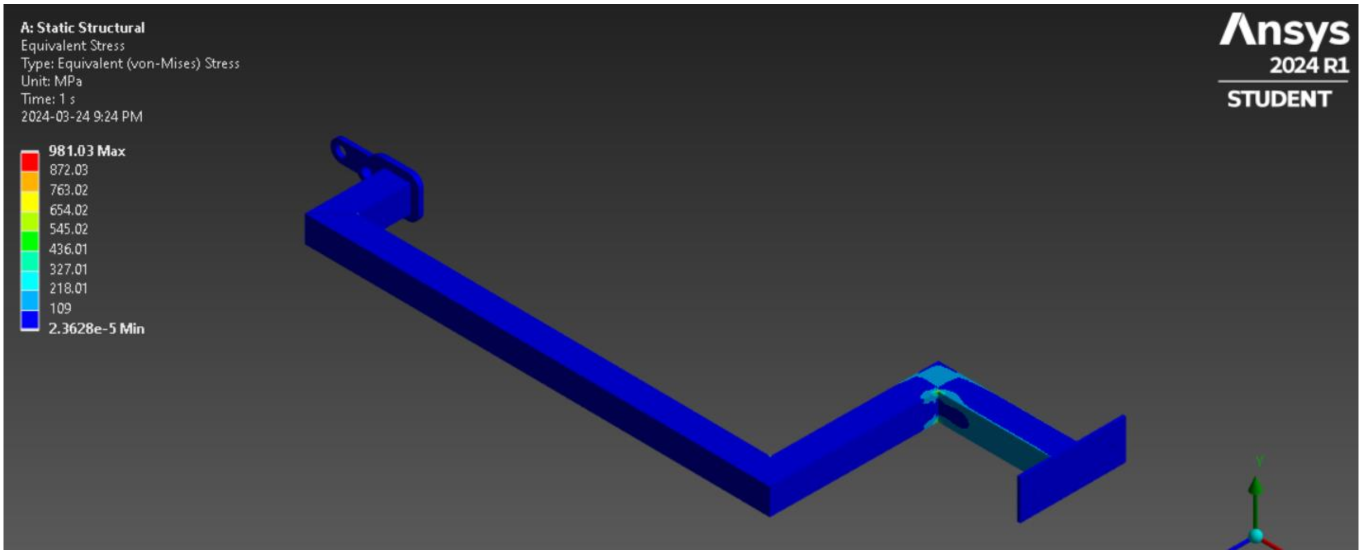


Figure 28 – Equivalent Stress

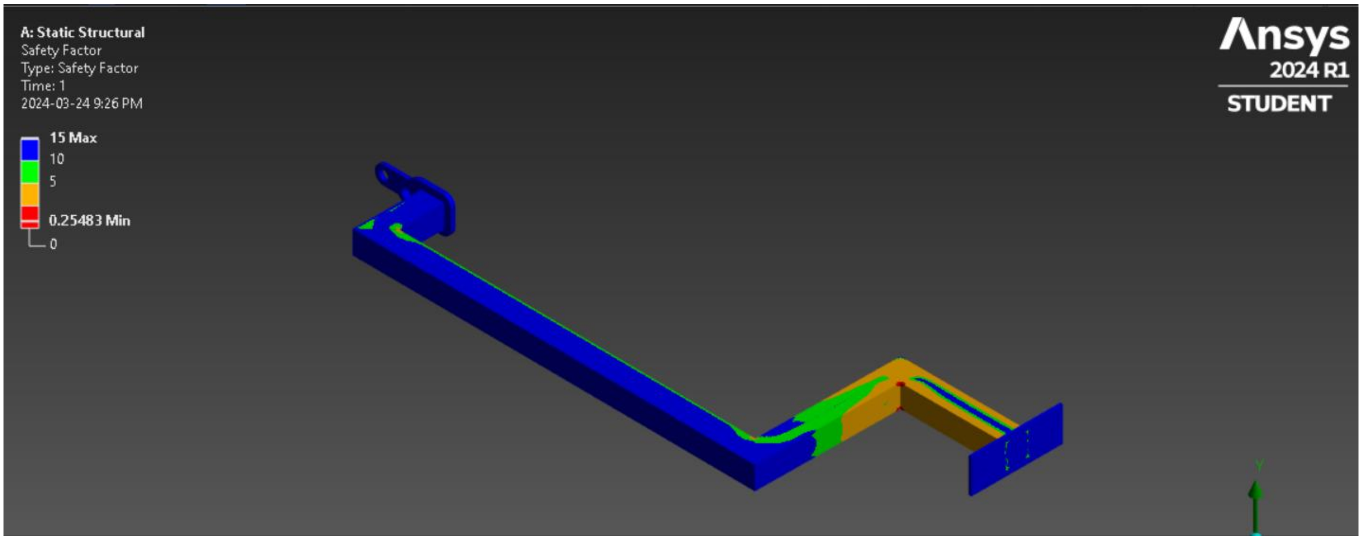


Figure 29 – Factor of Safety

The results are of the tests shown above are as follows:

1. Maximum Deformation: 4.415mm
2. Maximum Equivalent Stress: 981.03 MPa
3. Minimum FOS: 0.25

3.4Straps

3.4.1 Documentation of Strapping System

The strapping system is supposed to improve the safety of a trailer user by securing the wheelchair to the floor of the attachment.

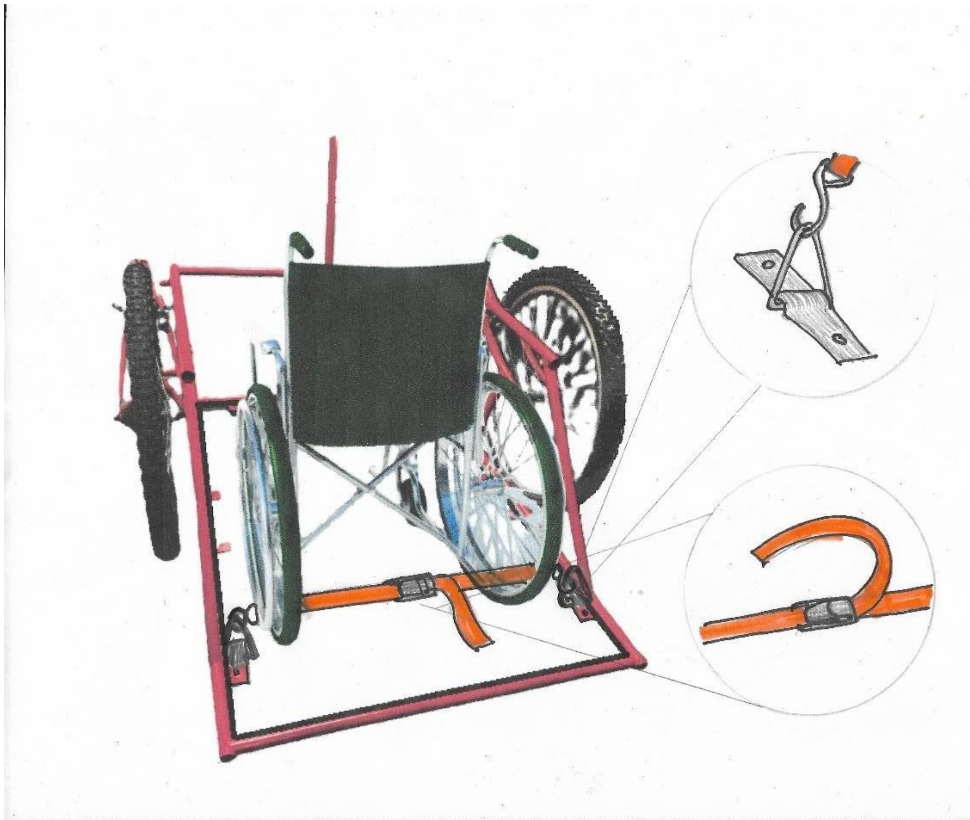


Figure 33 – Rear Strapping

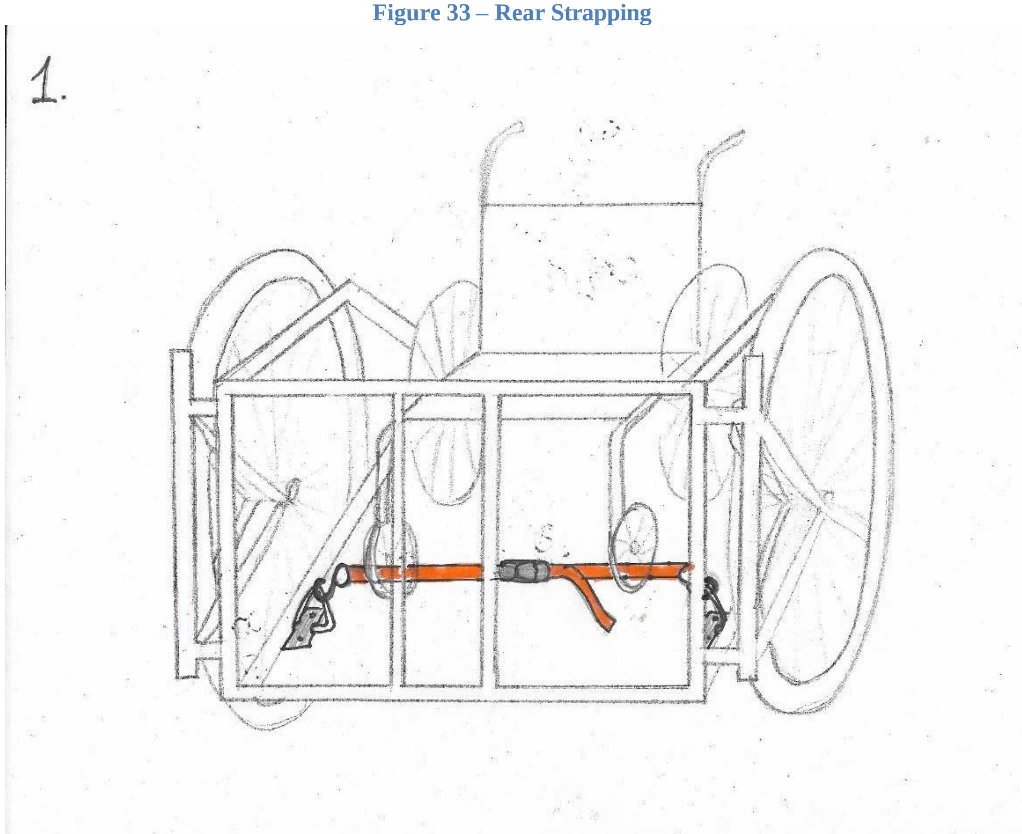


Figure 34 – Front Strapping

3.4.2 Prototype Analysis

Out of three ways of the strapping suggested earlier, we came to a conclusion that the first way would be the best for securing the wheelchair in a stable position as well as the most comfortable for the user. This is because other techniques did not provide leg space for the user, and the given strapping system should anchor the wheelchair at 4 different points when tensioned, which should minimize jostle. Completing the testing of this system is virtually impossible until we complete a concrete prototype.

3.5 Bill of Materials

The bill of materials is shown in the table below.

<table>
<tr><th>Item</th><th>Quantit
y</th><th>Need</th><th>Cost</th><th>Link</th></tr>
<tr><td>5mm thick steel plate [For Mount[</td><td>2</td><td>To attach the pipes to the rear axle.</td><td>2 x 20 = 40$*</td><td>https://a.co/d/8FDWnrg</td></tr>
<tr><td rowspan="3">1 inch OD steel pipe [For Mount]</td><td>2 x 400 mm</td><td>To attach the rear axle to the carriage.</td><td>45$*</td><td>https://www.amazon.ca/OD-Brushed-Stainless-Tubing-Custom/dp/B07KRMZPB1?th=1</td></tr>
<tr><td>260mm</td><td>To join the two parallel pipes behind the rear wheel.</td><td>13$*</td><td>https://www.amazon.ca/OD-Brushed-Stainless-Tubing-Custom/dp/B07KRMZPB1?th=1</td></tr>
<tr><td>125 mm</td><td>To create a connection between the mount and the carriage.</td><td>7$*</td><td>https://www.amazon.ca/OD-Brushed-Stainless-Tubing-Custom/dp/B07KRBWZC4?th=1</td></tr>
</table>

Husky 1-inch x 12 ft. Ratchet Tie-Down (4-Pack) **[Straps]**	1 pack	Straps are required to secure wheelchair on the trailer	$19.98 / each	https://www.homedepot.ca/product/husky-1-inch-x-12-ft-ratchet-tie-down-4-pack-/1001031415
Husky Light-Duty Black Anchor Points (4-Pack) [Straps]	1 pack	Anchors are required to attach the straps to the platform of the trailer	$9.44 / each	https://www.homedepot.ca/product/husky-light-duty-black-anchor-points-4-pack-/1001580425
Hinge	6	To attach the ramp with the floor	6 x 5 = 30$	https://www.homedepot.ca/en/home/categories/building-materials/hardware/door-hardware/door-hinges.html
Ramp	1	To easily put the wheelchair on the carriage	1 x 50= 50$	https://www.homedepot.ca/en/home/categories/building-materials/lumber-and-composites/plywood/mdf.html
Floor	1	The floor of the Carriage	Same as above	https://www.homedepot.ca/en/home/categories/building-materials/lumber-and-composites/plywood/mdf.html
Rod	1	The rod of the Carriage	1 x 20= 20$*	
Aluminium mount	1	The mount the bicycle with carriage	1x30 =30$	
TOTAL	N/A	N/A	139.42	N/A
TOTAL (with tax)			157.54	

* It may be possible to obtain this item for free through the University's Bike COOP or Brunsfield Center or some other source.

Listed in the following table are the electronics. Note that prices are omitted for this project because the electronics were obtained from uOttawa's Makerspace for free.

Component	Quantity
Arduino UNO	1
M2M jumpers	20-30
M2F jumpers	10
RED LED	1
LED STRIP	2
Slider Switches	2
Contact Switch	1
LCD	1
Voltage Source	5 V
PCBs	3-4
Speaker	1
Resistors	10k ohm(5-6)
Long single-strand wires	10-30
RGB LED strip	1
Buttons	5-10
Bluetooth Module (ZS-040)	1
GPS Module (Beitian BN-880)	1

4 Updating the Prototype Test Plan

Due to licensing problems with Wrike, the Gantt chart and the general planning for last week was omitted. As such, this week, the document contains a plan for both of the weeks' work. The new project management software being used for the remainder of the semester is Asana, which has all the functionalities required for this class, including task assignment, start and end dates for tasks, and a Gantt chart view.

4.1 Initial Prototype Analysis and Test Results

In the two figures shown below, there is a table listing out every task and a Gantt diagram. The table demonstrates (1) tasks to be done, (2) the person assigned with the responsibility to ensure that a particular task is completed, (3) the importance of the task, and (4) its status.

Initial Prototype				
Design of Floor in CAD 2	SK Sachin Kasbe...	Mar 1 – 15	High	Done
Do analysis for wood and metal floors	SK Sachin Kasbe...	Mar 1 – 6	Medium	Done
Add support beams to reduce flexion	SK Sachin Kasbe...	Mar 7 – 15	High	Done
Design of Ramp in CAD 3	SK Sachin Kasbe...	Mar 1 – 15	High	Done
Do analysis for wood and metal	SK Sachin Kasbe...	Mar 1 – 5	Medium	Done
Do stress analysis on hinges	SK Sachin Kasbe...	Mar 6 – 10	High	Done
Add ramp lock	SK Sachin Kasbe...	Mar 11 – 15	Medium	Done
Attachment Design in CAD 4	gl glele049@uo...	Mar 1 – 15	High	Done
Complete initial design	gl glele049@uo...	Mar 1 – 4	Low	Done
Complete CAD model	gl glele049@uo...	Mar 5 – 7	Medium	Done
Complete stress analysis on attachment	gl glele049@uo...	Mar 8 – 11	Medium	Done
Redesign attachment to one side	gl glele049@uo...	Mar 12 – 15	High	Done
Breadboad Prototype for Electronics 5	RU Raghav Kaus...	Mar 1 – 15	Medium	Done
Redo design with switches	RU Raghav Kaus...	Mar 1 – 5	Low	Done
Combine electronic systems	RU Raghav Kaus...	Mar 6 – 7	Medium	Done
Reprogram to run electronics together	RU Raghav Kaus...	Mar 8 – 11	High	Done
Test system integrated together	jh jhort062@u...	Mar 12 – 15	Medium	Done
Test GPS module and Bluetooth Module	jh jhort062@u...	Mar 1 – 5	Low	Done
Final Strap Possibilities 3	KP Kristina P	Mar 1 – 15	High	Done
Check different strapping positions	KP Kristina P	Mar 1 – 8	Medium	Done
Determine based on drawings best mounting system	KP Kristina P	Mar 9 – 12	Medium	Done
Finalize purchasing decision	KP Kristina P	Mar 13 – 15	Medium	Done
Purchasing Straps, Floor, Ramp, and Attachment 4	jh jhort062@u...	Mar 16 – 17	High	Done
Purchase Floor	jh jhort062@u...	Mar 16 – 17	Medium	Done
Purchase Ramp	jh jhort062@u...	Mar 16 – 17	Medium	Done
Purchase Attachment	gl glele049@uo...	Mar 16 – 17	High	Done
Purchase Straps	KP Kristina P	Mar 16 – 17	Medium	Done
Deliverable D	jh jhort062@u...	Mar 13 – 15	High	Done

Figure 1 - Table Outlining Plan for Initial Prototype

Figure 2 - Gantt Diagram of Initial Prototype

4.2 Revised Prototype Analysis and Test Results

In the two figures shown below, there is a table listing out every task and a Gantt diagram. The table demonstrates (1) tasks to be done, (2) the person assigned with the responsibility to ensure that a particular task is completed, (3) the importance of the task, and (4) its status. A plan for the upcoming week is also demonstrated.

Task name	Assignee	Due date	Priority	Task Progress
Prototype and Test				
Prototype Floor 4	SK Sachin Kasb...	Mar 21 – 22	Medium	Done
Acquire bolts, nuts, drill	SK Sachin Kasb...	Mar 21 – 22	Medium	Done
Mark flange holes with markers	SK Sachin Kasb...	Mar 21 – 22	Medium	Done
Drill holes in floor for bolts	SK Sachin Kasb...	Mar 21 – 22	Medium	Done
Mount support Beam	SK Sachin Kasb...	Mar 21 – 22	Medium	Done
Prototype Ramp 4	SK Sachin Kasb...	Mar 18 – 22	Medium	Done
Acquire bolts and nuts (8 - one for each flange) - M6	SK Sachin Kasb...	Mar 18 – 22	High	Done
Drill holes in board	SK Sachin Kasb...	Mar 21 – 22	High	Done
Pass nuts through board, support beam, and flange.	SK Sachin Kasb...	Mar 21 – 22	High	Done
Test stability of mount, check flexion of floor with wheelchair.	SK Sachin Kasb...	Mar 18 – 20	High	Done
Attachment 4	gl glele049@u...	Mar 18 – 22	High	Done
Acquire metal parts for attachment	gl glele049@u...	Mar 18 – 19	Medium	Done
Print out design to follow during welding	gl glele049@u...	Mar 18 – 19	Medium	Done
Weld components together	jh jhort062@uo...	Mar 20 – 22	High	Done
Test system by mounting it to wheel of bike	jh jhort062@uo...	Mar 20 – 22	High	Done
Mount Straps and Anchors 2	KP Kristina P	Mar 18 – 22	Medium	Done
Drill holes to mount straps	KP Kristina P	Mar 18 – 20	Medium	Done
Pass bolts through floor with	KP Kristina P	Mar 21 – 22	Medium	Done
Electronic PCB 3	RU Raghav Kaus...	Mar 23 – Today	High	In Progress
Create Diagram for PCB Design	RU Raghav Kaus...	Mar 18 – 22	High	Done
Solder components	RU Raghav Kaus...	Today – Mar 25	Medium	In Progress
Test soldered system	RU Raghav Kaus...	Today – Mar 26	Medium	Not Start...
Electronic Housing 3	KP Kristina P	Mar 25 – 31	Medium	Not Start...
Design Housing	KP Kristina P	Mar 25 – 26	Medium	Not Start...
Laser Print/Construct housing	KP Kristina P	Mar 27 – 28	High	Not Start...
Mount Housing to bike (probably zip ties but maybe bolt/nuts)	KP Kristina P	Friday	Medium	Not Start...
Paint 2	jh jhort062@uo...	Mar 25 – 29	Low	Not Start...
Acquire Black Paint	jh jhort062@uo...	Mar 25 – 26	Medium	Not Start...
Use University paint room to apply it to mount system	jh jhort062@uo...	Mar 27 – 29	Medium	Not Start...
Mount Electronics 3	jh jhort062@uo...	Mar 25 – 29	Medium	In Progress
Measure out wire length	jh jhort062@uo...	Mar 25 – 26	Medium	Not Start...
Solder wires to the PCB and Connectors	jh jhort062@uo...	Mar 25 – 26	Medium	Not Start...
Mount and attach system to the bike and trailer	jh jhort062@uo...	Mar 27 – 29	Medium	Not Start...
Reworking the Attachment	gl glele049@u...	Mar 25 – 30	Low	Waiting
Deliverable E	SK Sachin Kasb...	Mar 21 – Today	High	In Progress

Figure 3 - Gantt Diagram for Revised Prototype

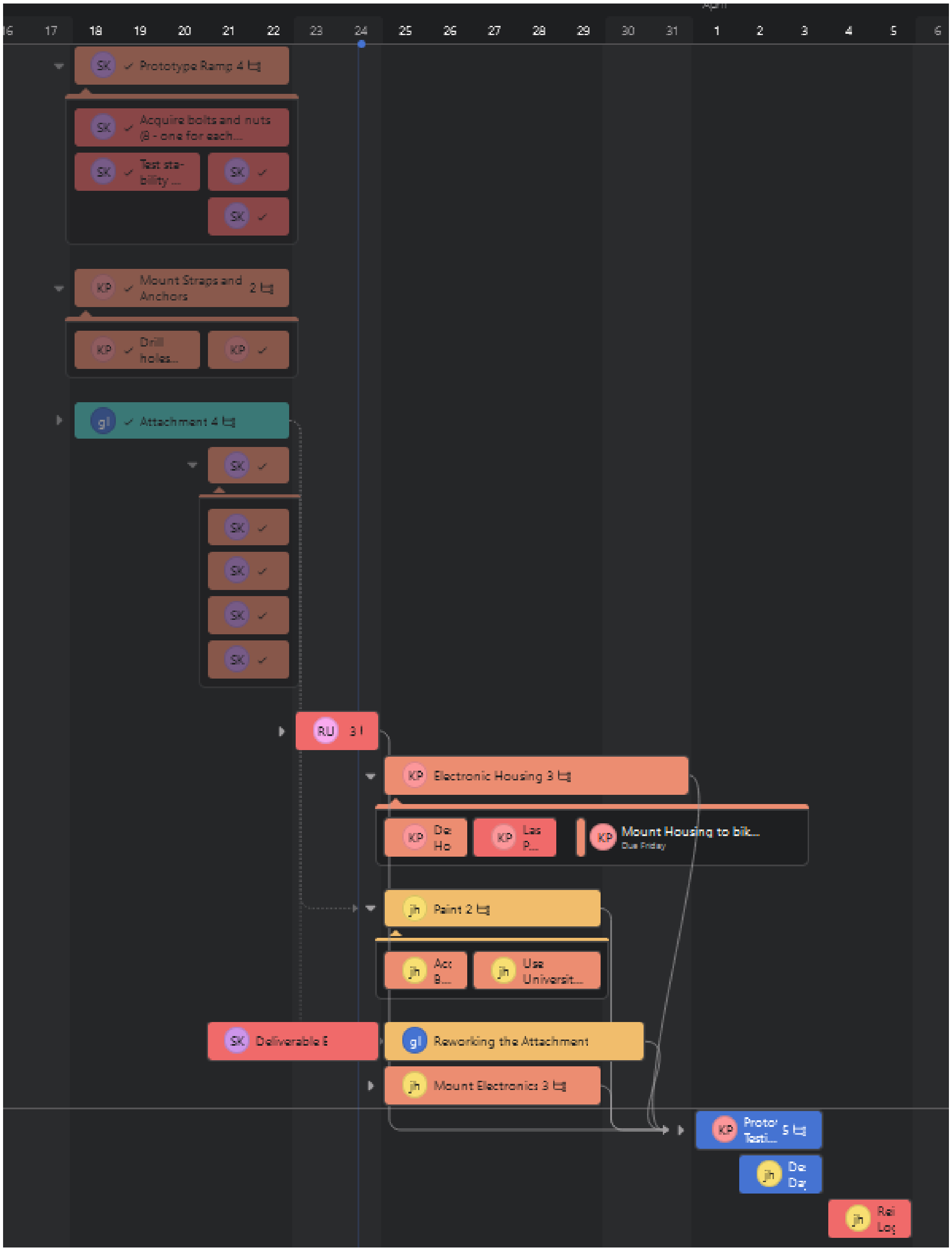


Figure 4 – Gantt Diagram for Revised Prototype Analysis and Test Results

5 Conclusions and Recommendations for Future Work

In conclusion, most of the electrical and mechanical features of the inclusive bike have been prototyped, and test results have been promising. On the mechanical side of things, the manufacturing process the manufacturing process has started and the physical prototype completion is in progress. On the electrical side, the Components are being soldered onto the PCBs for the finall assembly. The electrical system needs to be mounted and wired onto the physical prototype. A box for housing the electronics needs to be created.