Element D

Design Concepts Generation, Analysis, and Selection

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Introduction

After determining the design specifications for the hand-control driving aid, the next step is to create designs. By analyzing previous solutions on the market and collecting preferences on certain features through an independent survey, each member brainstormed individually and then created individual design concepts, and then continually narrowed down and combined ideas until finalizing one design. This report follows the process of developing and selecting a design.

Problem Statement

A spinal cord injury damages nerves which can cause long-term or permanent loss of function below the waist. Driving with this injury is impossible without special equipment and modifications. As of 2011, 36.5% of people with a spinal cord injury (SCI) in the US are reported to drive a modified vehicle. Studies show that this low number can be attributed to the high price of around $20,000 to $80,000 for modifications. Most patients feel a decreased quality of life because of their lack of transportation and fear of driving without another person's help.

Selecting a Design

Many processes were carried out to select a final design that the team agreed on. To start, each team member brainstormed a list of specific ideas for each different part of the hand-controlled driving aid. After researching and analyzing existing products and their functions, a list of design specifications that should be included in the final design was compiled (See Appendix A for full list).

- Performance: The hand-control driving aid shall allow customers to operate a vehicle using only their hands by having control over both braking and accelerating mechanisms.
- Installation: The hand-control driving aid should be able to be installed independently and easily by the user within three minutes.
- Length: The hand control driving aid shall be expandable of a minimum of 5 additional inches and the minimum length of the shaft will be 24 inches.
- Clamp: There must be a clamp that is securely locked onto the pedal so that it cannot be moved with less than 500 lbs of force.

Using this list, six concept sketches were created along with a description of the operation, two for each member (See Appendix B for others). There are many possible solutions, most involving a device that manually pushes down on each pedal. Using a decision matrix that

consisted of features of ease of installation, weight, simplicity, ease of use, affordability, preference, size, safety, and adjustability of the product, the top three designs were chosen to be shown to customers (See Appendix E for full matrix). They were presented in a survey that was sent out to relevant people and included questions asking about preferences for specific features of the product that were different in each design.

Figure 4.1: Concept Design Matrix

Decision Matrix

Designs	Ease of Installation	Weight	Simplicity	Ease of Use	Affordability	Preference	Size	Safety	Adjustibility	**Total Score**
1	9	8	6	10	6	9	7	7	10	72
2	9	5	8	7	5	5	7	5	10	61
3	10	8	8	9	7	6	6	5	10	69
4	10	9	8	6	8	4	7	2	10	64
5	9	6	6	10	6	9	6	7	10	69
6	9	6	7	9	6	7	6	7	10	67

The highest-rated concept designs shown in the matrix were chosen to be added to the customer survey for the public to choose from.

The survey results concluded that the product should include adjustability features, a push/pull function, a rubber handle grip material, and a horizontal handle orientation. The design was altered to include the preferences of the customers (See Appendix D for all data). The team agreed on a final design that was safer, less expensive, and more unique than current market competitors.

Concept #1: Push-pull single-handle Hand-controlled Driving Aid
This design operates by pushing to accelerate and pulling to brake. The height is adjustable and features a horizontal, rubber handle. This concept would estimate to take less than 2 minutes to install as it involves velcro to the floor of the car and screws to clamp.

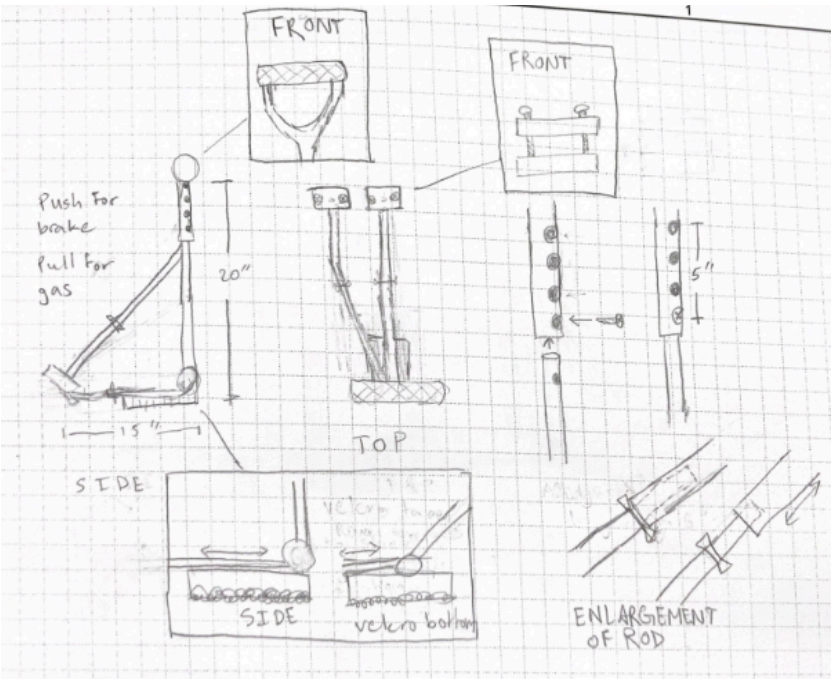


Figure 4.2: Concept #1: Push-pull single-handle hand-controlled driving aid

Concept #2: Double-handle Hand-controlled Driving Aid

This sketch includes multiple possible designs of clamps for the brake and accelerator pedals, handle grips, and rod and the adjustment. The clamps are designed as a sandwich clamp that consists of two parts: one that goes above the pedal and one that goes under. The handle design includes a gripped rubber material to provide more comfort for the user. The adjustment designs include a clamp that can be tightened and a rod with holes with a rod that can slide inside.

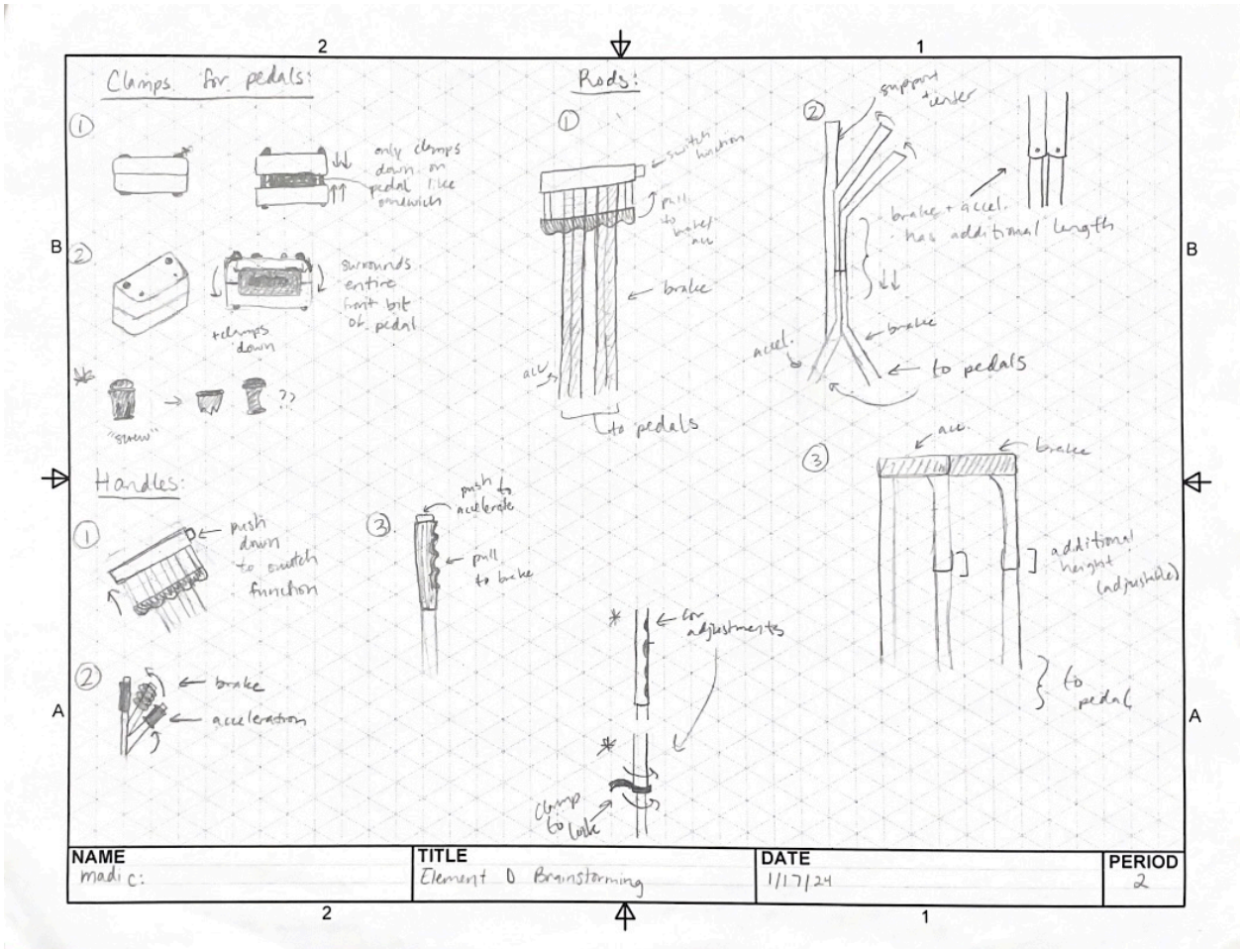


Figure 4.3: Concept #2: Set of designs for various parts

Concept #3: Push-pull Hand-controlled Driving Aid

This design consists of a handle and three rods that push down on the accelerator and brake pedals to operate the vehicle. The user pushes the handle on top to brake the car: the rod attached directly to the casing moves forward with the handle. The user pulls the handle to accelerate the car: the road moves back with the handle and pushes the rod that it is connected to forward. It includes a casing around the rods for stabilization and safety.

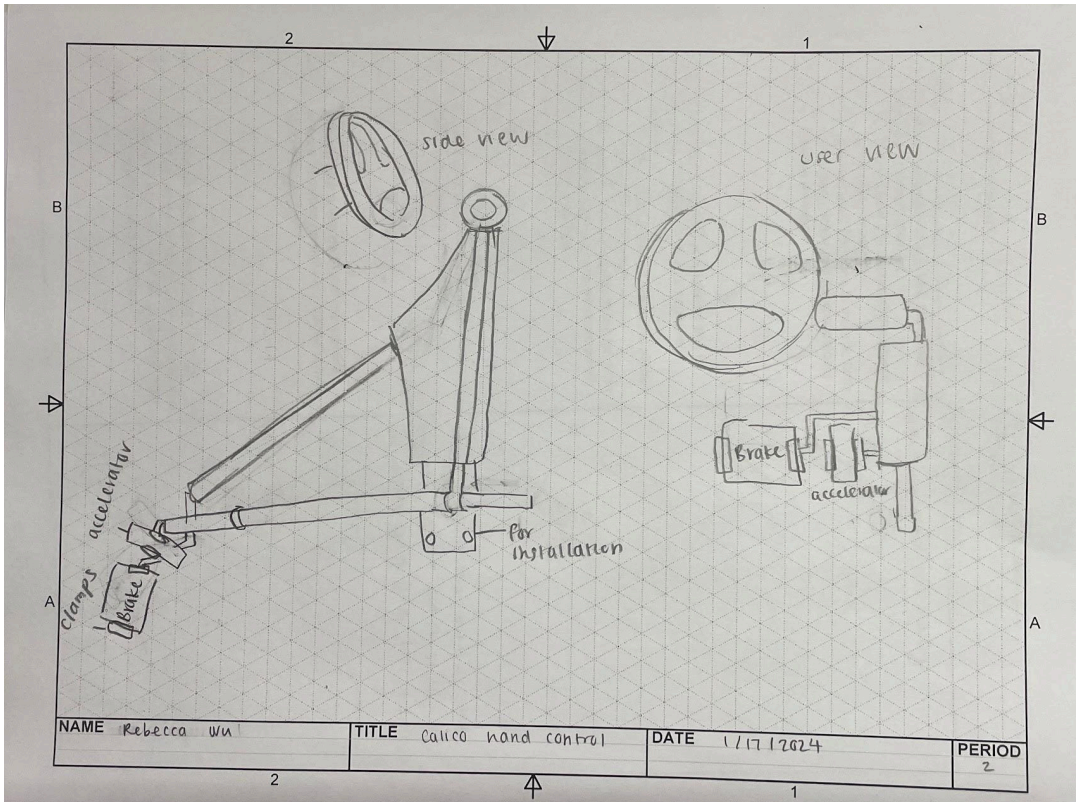


Figure 4.4: Concept #3: Push-pull Hand-Controlled Driving Aid

Voice of Customer Survey Data

A survey was conducted and sent to people in or related to the medical field. Of the responders, 45.5% were nurses or caretakers who work with patients, 6.1% responders were patients or former patients of SCI, and 12.1% were relatives or friends of SCI patients. The first question asked the responders how they would prefer to use the product with the handle. This would decide a major feature of the final product and how it compares to other solutions on the market. 60.6& of the respondents preferred to use one handle and push to brake while pulling for acceleration, which was considered in the final design.

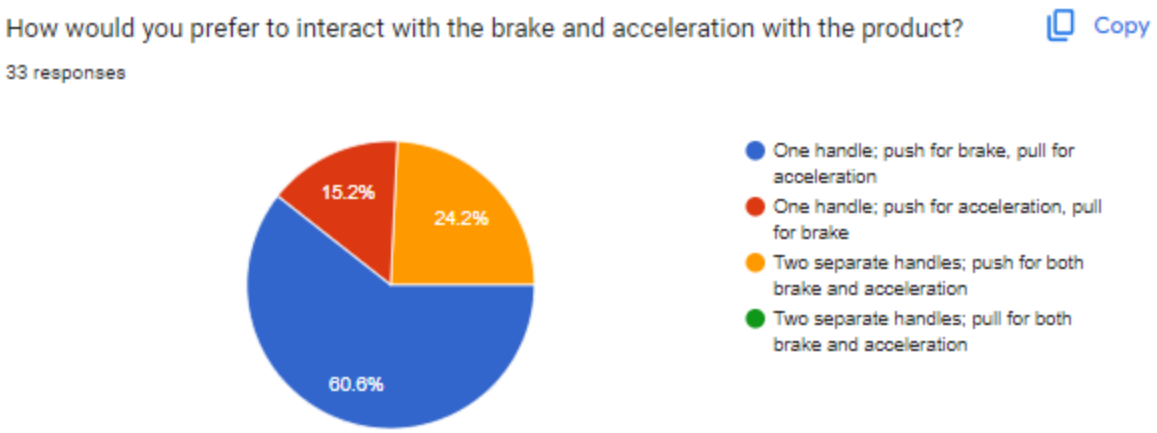


Figure 4.5: Survey results of which handle interaction is most preferred

An important feature of the device is the adjustability of the height. Having this function will allow customers to move the two rods connected to the pedal clamps from 16 to 24 inches and provide comfort during use. However, since this feature is not necessary for the main function of the driving aid, questioning the importance of adjustability on the survey would help decide whether it should be included in the final design. The majority of respondents answered between 7 and 10, with 30.3% of all respondents answering with 10. Adjustable rods were added to the final design of the product.

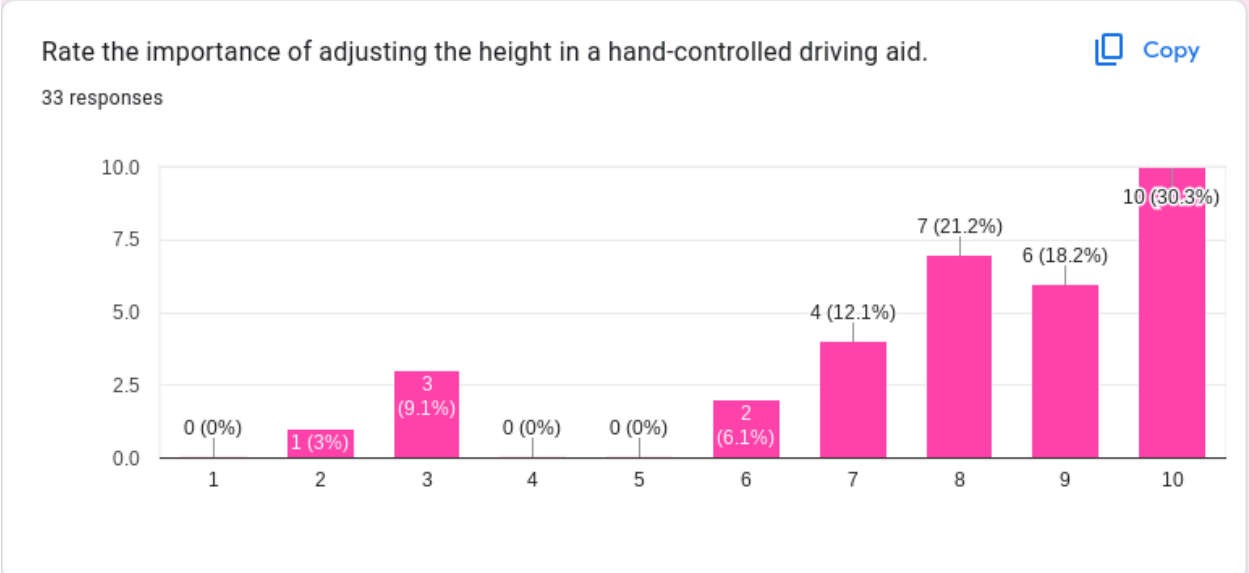


Figure 4.6: Survey results ranking the importance of adjustability of the hand-controlled driving aid

Final Design

Using the original concept designs of each team member combined into one and customer survey feedback, the final drawing of the product was created (for detailed drawings of each part, see Appendix F).

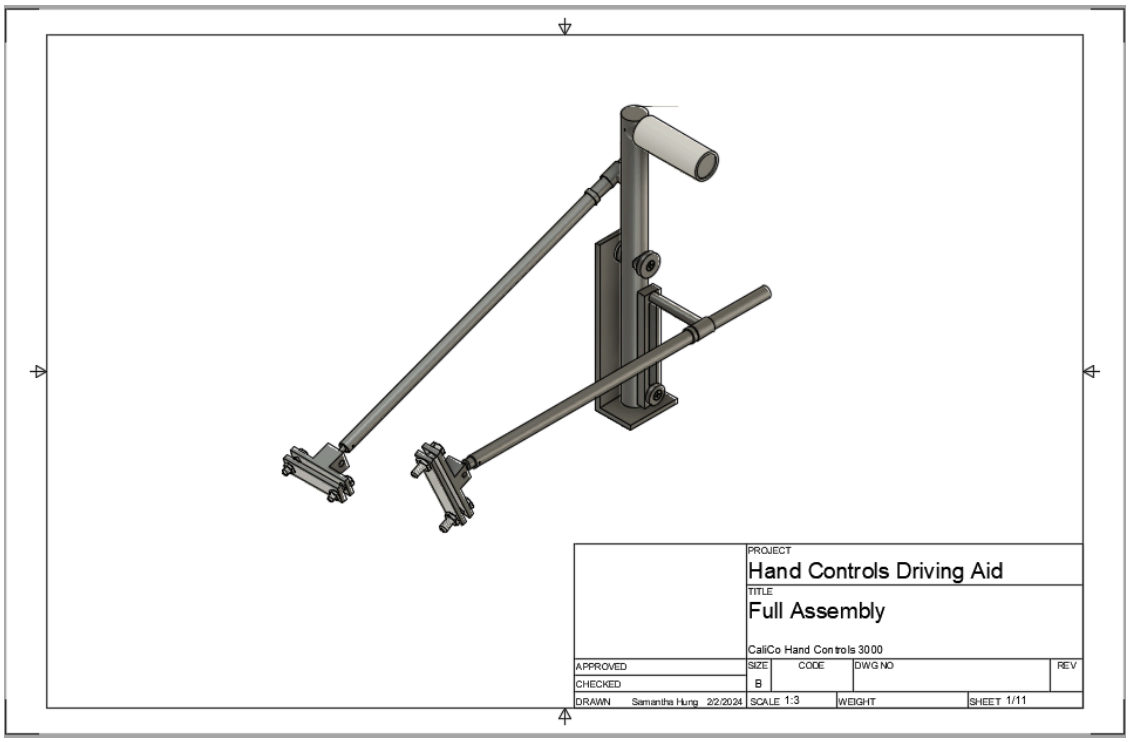
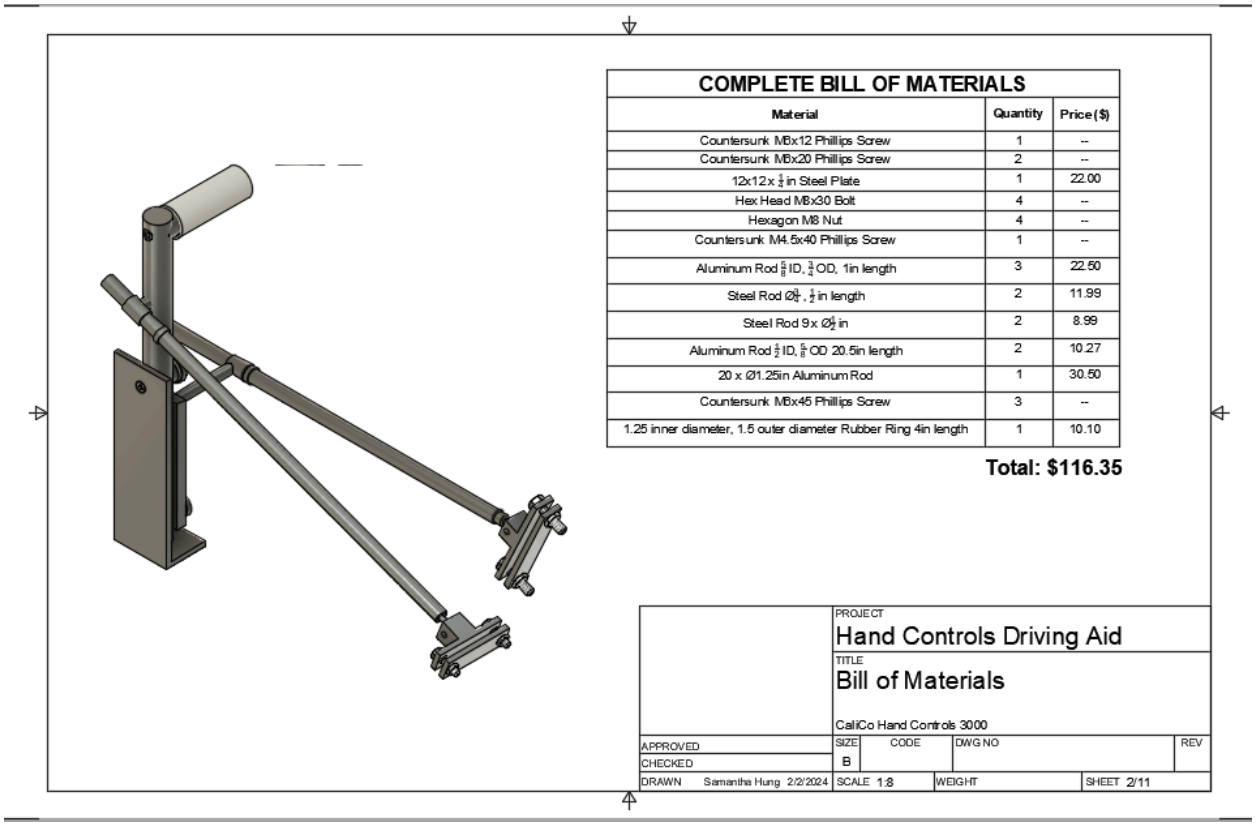


Figure 4.7: Isometric view of the full and final design of the hand-controlled driving aid

Figure 4.7 showcases a hand-controlled driving aid with one handle that pushes to break and pulls to accelerate, a rubber grip, and a horizontal handle orientation that follows the customer survey results.



COMPLETE BILL OF MATERIALS

Material	Quantity	Price ($)
Countersunk M8x12 Phillips Screw	1	--
Countersunk M8x20 Phillips Screw	2	--
12x12 x $\frac{1}{4}$ in Steel Plate	1	22.00
Hex Head M8x30 Bolt	4	--
Hexagon M8 Nut	4	--
Countersunk M4.5x40 Phillips Screw	1	--
Aluminum Rod $\frac{5}{8}$ ID, $\frac{3}{4}$ OD, 1in length	3	22.50
Steel Rod Ø$\frac{1}{4}$, $\frac{1}{2}$ in length	2	11.99
Steel Rod 9 x Ø$\frac{1}{2}$ in	2	8.99
Aluminum Rod $\frac{1}{2}$ ID, $\frac{5}{8}$ OD 20.5in length	2	10.27
20 x Ø1.25in Aluminum Rod	1	30.50
Countersunk M8x45 Phillips Screw	3	--
1.25 inner diameter, 1.5 outer diameter Rubber Ring 4in length	1	10.10

Total: $116.35

PROJECT: Hand Controls Driving Aid
TITLE: Bill of Materials
CaliCo Hand Controls 3000
APPROVED
CHECKED
DRAWN Samantha Hung 2/2/2024
SIZE B | CODE | DWG NO | REV
SCALE 1:8 | WEIGHT | SHEET 2/11

Figure 4.8: Another isometric view of the final design including a bill of materials

Figure 4.8 includes a bill of materials which provides information on the material of each component of the final product. For the main rods and components, a combination of steel and aluminum is used which follows the initial design specifications seen in Appendix A.

Product Description

The product is a hand-controlled device that allows the user to drive with only the use of their hands. The driving aid includes two pairs of separate aluminum rods that extend from the larger main body of the device down to both pedals. One pair of rods extends to the brake pedal, and the other two rods extend to the accelerator pedal. The main body of the device consists of one large rod fastened onto an L-shaped 9 x 3 x ¼ steel platform with a countersunk screw. Protruding to the left side on the superior end of the main rod is the 1.5-inch diameter and 4-inch long handle which is positioned in a horizontal orientation. This handle is covered by a 0.25-inch thick layer of rubber.

There are a series of nine 0.125-inch diameter holes 1 inch apart from each other on the superior end of the lower rods that extend to the accelerator and brake pedals to allow the user to adjust the device to their desired length anywhere from a minimum of 16 inches to 24 inches. The new length can be secured by placing a ¾ inch diameter and ½-inch-long steel rod through one of the nine holes. On the lower end of these rods are rectangular steel clamps that latch onto the car pedals with a sandwich-like mechanism. On the top layer clamp is one Hex Head M8 x 30 Bolt on both sides of where the rod is connected to the clamp. On the bottom layer clamp, an M8 Steel Nut is used to secure the Hex Head M8 x 30 Bolts coming through from the top layer clamp. A hinge joint type of mechanism, including a cylinder-like shape that is directly connected to the rod and the open space in the clamp, is used to connect the rod to the clamp. This joint mechanism is kept in place by a smaller smooth 0.25-inch diameter rod going through the center of the cylinder-like shape in the main rod.

The superior ends of the accelerator and brake rods are attached to opposite sides of the main body. The accelerator rod is attached directly to the main rod with a countersunk screw and the clamp is in a horizontal position. The brake rod extends out from the main rod with a countersunk screw and the clamp is in a vertical position.

Operation

The product should allow the user to drive an auto-transmission vehicle without the use of their lower body. To properly install the device to the vehicle, the input would be to attach the clamps onto the brake and accelerator pedals by tightening two bolts and nuts for each clamp. This process should take no more than three minutes. The output would be the attached and installed device that rests on the right hand side of the driver.

To interact with the accelerator pedal, the input would be pushing the horizontal handle forward. When the handle is pushed forward, the main rod tilts forward to prevent the pair of rods extending to the brake pedal from moving in the same direction. The output would be the pair of rods clamped onto the accelerator pedal pushing down on that pedal with a force proportional to the user’s pushing force on the handle.

To interact with the brake pedal, the input would be pulling the horizontal handle towards the user. A pulling motion causes the main rod to tilt back to shift the appropriate pair of rods forward while preventing the pair of rods extending to the accelerator pedal from moving in the same direction. The output would be the pair of rods clamped onto the brake pedal pushing down on that pedal with a force proportional to the user’s pulling force on the handle.

Justification

This product solves the issue of a lack of independent driving by recovering spinal cord injury patients. The final concept was chosen because of its simplistic design and operation.

It is better than alternative solutions for multiple reasons. The simple design reduces hassle and allows for a shorter installation process as the only requirement is to screw in the clamps to secure the pedals to the product. The design also saves time and leads to an easier and shorter production process as there are no complicated mechanics to make sure the appropriate pedals are being pushed down. This design follows all significant design specifications listed in Appendix A. It allows the customers to operate the vehicle using only their hands and to install the product independently. The design has a ribbed handle, allows for the rod to adjust to 24 inches in length, and is sized appropriately so the user can decide where to place the hand-controlled driving aid. The simplicity of the design also allows it to be lightweight and under or equal to 10 lbs. The entire product is to be made out of stainless steel and aluminum for durability. The handles are covered by a decent layer of rubber for comfort and security. This material also allows the product to withstand a temperature of 110^{o}F and to be used with rarely any maintenance. The clamp is secure enough so the product cannot be moved with less than 500 lbs of force. Regarding aesthetics, the customers will have an option of paying extra to customize the product by spray painting it baby pink and white or gray and black and will be finished with a sealant to maintain a clean appearance. Overall, this design will improve the quality of life of the user because it allows them to drive comfortably and independently.

Conclusion

Many different factors were considered when selecting the final design of the product. The numerous brainstormed ideas were brought down to three separate designs by comparing the features and functions of each. A customer survey was also conducted to ensure the success of the product in the market. Using the initial concept sketches and customer feedback, a final design was decided on and created using Fusion 360. The intended operation of this device is to allow spinal cord injury patients to drive a vehicle independently and with only the use of their upper body. Each feature of the CaliCo Hand Control 3000 aligns with the specifications which are outlined in the Justification section and Appendix A of this document.

Appendices

Appendix A: Design Specifications

1. **Performance**
    - **Specification:**
      The hand-control driving aid shall allow customers to operate a vehicle using only their hands by controlling both braking and accelerating mechanisms.

      Rationale:
      All current hand-control driving aids on the market[1] allow any disabled driver without the function of their lower body to fully have access to the brake and accelerator pedals.

    - **Specification:**
      The hand-control driving aid should be able to be installed independently and easily by the user within three minutes.

      Rationale:
      The device allows for the user to have more independence if installation requires the effort of one person.[2]

2. **Customer Needs/Ergonomics**
    - **Specification:**
      The hand control driving aid shall have a gripped handle within arms' reach.

      Rationale:
      By placing the handle within arm's reach, the hand can rest comfortably on the driving aid which allows the user to be able to drive for long hours without discomfort. A gripped handle will also increase the comfortability of use.

    - **Specifications:**

[1](N.d.). Retrieved from https://docs.google.com/spreadsheets/d/1jNNn9SnTOoFmn8VdnXaJ8JoZ5-aqWw5v3OziMGyrtQg/edit#gid=1246083777

[2]Standards for Automotive Adaptive Equipment. (2021). Retrieved from https://www.acces.nysed.gov/vr/standards-automotive-adaptive-equipment#Primary

Users shall be able to decide where to place the hand-controlled driving aid device in relation to the OEM pedals or steering wheel/column.

Rationale:
According to Hand Controls 16.5 in the Quality Assurance Program (QAP)[3] Guidelines, when installing mechanical/manual hand controls in a vehicle with adjustable OEM (Original Equipment Manufacturer) parts, the pedal or steering column must be rendered non-adjustable. The mobility equipment dealer, driver rehabilitation specialist, and client shall determine the location of the OEM pedals or steering wheel/column before disconnection.

3. Size and Weight Specifications

- **Specification:**
  The hand-control driving aid shall not weigh over 10 pounds.

  Rationale:
  Based on the current products on the market, the average range was 3-15 lbs, thus any weight less than 10 lbs is considered lightweight.

- **Specification:**
  The hand control driving aid shall be expandable of a minimum of 8 additional inches and the minimum length of the shaft will be 16 inches.

  Rationale:
  Most of the current products on the market include an adjustable feature for user comfort and have a minimum length of 16 inches to stretch from the brake and accelerator pedals to where the hand is placed.[4]

4. Materials

- **Specification:**
  The hand-control driving aid shall be made out of steel or aluminum.

  Rationale:

[3]QAP Guidelines. (2023). Retrieved from https://nmeda.org/qap/guidelines/
[4](N.d.). Retrieved from https://docs.google.com/spreadsheets/d/1jNNn9SnTOoFmn8VdnXaJ8JoZ5-aqWw5v3OziMGyrtQg/edit#gid=1246083777

According to the Similar Solutions Matrix[5], all rods were made out of either steel or aluminum. This is because steel is durable and rigid, and aluminum is lightweight. These two materials have different benefits depending on what properties are needed.

- **Specification:**
  The hand-control driving aid will use an insulated material, such as rubber, for the handle, so it is comfortable to hold.

  Rationale:
  According to Scott's Fort Collins Auto[6], the temperature inside a car is typically 48 degrees Fahrenheit greater than the outdoor temperature in the summer. Therefore, it often reaches over 100 degrees Fahrenheit. Because of this, it is dangerous to touch conductive metals such as steel in this environment; thus an insulated handle is vital.

5. Safety and Legal Issues

- **Specification:**
  There must be a clamp that is securely locked onto the pedal so that it cannot be moved with less than 500 lbs of force.

  Rationale:
  The average force a clamp applies is 500 lbs. This ensures that the product is secured and can not be moved unintentionally.

- **Specification:**
  The hand-control driving aid shall only be installed in automatic transmission vehicles.

  Rationale:
  To ensure safety, the device should not be able to detach from the pedals without a significant amount of force added. According to Hand Controls 16.1 in the Quality Assurance Program (QAP) Guidelines, "Hand controls for accelerator and

[5](N.d.). Retrieved from https://docs.google.com/spreadsheets/d/1jNNn9SnTOoFmn8VdnXaJ8JoZ5-aqWw5v3OziMGyrtQg/edit#gid=1246083777

[6]How Hot Do Cars Get in the Summer?: Scott's Fort Collins Auto. (2019). Retrieved from https://www.scottsfortcollinsauto.com/how-hot-do-cars-get-in-the-summer/#:~:text=After%20an%20hour%2C%20the%20average,temperature%20ever%20recorded%20on%20earth

brake operations shall only be installed in vehicles with power brakes, power steering, and automatic transmission.[7]"

6. Target Cost

- **Specification:**

  The manufacturing cost for this product will not exceed $200. The market price will be on the lower end ranging from $200-250. The profit margin shall range from 10-20%, thus the selling product shall be 10-20% greater than the production cost.

  Rationale:

  The average cost of a product in the market is $500. This product aims to be below the average cost to be more accessible to users. According to a survey conducted on patients, their family members, and their nurses, the majority would pay more than $200 for this product. Therefore, it's most appropriate to cap the production price at $200 and have the selling price be 10-20% higher.

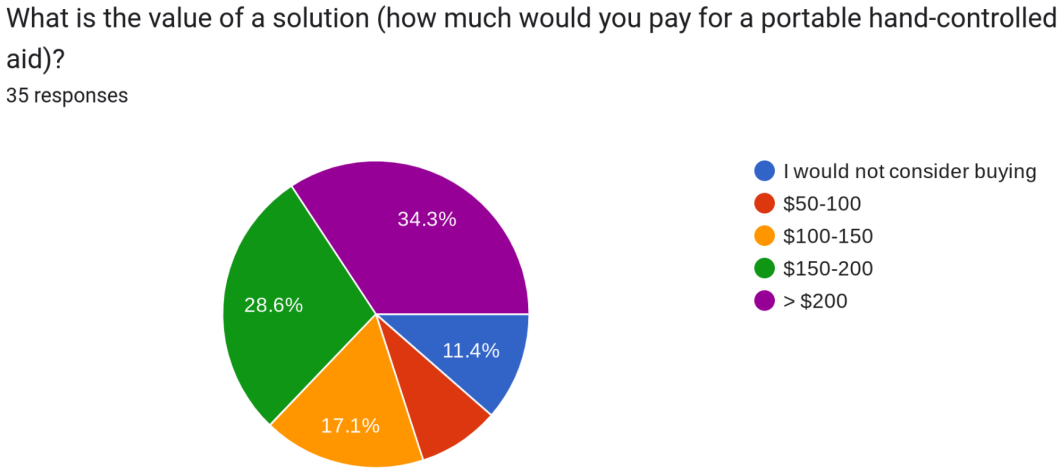


Figure 4.9: Value of a Solution - Survey Responses

34.3% of 35 survey takers would be willing to pay over $200 for a portable hand-controlled driving aid.

7. Service life/Durability

- **Specification:**

  The hand control driving aid will be functional for around 50 years.

[7] QAP Guidelines. (2023). Retrieved from https://nmeda.org/qap/guidelines/#_Toc72740541

Rationale:

According to Metals Warehouse, an ISO-certified company, aluminum has a lifespan of over 40 years. Stainless steel can last over 50 years.[8]

8. Operating Environment

- **Specification:**

  The hand control driving aid will be able to withstand a temperature of 110° Fahrenheit.

  Rationale:

  According to a study conducted by scholars from Stanford School of Medicine, the interior of a parked vehicle during a summer day can reach temperatures of 72 to 96 degrees Fahrenheit.[9]

Table 1: Estimated Vehicle Interior Air Temperature vs. Elapsed Time

Estimated Vehicle Interior Air Temperature vs. Elapsed Time						
Elapsed Time (minutes)	Outside Air Temperature (°F)					
	70	75	80	85	90	95
0	70	75	80	85	90	95
10	89	94	99	104	109	114
20	99	104	109	114	119	124
30	104	109	114	119	124	129
40	108	113	118	123	128	133
50	111	116	121	126	131	136
60	113	118	123	128	133	138
>60	115	120	125	130	135	140

Table 1 displays various estimated interior air temperatures as time progresses in specific external air temperatures.

9. Maintenance

- **Specification:**

  Aluminum parts of the hand control driving aid will require no maintenance. Stainless steel is used, and maintenance will be required every once a month.

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[8]Asdf, A. (2021). The Lifespan & Recyclability Of Aluminium And Steel. Retrieved from https://www.metalswarehouse.co.uk/lifespan-recyclability-aluminium-steel/#:~:text=Stainless%20steel%20refers%20to%20any,corrosion%20due%20to%20water%20exposure

[9]Inside Car Temperature Calculator. (n.d.). Retrieved from https://goodcalculators.com/inside-car-temperature-calculator/

Rationale:
Aluminum requires no maintenance. Stainless steel is highly resistant to scratches, dents, and warping, and it will be able to function well without much maintenance. However, it must be cleaned once a month to prevent the material from rusting.

10. Aesthetics

- **Specification:**
  The hand-control driving aid will come in the colors baby pink and white to create a distinguishable design and appeal to target consumers.

  Rationale:
  To create a design that is unique and stands out from other products which are usually black or gray, the CaliCo's hand controls will have an iconic pink tint.

- **Specification:**
  The hand-control driving aid will be finished with sealant.

  Rationale:
  To avoid scratches and maintain a clean appearance, a finish will be added. This will also keep the paint from peeling.

Appendix B: Brainstorming Ideas

- **Material/Form:**
  - All stainless steel (including rod, handles, screws); rubber padding to cover handle for comfort
  - Stainless steel for only rod and handles; aluminum for the screws
  - Foam pads for cushion on handles
  - Rubber for cushion on handles
  - Bamboo for rod + handles; foam padding for cushion on handle; stainless steel for screws
  - Bamboo for rod + handles; rubber padding for cushion on handle; stainless steel for screws
  - Skinnier shape for more space in driver seat area (just rods, no protective covering)

    - Bulkier shape (protective covering over both brake and acceleration rods to ensure no items get stuck and cause issues)
    - Plastic covering
    - Bamboo covering
    - Ridges on handles for better grip
    - Depressions for fingers to fit into on handles
    - Ridges, but no depressions (rubber)
    - depressions, but no ridges (rubber)
    - Ridges, but no depressions (foam)
    - Depressions, but no ridges (foam)
    - Multiple holes in rod for ultimate length adjustment
- **Function**:
    - Brake and Acceleration:
        - Switch attached on side (flipped up for accelerate and flipped down for break)
        - Button attached on side (hold down to brake and release to accelerate)
        - 2 separate handles to pull/push on right next to each other (one for brake, one for acceleration); vertical
        - 2 separate handles to pull/push on right next to each other (one for brake, one for acceleration; at an angle for ease of use
        - With additional third rod as support
        - 2 separate handles to pull/push on right next to each other (one for brake, one for acceleration; at an angle for ease of use
            - No rod
- **Attachment to Pedals:**
    - Claw-like clamps (stainless steel)
    - Claw-like clamps (aluminum)
    - Claw-like clamps (bamboo)
    - Surrounding clamps (stainless steel)
    - Surrounding clamps (aluminum)
    - Surrounding clamps (bamboo)
    - Sandwich-like clamps (stainless steel)
    - Sandwich-like clamps (aluminum)
    - Sandwich-like clamps (bamboo)
- Consists of 2 parts
    - One part for each pedal: braking and acceleration
    - Can use 1 handle with 2 functions
        - push/pull
        - push/rock
        - push/right angle

- Using push/rock: push to brake, pull to accelerate
    - Uses 2 rods/parts
        - Push causes rod 1 to push down on the brake pedal
        - Pull causes rod 1 to extend and cause rod 2 to move forward and push down on accelerator
- Using 2 handles
    - One handle for each function
    - Push right handle in to accelerate
    - Push left handle in to brake

Need:

- Allows user to operate device with only hands
- Able to be installed independently (3 min)
- Gripped handle and within arm's reach
- User can decide where to install device
- <10 lbs
- Adjustable to an additional 5 inches of the 20 inch shaft
- Made from steel or aluminum
- Clamp is securely locked to pedal and cannot be moved w/ <500 lbs of force
- Only installed in auto transmission vehicles

Want:

- Insulated material (rubber) for the handle
- Manufacturing cost < $200
- Market price $200-250
- Can be used for >50 years
- Can withstand 110 degrees Fahrenheit
- Will be pink or white
- Finished with a sealant

Brainstorming Sketches

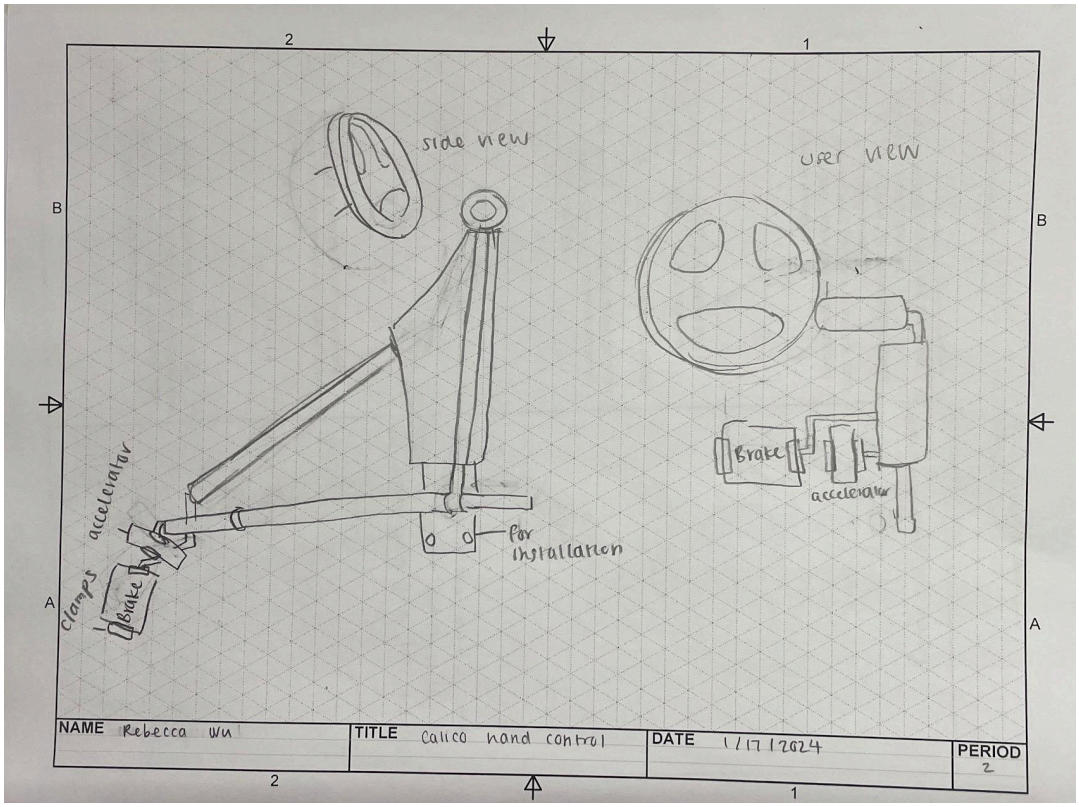

Figure 4.10: Initial Push/Pull hand-controlled driving aid design

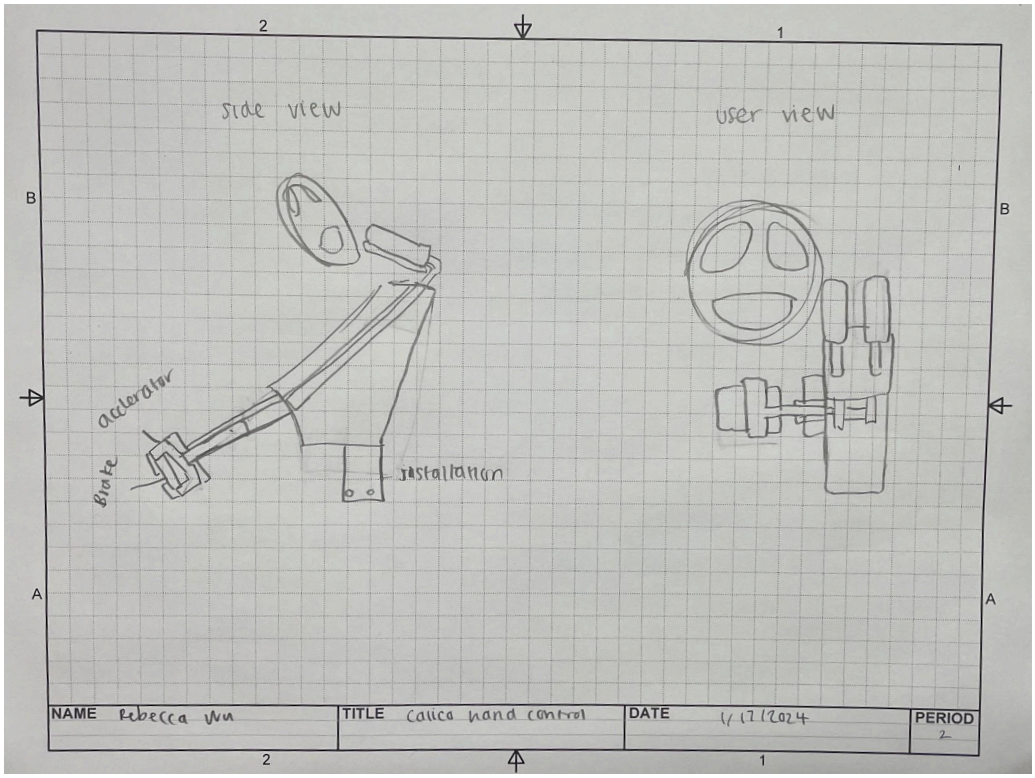

Figure 4.11: Initial double handle hand-controlled driving aid design

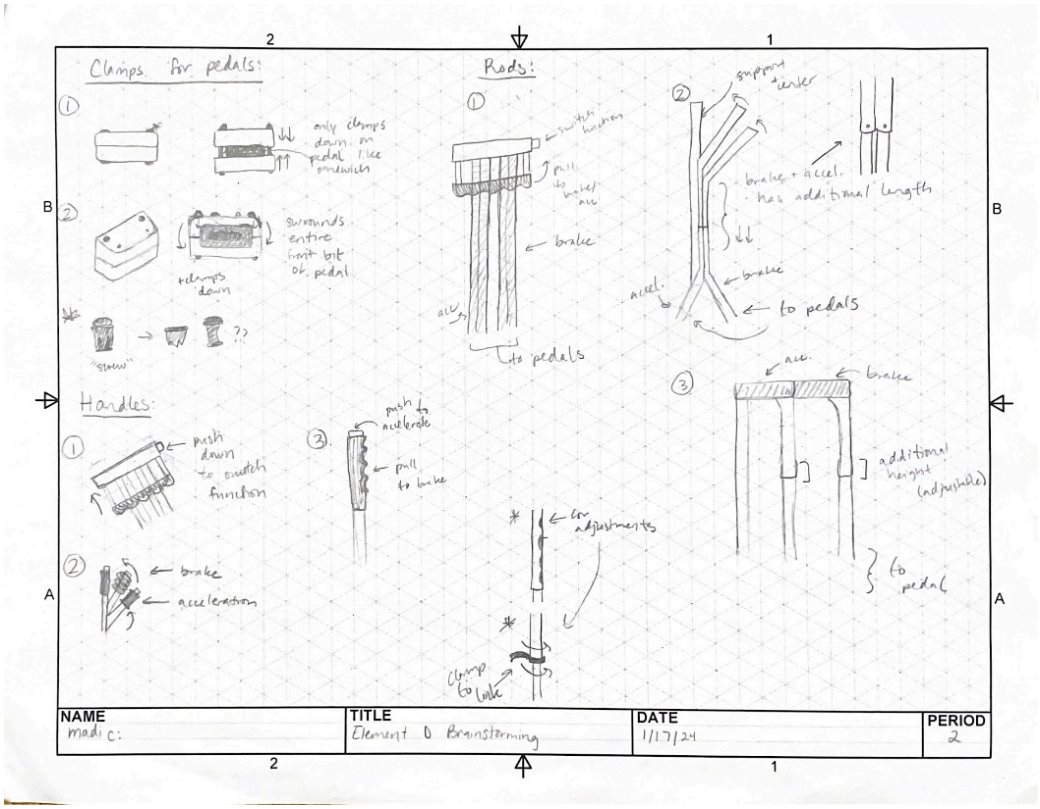

Figure 4.12: Various designs of separate parts of the product

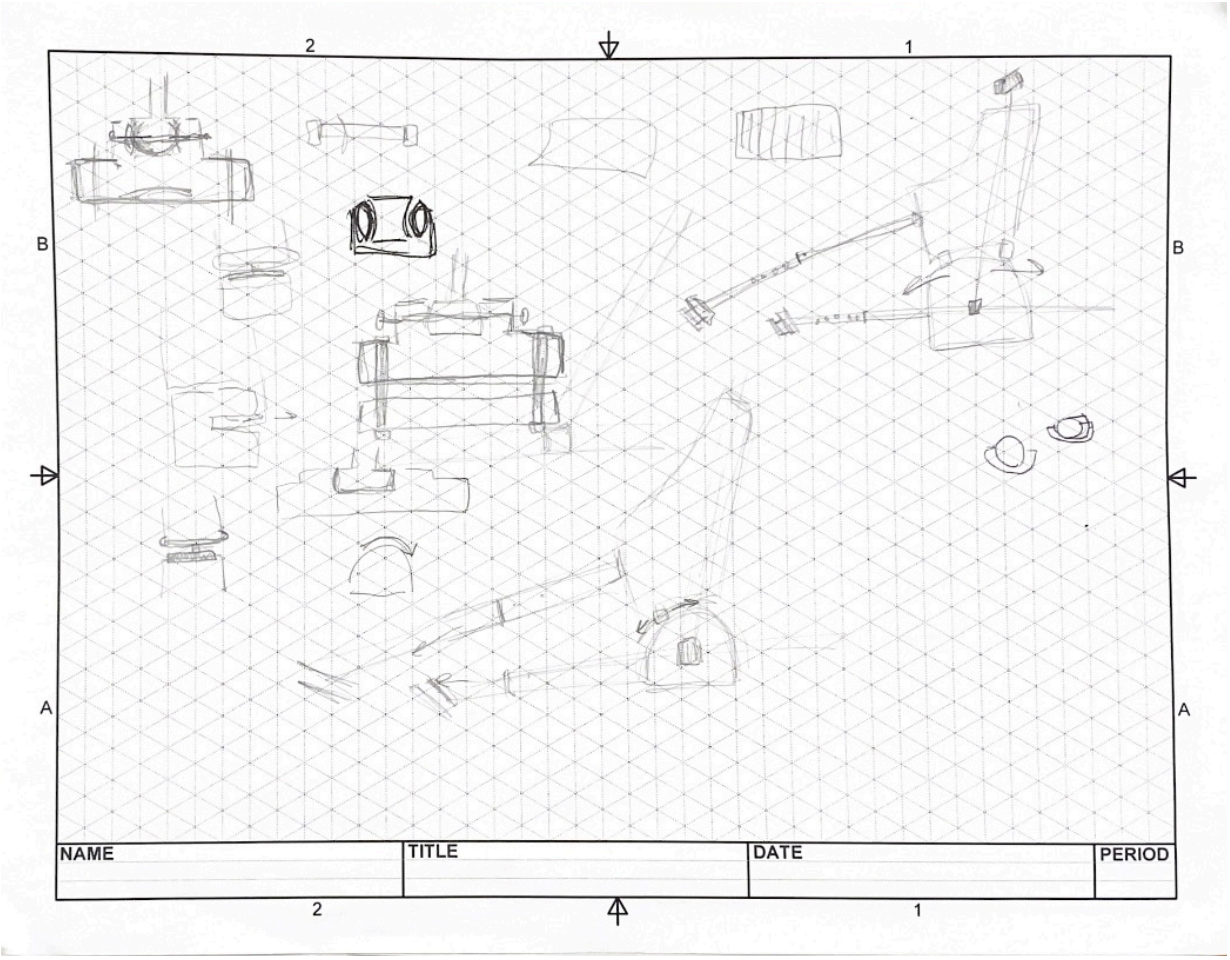

Figure 4.13: Specific designs related to adjustability, clamps, and rotational functions

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Appendix C: Product Concepts

Concept 1

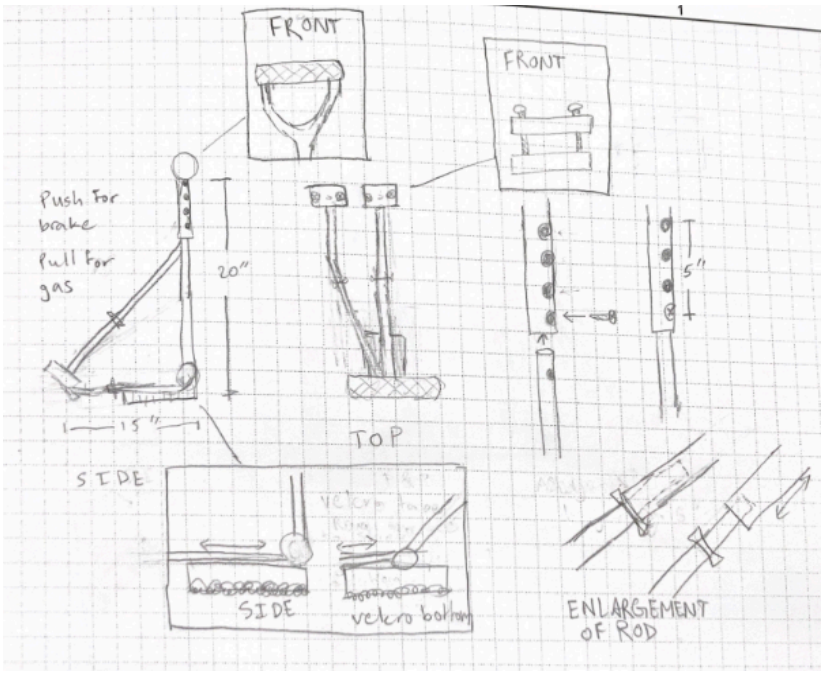

Figure 4.14: Concept #1: Push-pull single handle hand-controlled driving aid

Product Description

A push/pull hand control allows people with spinal cord injury (SCI) to drive using their hands. The product uses clamps to secure the brake and gas pedal and lies flat on the floor of the car on the driver's side. The bottom of the hand controls have velcro and come up with velcro tape to put on the ground to avoid slippage. Two metal rods connect the handles to the pedals, which are adjusted with a screw and various holes at different lengths. The handle will be made out of silicone with a criss-cross design to make it easier to grip.

Operation

The clamps sandwich the pedal with two flat blocks of aluminum that have screws on either side. By pushing the handle forward, the metal rod presses down on the gas. The farther forward the user pushes, the harder it presses on the gas pedal. Conversely, by pulling the handle towards the user, a separate rod is used to connect to the brake pedal. In the case of an emergency, yanking the handle towards the user will be able to brake quicker.

Justification

With this simplistic design, it is cost-efficient and will be significantly lower than the average price of solutions on the market: $500. It is far more affordable than vehicle modifications, which range between $20,000 to $80,000 and this product can also be attached temporarily depending on the user's needs. It will fit within the size and weight specifications by being a minimum of 20 inches long and weighing no more than 10 pounds. This product can improve the quality of life by increasing accessibility to driving, consequently allowing people with

disabilities to be more independent. Since this product is mostly made out of steel, it is predicted to last around 50 years and can be reused afterward. With the handle being made with an insulated material, it can be left in the car during hot weather for a few hours.

Concept 2

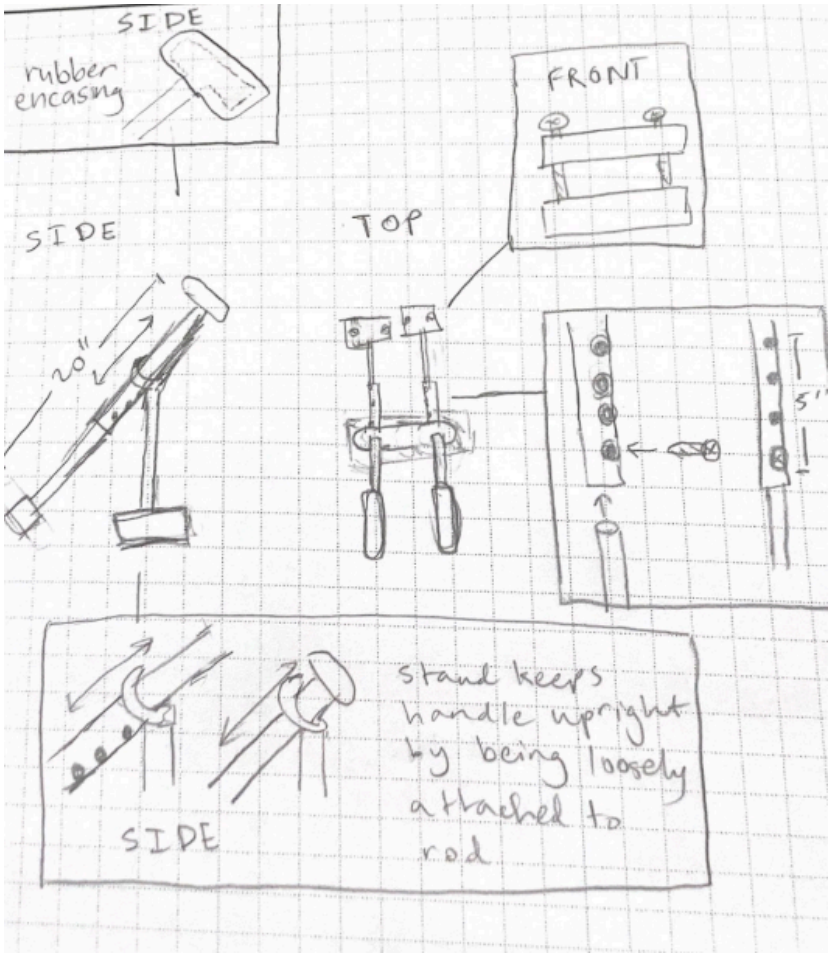

Figure 4.15: Concept #2: Double handle hand-controlled driving aid with adjustability

Product Description

This hand control device consists of two handles, the left for brake and the right for gas. Some clamps secure the pedals by having small plates of metal with screws on either side to squeeze the pedal from above and below. The steel rods attach to the clamps. The handle will be a cylindrical rubber covering around the rod. There is a stand that surrounds the rods so they can slide through it and also it can remain in an upright position when it is not being held. The length of the rods can be adjusted within 5 inches by putting the screw in a series of holes in varying lengths.

Operation

How far forward the handle is pushed corresponds with how much pressure is applied to the pedal. When there is no pressure applied, a compressed spring will return the rod and handle to a vertical position. This design aims to mimic the foot motion of driving and replace it with the user's right hand, by having one handle correspond with one pedal.

Justification

With this simplistic design, it is cost-efficient and will be significantly lower than the average price of solutions on the market: $500. It is far more affordable than vehicle modifications, which range between $20,000 to $80,000 and this product can also be attached temporarily depending on the user's needs. It will fit within the size and weight specifications by being a minimum of 20 inches long and weighing no more than 10 pounds. This product can improve the quality of life by increasing accessibility to driving, consequently allowing people with disabilities to be more independent. Since this product is mostly made out of steel, it is predicted to last around 50 years and can be reused afterward. With the handle being made with an insulated material, it can be left in the car during hot weather for a few hours.

Concept 3

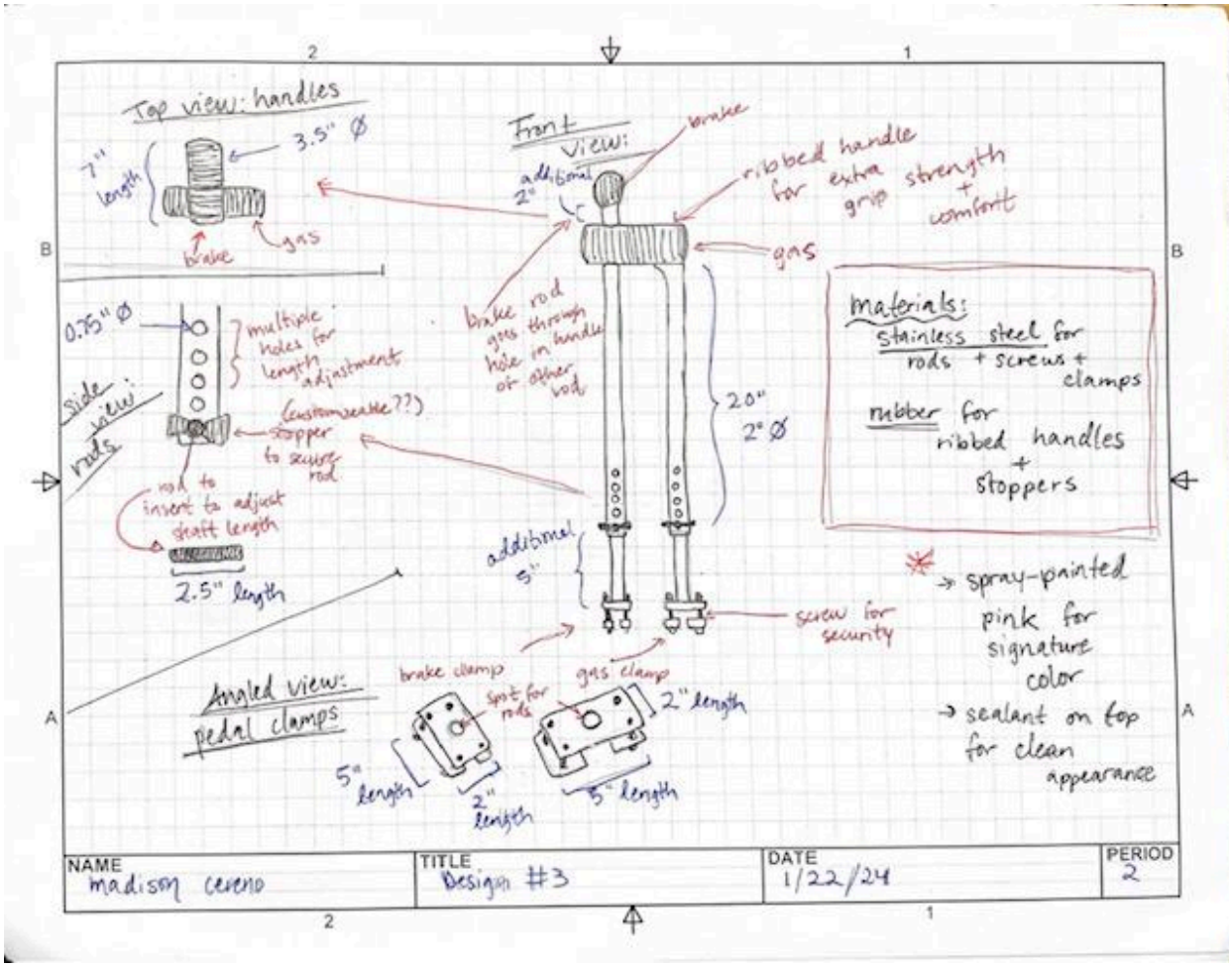

Figure 4.16: Concept #3: Double handles with opposite orientation hand-controlled driving aid

Product Description

The product is a driving aid for recovering Spinal Cord Injury patients or people who have little to no function below the waist, and therefore cannot use pedals to accelerate and brake. Design #3 consists of two separate rods that extend and clamp onto the brake and accelerator pedals. These rods can be secured to the pedals by turning the four screws on the corners of the clamps. The handles on the rods are ribbed and made out of rubber for grip support and comfort. The rods are also adjustable by 5 extra inches to account for user preference. The length can be adjusted by inserting a small rod into one of the holes on the two main rods (the rods extending down to the brake and gas pedals) and placing the rubber stopper on the rod for security. The handles are oriented differently according to the purpose of the rod (i.e. the vertical handle for the brake and the horizontal handle for the gas).

Operation

The intended operation includes the user pushing down on each separate handle to interact with the gas and brake pedals. There are multiple inputs and outputs in the operation of this product.

Regarding the installation process, the input would be turning the four screws on the clamps and the output would be the clamp securely connecting each of the rods to their respective pedals. Regarding the adjustability of this product, the input would be inserting the small rods into one of the holes on the lower end of the main rods (extending to the brake and gas pedals) and the output would be the user having the main rods at their desired lengths. Regarding the intended operation of this product, the input would be the user pushing down on each handle and the output would be the brake and gas pedals being pushed down on by the rods, which results in the car moving forward or stopping.

Justification

This product solves the problem of the lack of independent driving done by spinal cord injury patients by allowing the user to drive without the use of their lower body. It is better than alternative solutions for multiple reasons. The simple design reduces hassle and allows for a shorter installation process as the only requirement is to screw in the clamps to secure the pedals to the product. The design also saves time and leads to an easier and shorter production process as there are no complicated mechanics to make sure the appropriate pedals are being pushed down. This design follows all significant design specifications listed in Element C. It allows the customers to operate the vehicle using only their hands and to install the product independently. The design has a ribbed handle, allows for the rod to adjust to 25 inches in length, and is sized appropriately so the user can decide where to place the hand-controlled driving aid. The simplicity of the design also allows it to be lightweight (specifically not over 10 lbs). The entire product is to be made out of stainless steel for durability and the handles and stoppers are made out of rubber for comfort and security. This material also allows the product to withstand a temperature of 110^{o}F and to be used with rarely any maintenance. The clamp is secure enough so the product cannot be moved with less than 500 lbs of force. Regarding aesthetics, the product will be spray painted baby pink and white and will be finished with sealant to maintain a clean appearance. Overall, this design will improve the quality of life of the user because it allows them to drive comfortably and independently.

Concept 4

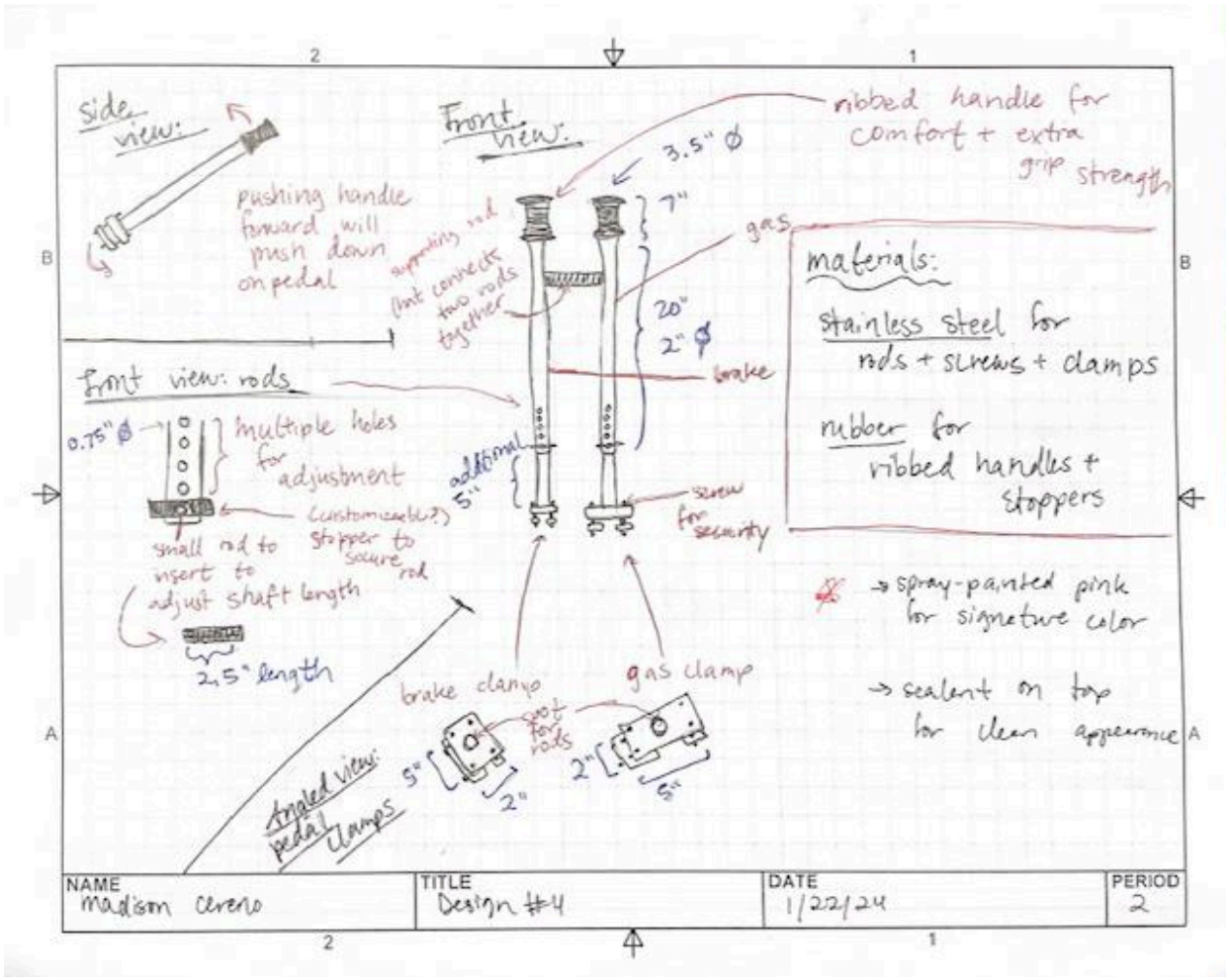

Figure 4.17: Concept #4: Double handle hand-controlled driving aid with rubber grips and adjustability

Product Description

The product is a driving aid for recovering Spinal Cord Injury patients or people who have little to no function below the waist, and therefore cannot use pedals to accelerate and brake. Design #4 consists of two separate rods that extend and clamp onto the brake and accelerator pedals. These rods can be secured to the pedals by turning the four screws on the corners of the clamps. The handles on the rods are ribbed and made out of rubber for grip support and comfort. The rods are also adjustable by 5 extra inches to account for user preference. The length can be adjusted by inserting a small rod into one of the holes on the two main rods (the rods extending down to the brake and gas pedals) and placing the rubber stopper on the rod for security. The rods themselves are separate from each other but are connected with a supporting rod for better stability.

Operation

The intended operation includes the user pushing down on each separate handle to interact with the gas and brake pedals. There are multiple inputs and outputs in this operation of this product. Concerning the installation process, the input would be turning the four screws on each of the clamps and the output would be the clamp securely connecting each of the rods to the appropriate pedals. Regarding the ability to adjust the length of this product's main rods, the input would be inserting the small rods into one of the holes on the lower end of the main rods (extending to the brake and gas pedals) and the output would be the user having the main rods at their desired lengths. Concerning the intended operation of this product, the input would be the user pushing each handle forward and the output would be the brake and gas pedals being pushed down on by the rods at an angle, which results in the car moving forward or stopping.

Justification

This product solves the problem of the lack of independent driving done by spinal cord injury patients by allowing the user to drive without the use of their legs. Design 4 is better than other solutions for multiple reasons. The design saves time and leads to an easier and shorter production process as there are no complicated mechanics to make sure the appropriate pedals are being pushed down. It also reduces hassle and allows for a shorter installation process as the only requirement is to screw in the clamps to secure the pedals to the product. This design follows all significant design specifications listed in Element C. It allows the customers to operate the vehicle using only their hands and to install the product independently. The design has a ribbed handle, permits the rod to adjust to 25 inches in length, and is sized appropriately so the user can decide where to place the hand-controlled driving aid. The simplicity of the design also allows the weight of the product to be under 10 lbs. The entire product is to be made out of stainless steel for durability and the handles and stoppers are made out of rubber for comfort and security. The materials used enable the device to withstand a temperature of 110^{o}F and to be used with rarely any maintenance. The clamp is secure enough so the product cannot be moved with less than 500 lbs of force. Concerning appearance and aesthetics, the product will be spray painted baby pink and white and will be finished with sealant to maintain a clean look. Overall, this design will improve the quality of life of the user because it allows them to drive comfortably and without outside help.

Concept 5

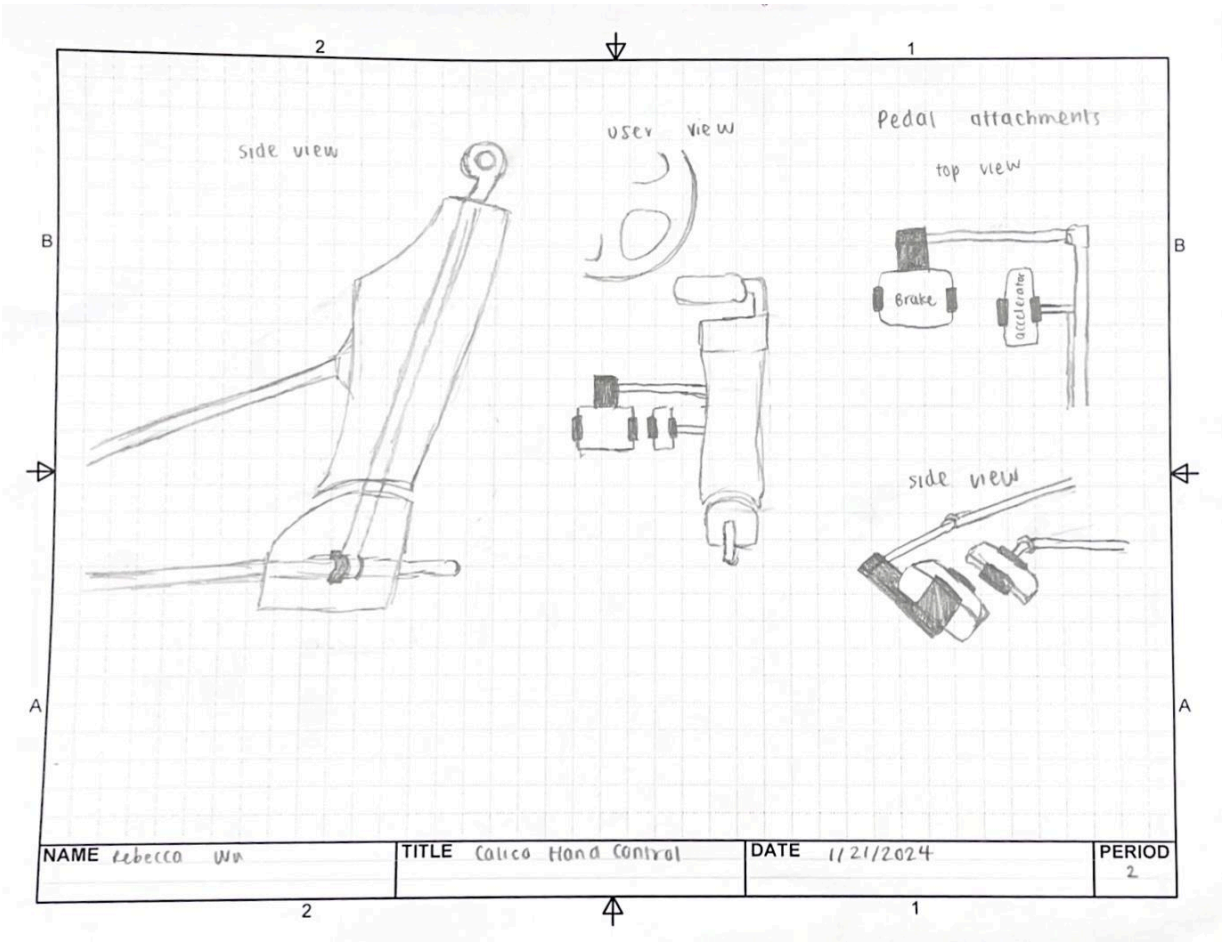

Figure 4.18: Concept 5:Push/pull single handle hand-controlled driving aid with casing

Product Description

The CaliCo Hand Control 3000 is a driving aid for people with disabilities who have lost their lower body function, allowing them to operate a car using only their hands. It consists of two parts that control each function of the product: braking and acceleration. It also includes a handle, several rods, two clamps for each pedal, a casing, and parts for installation. It is installed on the right side of the driver seat near the pedals and can only be operated using the right hand. This design specifically allows the user to operate the vehicle with their feet while the hand control is still installed so a healthy person can also drive the same vehicle if needed.

Operation

When the user pushes the handle, the car brakes. A metal rod (steel) is attached directly to the plastic casing under the handle so when the handle moves forward, so does the rod which pushes the brake pedal down. When the user pulls the handle back, the car accelerates. The handle is attached to a steel rod which is connected to another rod that clamps onto the accelerator pedal. It

is connected in an “L” shape: the rod connected to the handle is pulled back and pushes the other rod forward into the accelerator pedal.

Justification

The product will improve the quality of life of people with disabilities by allowing them to operate a vehicle independently. Many people who have lost the functions of their legs depend on family members or caretakers to travel around. If they can drive using hand operations, they can travel alone. The product also saves money and time because of its simple installation and design. The most common options for hand-controlled driving aids consist of direct vehicle modifications. The cost often ranges from $3000 to $6000. The Calico Hand Control 3000 is expected to be around $200, providing customers with an inexpensive option. Other products on the market that are similar in price are often too simple and might threaten the user's safety. The product is expected to have a quick installation that can be done independently which saves much time and energy compared to having someone modify a vehicle to include hand controls.

Concept 6

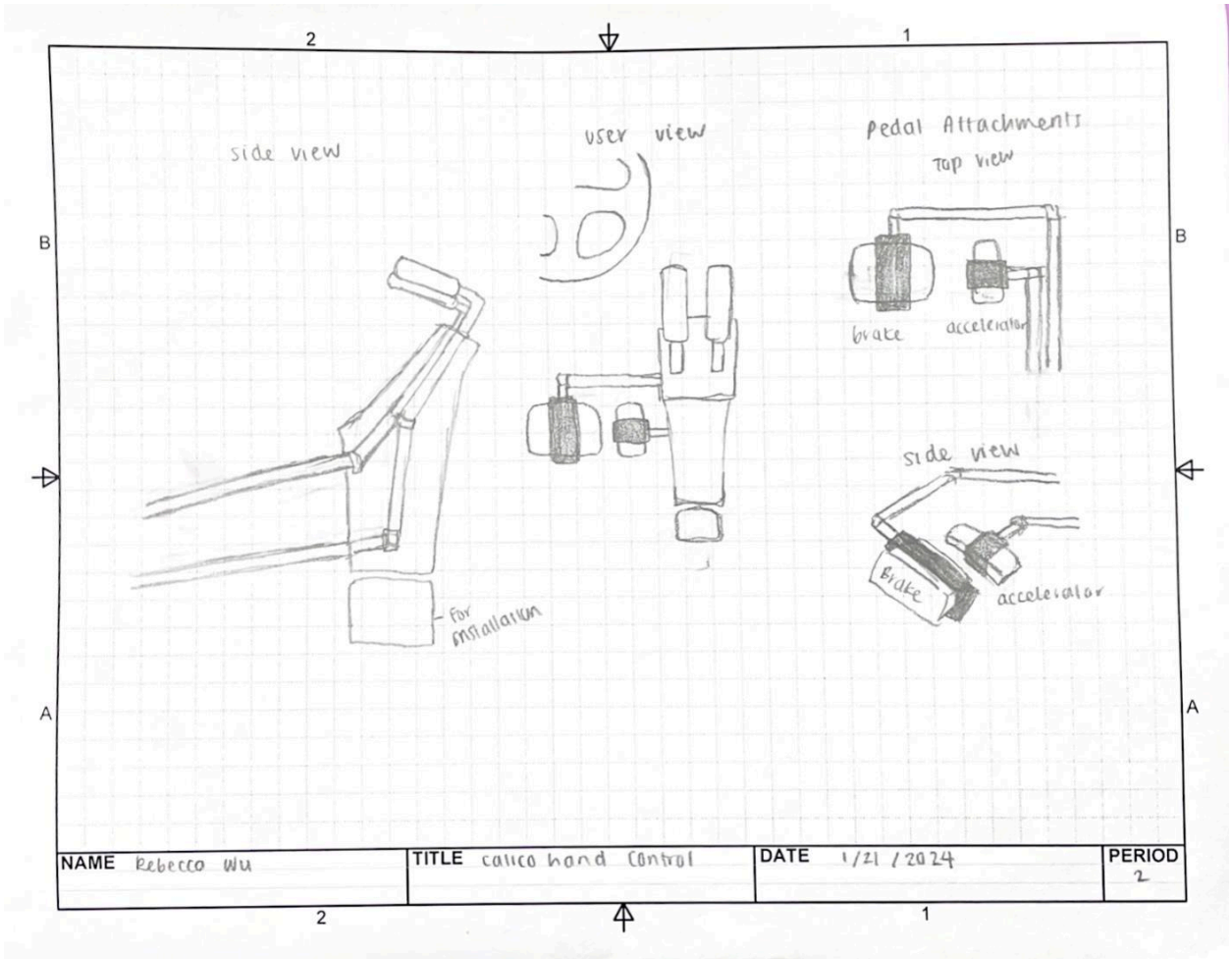

Figure 4.19: Concept #6: Double handle hand-controlled driving aid with casing

Production Description
The CaliCo Hand Control 3000 is a driving aid for people with disabilities who have lost the function of their lower body that allows them to operate a car using only their hands. It consists of two parts that control each function of the product: braking and acceleration. It includes two handles, several rods, two clamps for each pedal, a casing, and parts for installation. It is installed on the right side of the driver seat near the pedals and can only be operated using the right hand.

Operation
When the user pushes the leftmost handle, the car brakes. A metal rod (steel) with a clamp on one end is attached directly to the handle so that when the handle moves forward, so does the rod pushing the brake pedal down. When the user pushes the rightmost handle, the car accelerates. The handle is attached to a metal rod (steel) which is connected to a clamp that locks onto the accelerator pedal. It has a similar process to the brake handle. The two rods are fitted into a casing that remains static as the rods move up and down so that the hand control is stable and fitted well when in use.

Justification
The product is designed to enhance the quality of life for individuals with disabilities by enabling them to operate a vehicle independently. Many individuals who have lost the use of their legs currently rely on family members or caregivers for transportation. By allowing them to drive using hand controls, the product empowers them to travel independently. Additionally, the product offers cost and time savings due to its straightforward installation and design.

Traditional hand-controlled driving aids typically involve direct modifications to the vehicle, with costs ranging from $3000 to $6000. In contrast, the Calico Hand Control 3000 is anticipated to be priced around $200, providing a more affordable option for customers. Other products in a similar price range often lack the necessary sophistication and may compromise user safety. The product is designed for quick and independent installation, offering a time and energy-efficient alternative to vehicle modifications performed by others.

Appendix D: Consumer Feedback

The consumer feedback survey consisted of two sections: demographics and preferences in designs. Three different sketches of the concept designs were included for the respondents to reference.

The demographic portion of the survey asked respondents about their relation to SCI patients, how long they have been driving, how many cars are in their household, and the number of drivers sharing a car in their household.

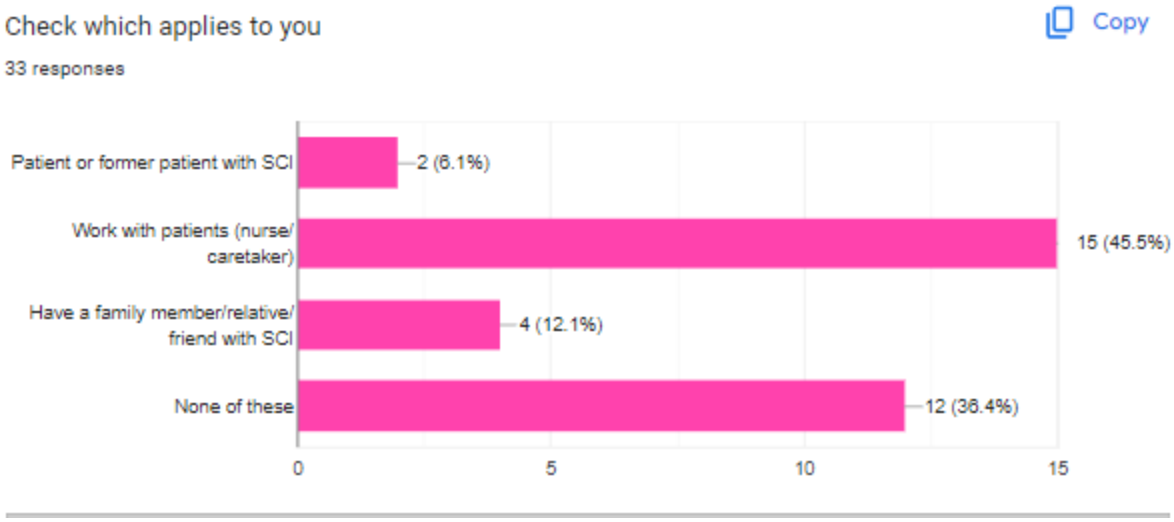

Figure 4.20: Survey results of the respondents' relation to SCI patients

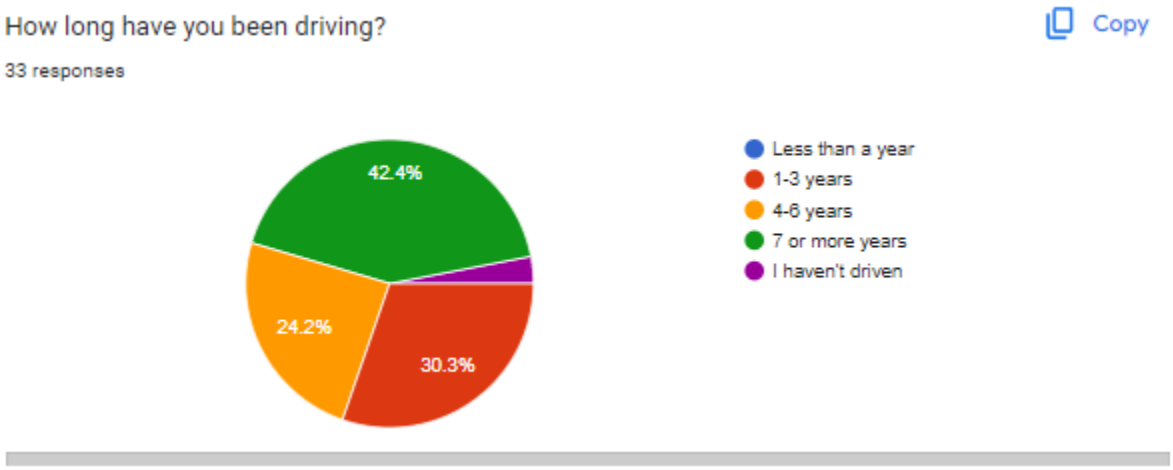

Figure 4.21: Survey results relating to how long each respondent has been driving

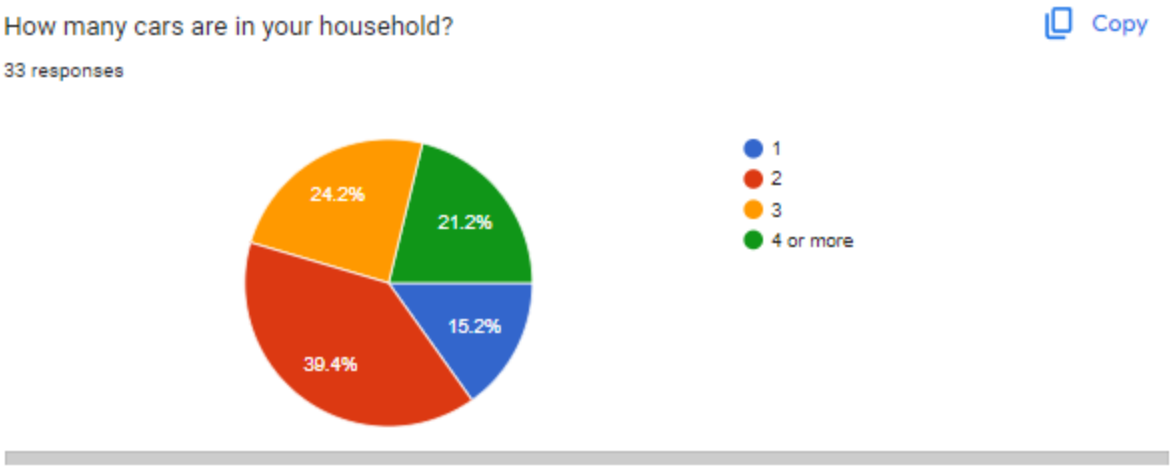

Figure 4.22: Survey results relating to how many cars are in a respondent's household

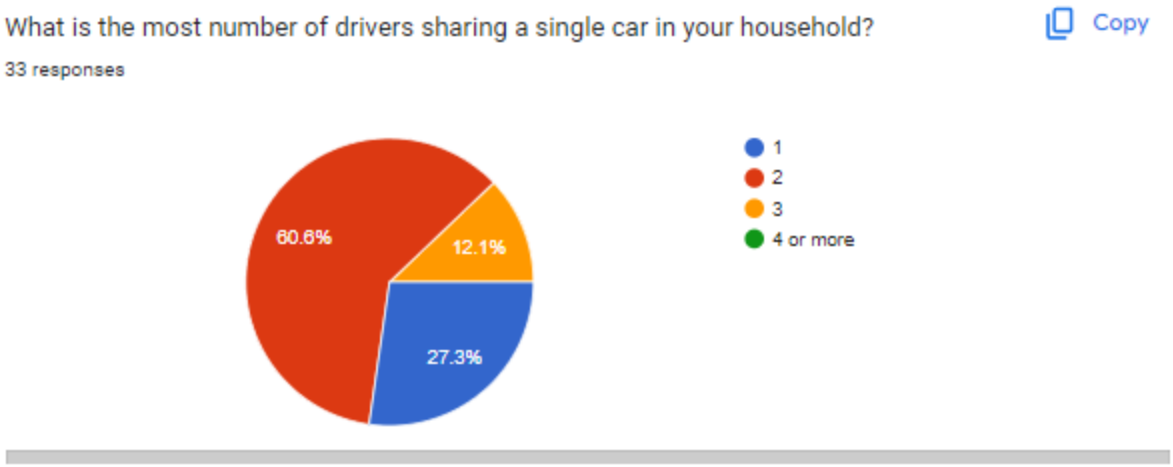

Figure 4.23: Survey results of how many drivers share a car in a respondent's household

The preferences in the design portion of the survey asked respondents about their preferences between the different features of the concept sketches provided. There were multiple questions related to the comfortability of use and the main function of the product.

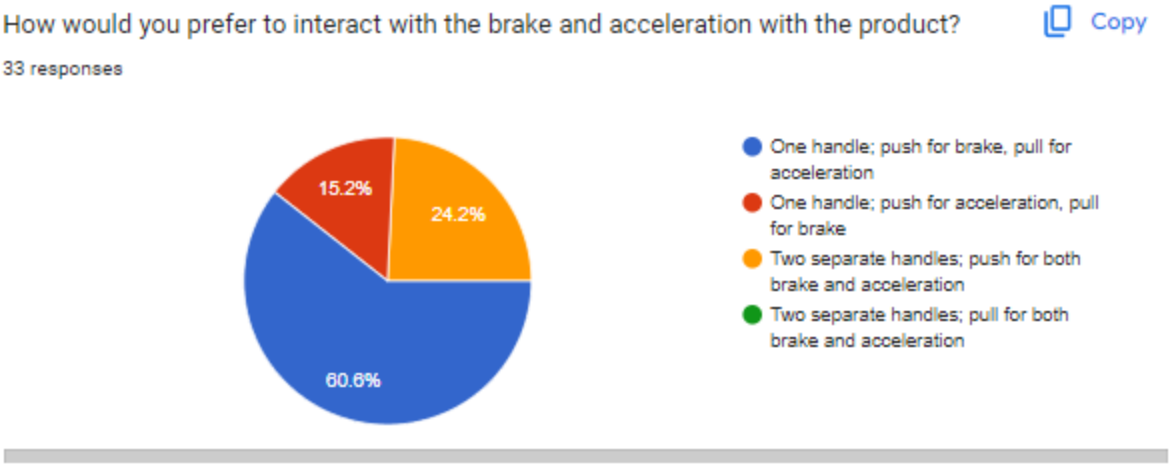

Figure 4.24: Survey results relating to the preference in interaction with the handle

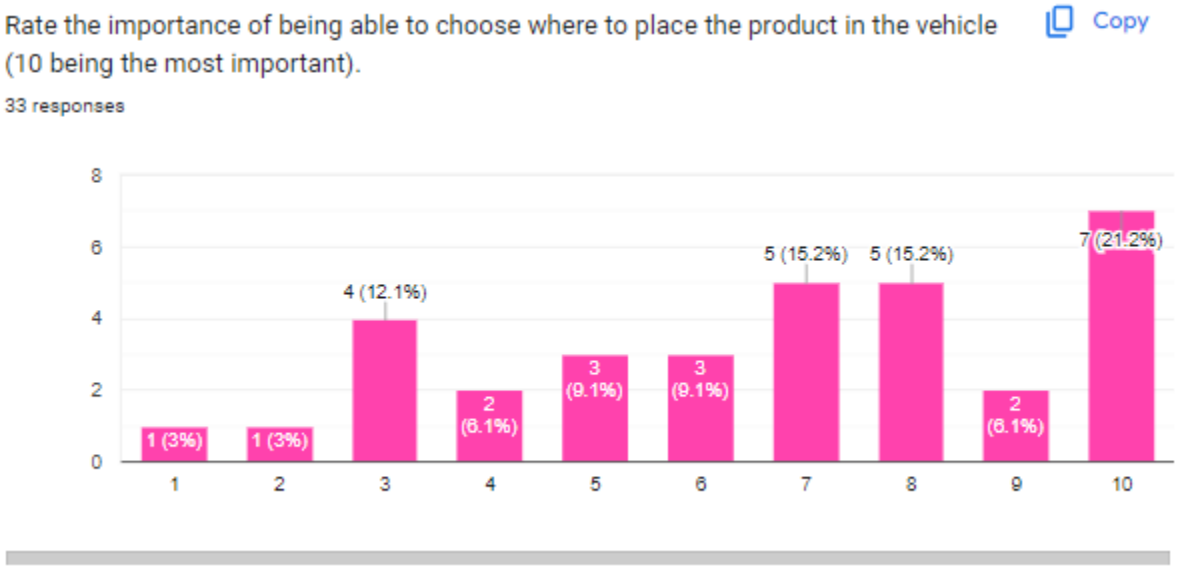

Figure 4.25: Survey rating of the importance of choosing the product's placement

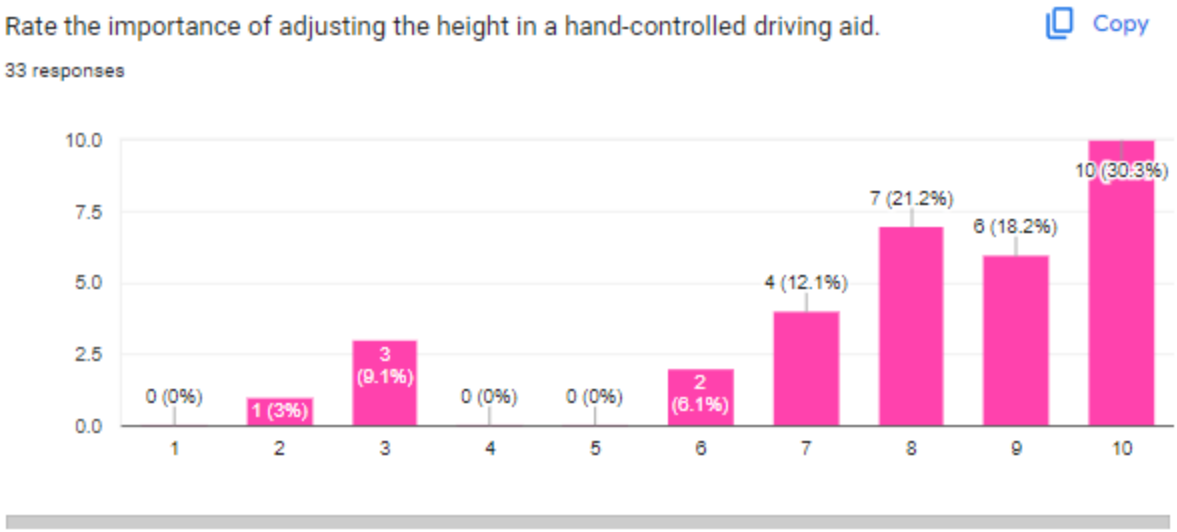

Figure 4.26: Survey rating of the importance of height adjustability in the product

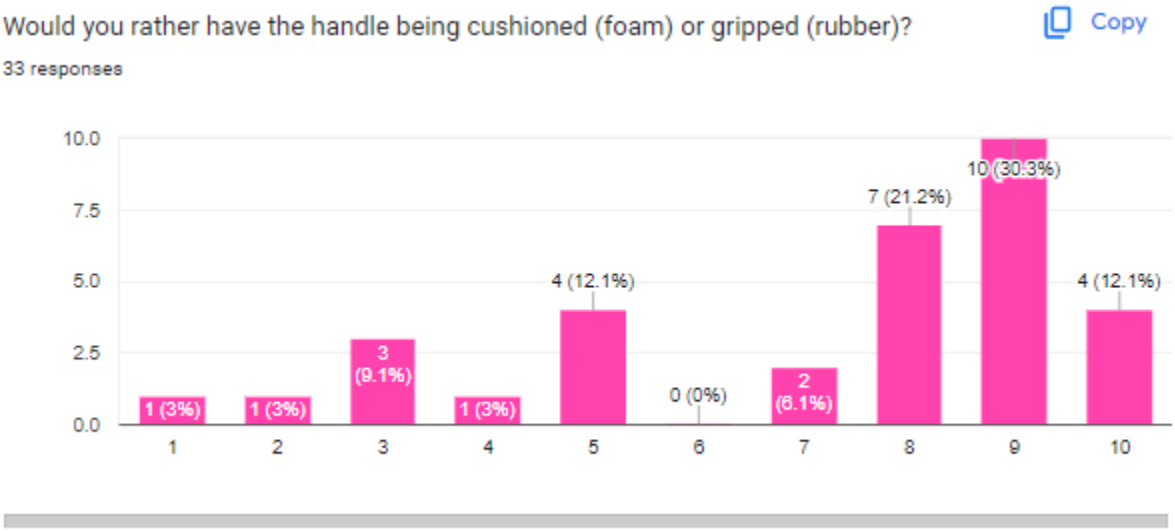

Figure 4.27: Survey results of customer preference for handle material

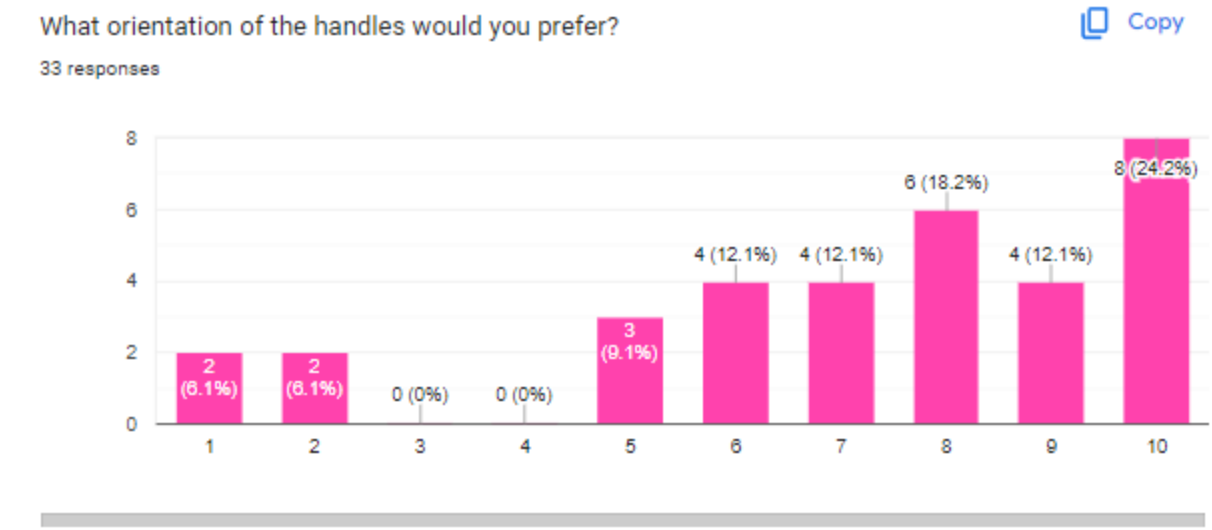

Figure 4.27: Survey rating of customer preference in handle orientation

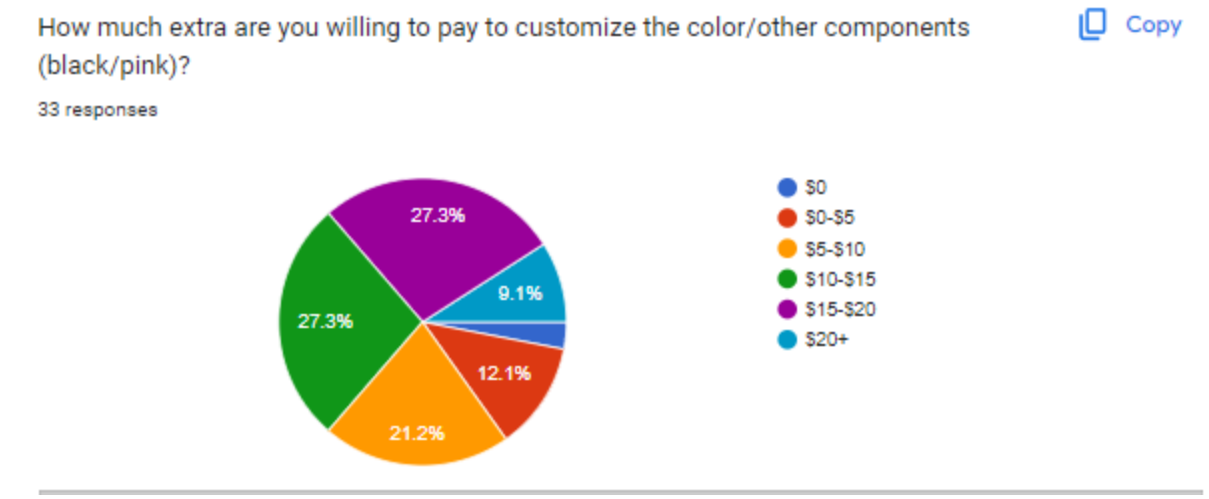

Figure 4.28: Survey results of customers' desired price range for product customization

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Appendix E: Decision Matrices

A decision matrix is used to narrow down to one or a few designs by quantifying important criteria and selecting the design with the greatest total. Each design was evaluated based on ease of installation, weight, simplicity, ease of use, and affordability, and was given a number on a scale between 1 and 10 for each criterion (10 being the best). The rankings for all the criteria are added up for each design with the final column being the final decision.

Figure 4.29: Decision matrix of rankings in the importance of each feature in the concept designs

Decision Matrix

Designs		Ease of Installation	Weight	Simplicity	Ease of Use	Affordability	Preference	Size	Safety	Adjustibility		Total Score		
1		9	8	6	10	6	9	7	7	10		72		
2		9	5	8	7	5	5	7	5	10		61		
3		10	8	8	9	7	6	6	5	10		69		
4		10	9	8	6	8	4	7	2	10		64		
5		9	6	6	10	6	9	6	7	10		69		
6		9	6	7	9	6	7	6	7	10		67		

Appendix F: Complete set of Working Drawings

Appendix F features a detailed drawing of each individual component of the hand-controlled driving aid. All parts are considered including each screw, nut, and bolt. However, the installation method is still tentative and is not shown in the drawings.

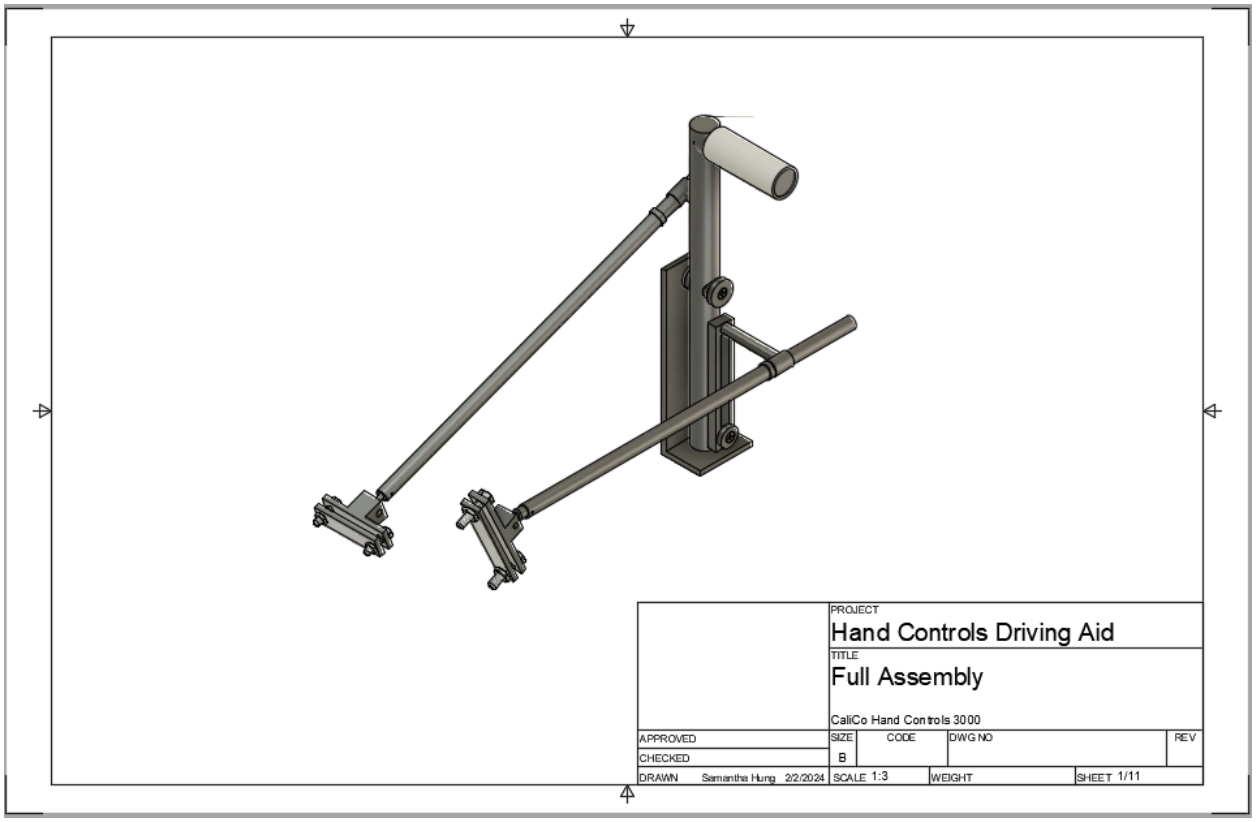
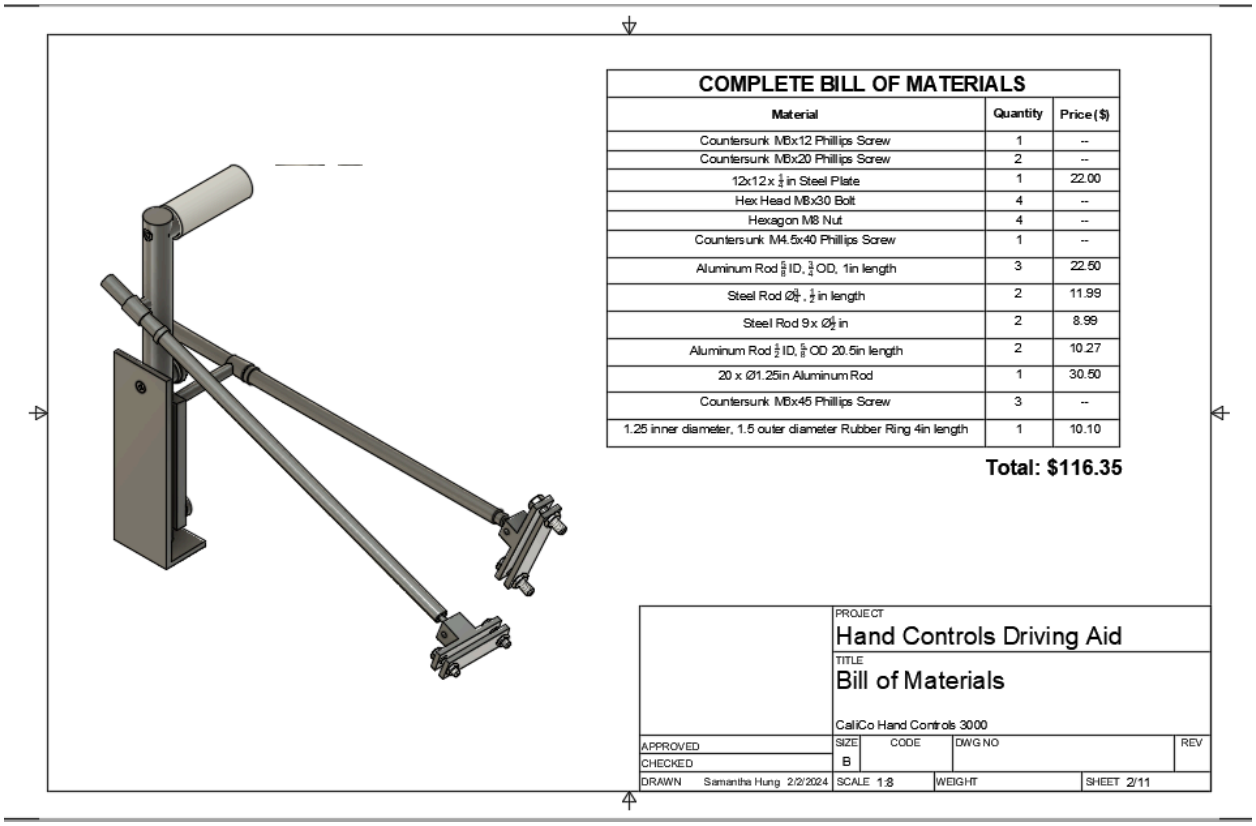


Figure 4.30: Isometric view of the final design



COMPLETE BILL OF MATERIALS

Material	Quantity	Price ($)
Countersunk M8x12 Phillips Screw	1	--
Countersunk M8x20 Phillips Screw	2	--
12x12 x $\frac{1}{4}$ in Steel Plate	1	22.00
Hex Head M8x30 Bolt	4	--
Hexagon M8 Nut	4	--
Countersunk M4.5x40 Phillips Screw	1	--
Aluminum Rod $\frac{5}{8}$ ID, $\frac{3}{4}$ OD, 1in length	3	22.50
Steel Rod Ø$\frac{1}{4}$ x $\frac{1}{2}$ in length	2	11.99
Steel Rod 9 x Ø$\frac{1}{2}$ in	2	8.99
Aluminum Rod $\frac{1}{2}$ ID, $\frac{5}{8}$ OD 20.5in length	2	10.27
20 x Ø1.25in Aluminum Rod	1	30.50
Countersunk M8x45 Phillips Screw	3	--
1.25 inner diameter, 1.5 outer diameter Rubber Ring 4in length	1	10.10

Total: $116.35

PROJECT
Hand Controls Driving Aid
TITLE
Bill of Materials
CaliCo Hand Controls 3000

APPROVED	SIZE	CODE	DWG NO	REV
CHECKED	B			
DRAWN Samantha Hung 2/2/2024	SCALE 1:8	WEIGHT	SHEET 2/11	

Figure 4.31: Isometric view from behind including a bill of materials

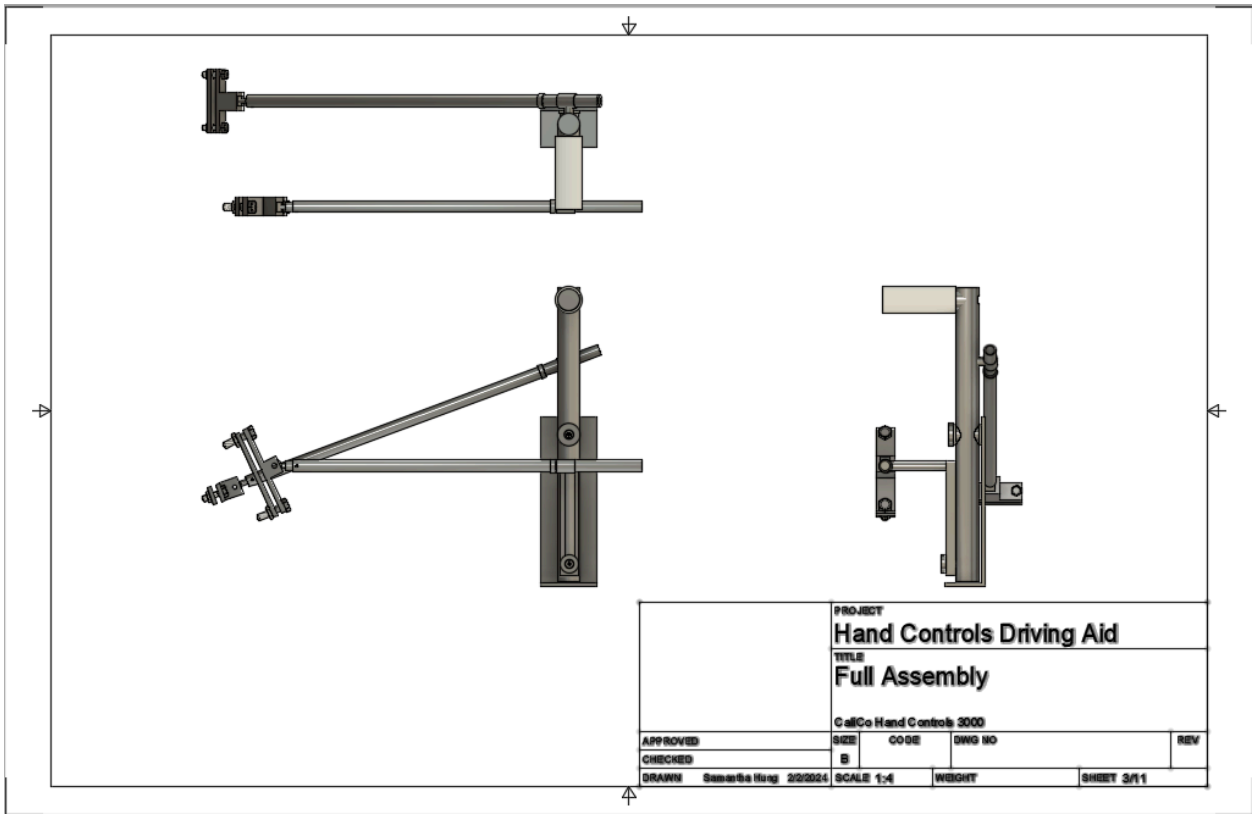


Figure 4.32: Top, front, and side views of the final design

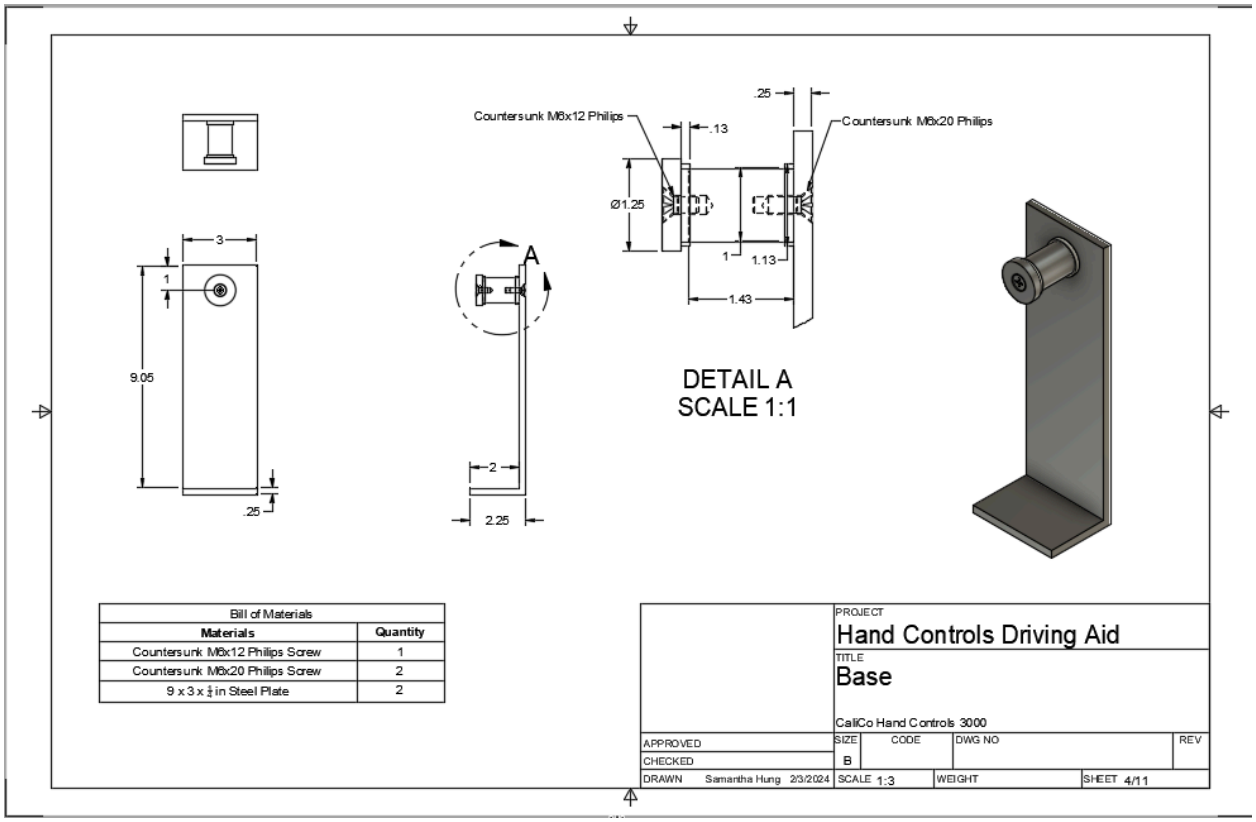


Figure 4.33: Detailed drawing and isometric view of the base component

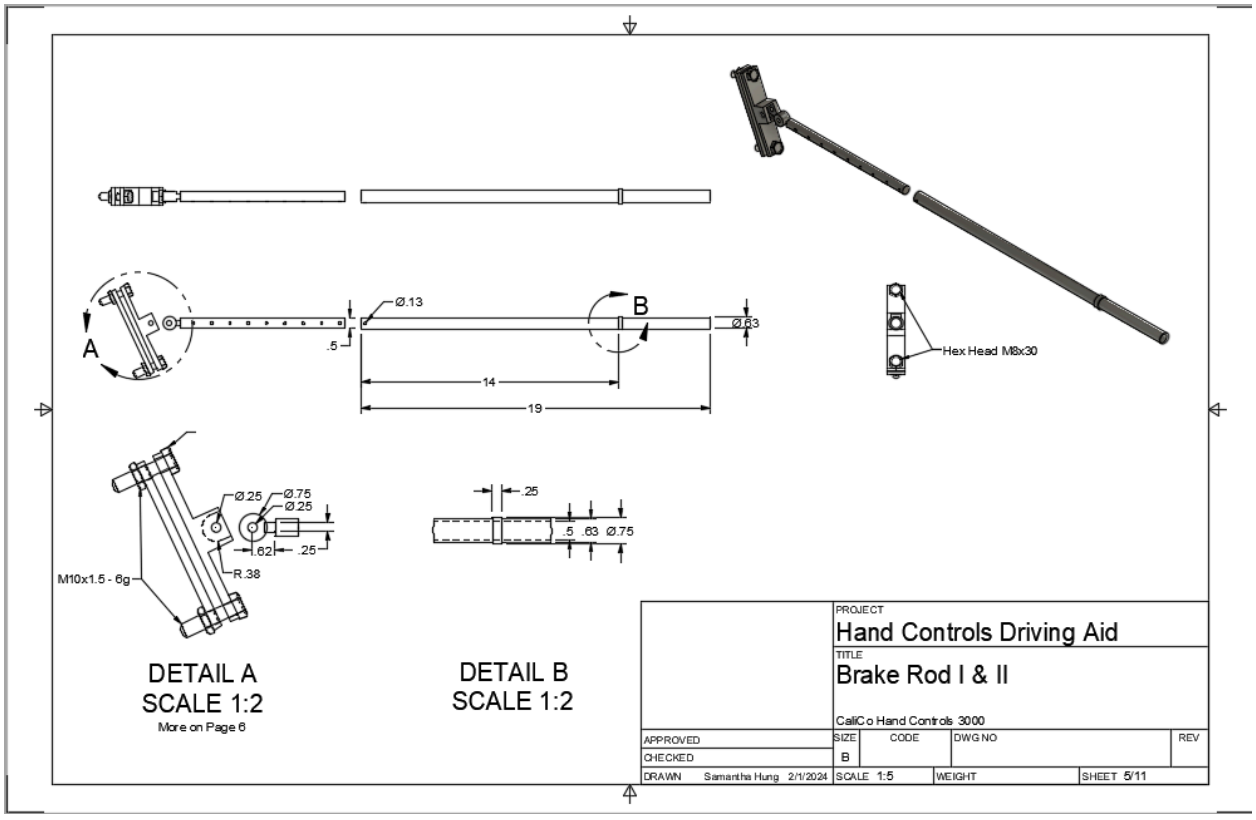


Figure 4.34: Detailed drawing and isometric view of the brake rod component

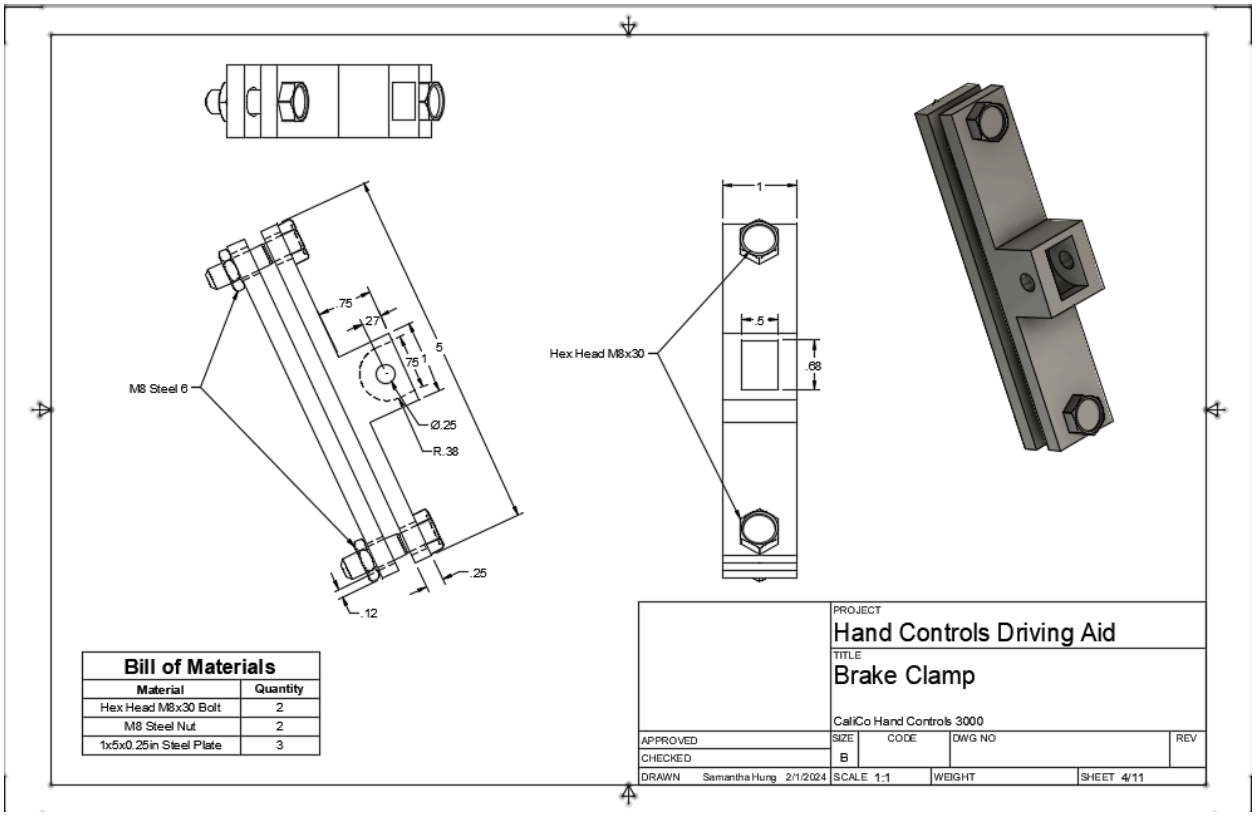


Figure 4.35: Detailed drawing and isometric view of the brake clamp component

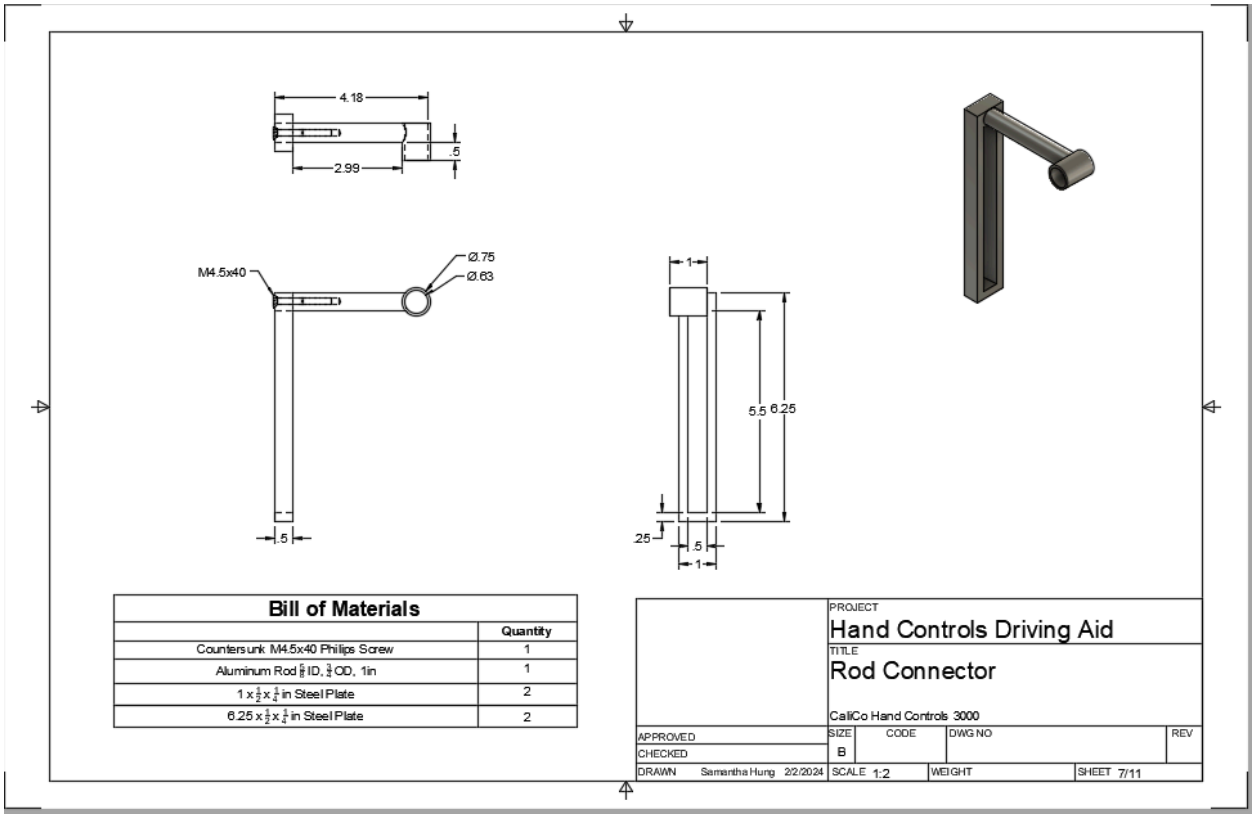


Figure 4.36: Detailed drawing and isometric view of the rod connecter component

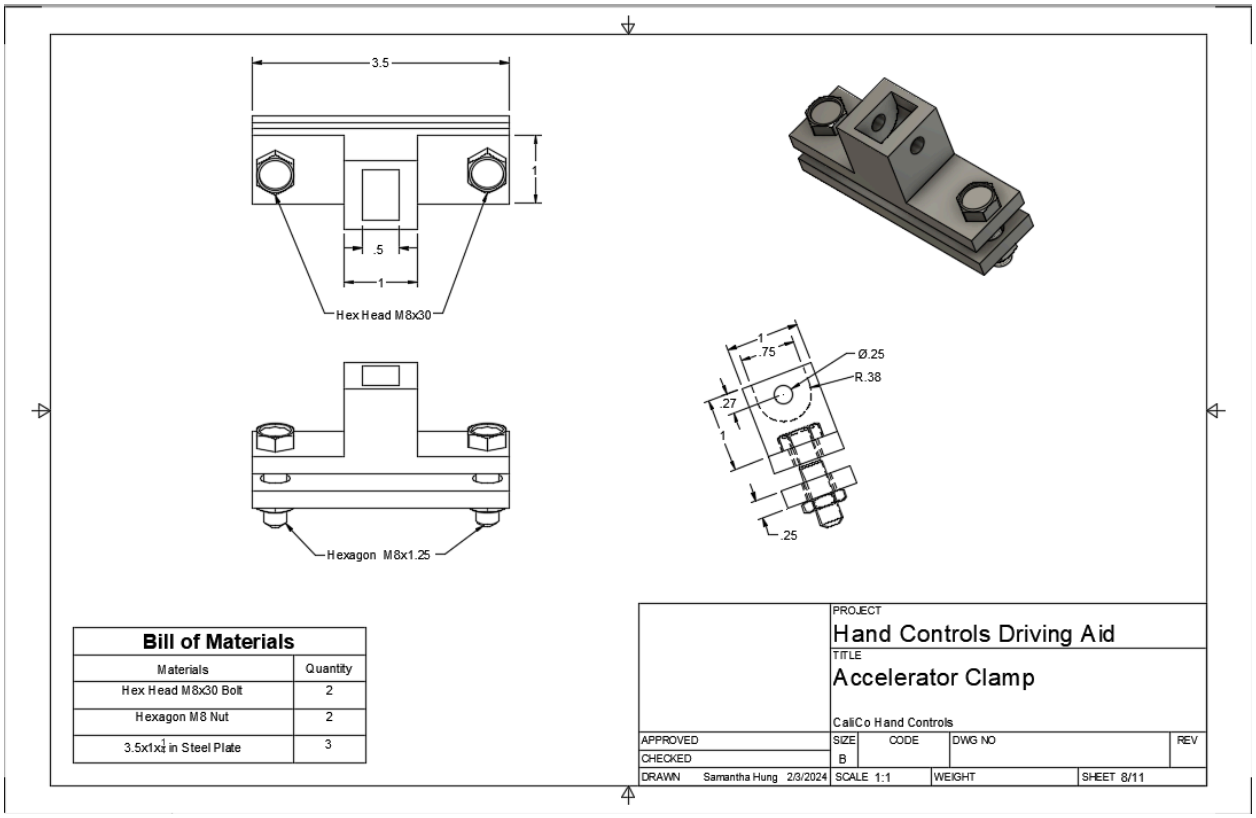


Figure 4.37: Detailed drawing and isometric view of the accelerator clamp component

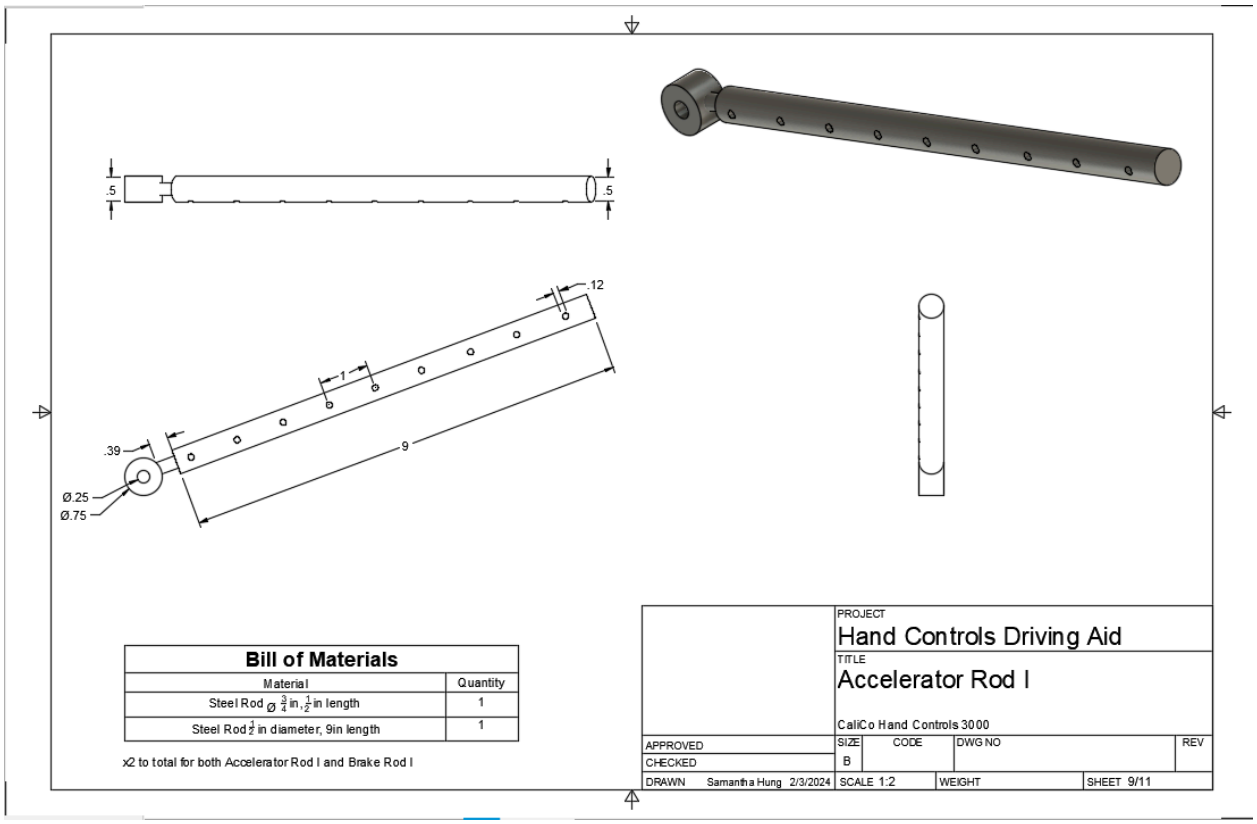


Figure 4.38: Detailed drawing and isometric view of the accelerator rod component

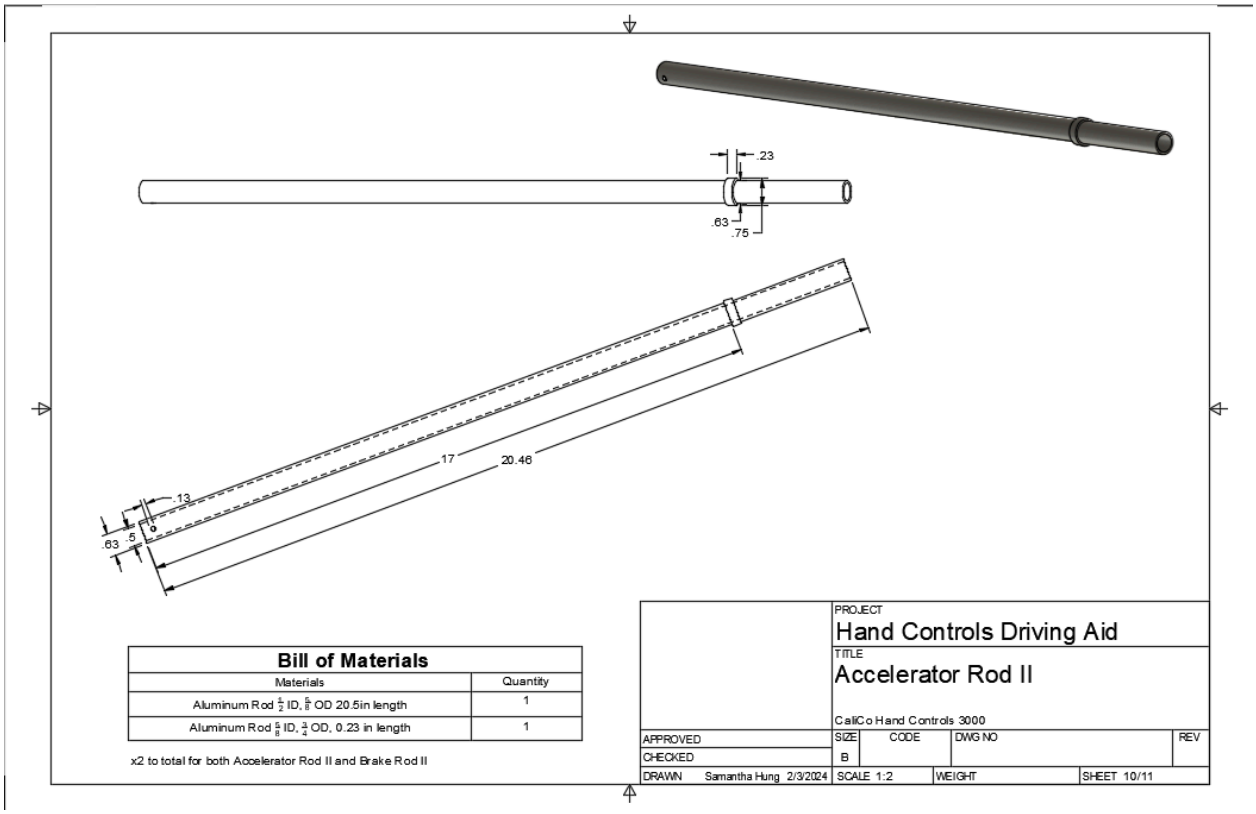


Figure 4.39: Detailed drawing and isometric view of the accelerator rod component

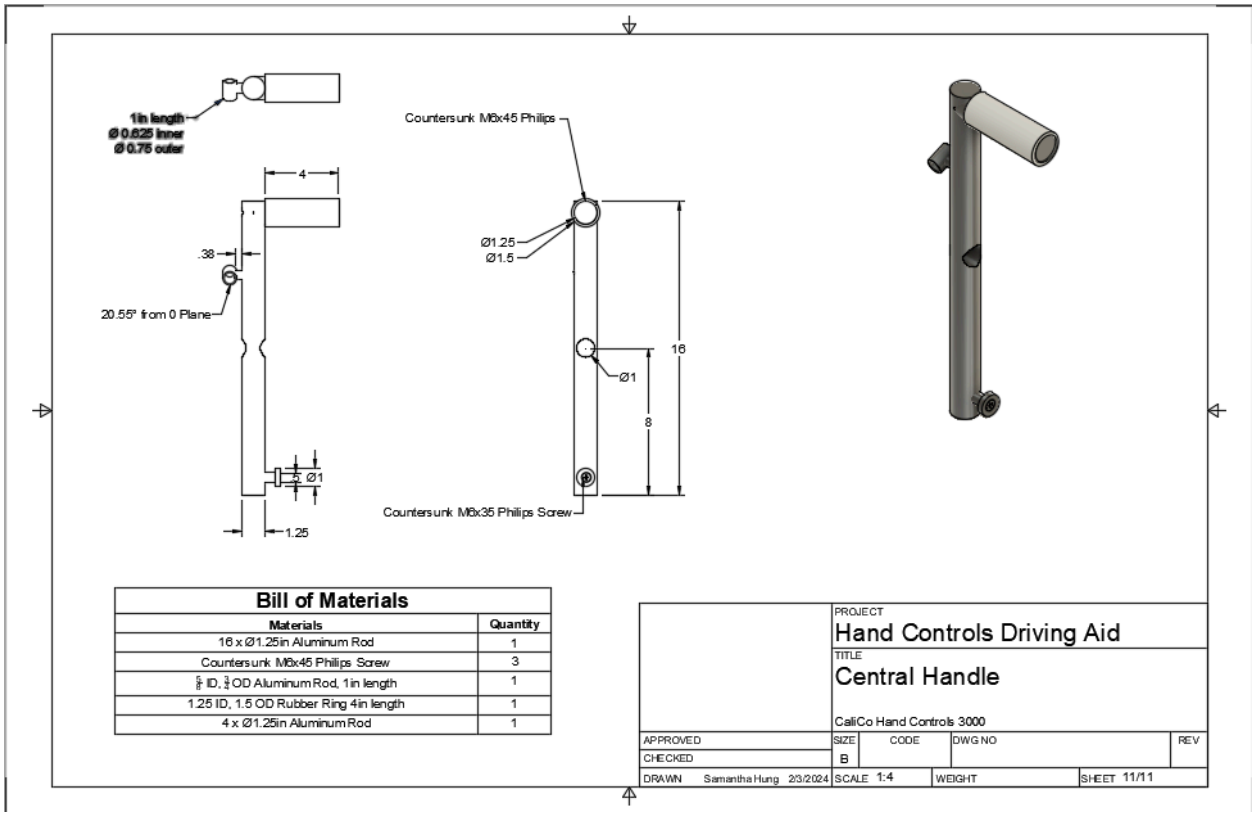


Figure 4.40: Detailed drawing and isometric view of the central handle component