

Engineering Design and Development

May 22, 2024

JigTurn

Animish Jain

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1. PROBLEM STATEMENT

1.1. Problem Statement

Typically, bicyclists use hand signals on the road in order to indicate if they are stopping, going forward, or trying to turn. This practice has been common for many years, however, the problem is that it involves extending one arm away from the handlebars, which often limits the rider's ability to control the bicycle, and can sometimes be fatal. Since this requires the biker to take their hands off the handlebars, it poses a major safety risk and the rider may not be able to maneuver or stop the bicycle quickly if they need to. Additionally, in adverse weather conditions at night, using hand signals can become especially more challenging and they may not be sufficiently visible to others, which can significantly increase the likelihood of accidents.

Currently, on the market there are solutions such as electronic turn signals that address this issue. They allow riders to signal their intentions on the road without using their hands. However, these devices often are often very high cost (> \$50) and often require the user to manually indicate when they are completed with their turn. This not only further distracts the rider from focusing on the road, but it is also less intuitive to use and could be improved.

1.2. Justification and Research on the Problem

As mentioned above, using typical hand signals on a bicycle significantly compromises rider safety as it requires the rider to remove one hand from the handlebars. Because of this, a rider will lose a significant amount of control over the bicycle, particularly when they need to brake for emergencies or maneuver their way out of an accident (Hunter, Stewart, & Stutts, 1995).

During the night time or in volatile weather conditions, using hand signals is much harder as the

visibility decreases exponentially and thereby increases the risk for a potential accident (Rodgers, 1995). Moreover, various studies have found that there is a direct correlation between the increased risk of an accident when a bicyclist is riding with one hand or they are in complex traffic environments or on uneven terrain (Kim, Kim, & Ulfarsson, 2007).

In order to evaluate whether or not local bicycle users believed our problem statement to be valid, we surveyed 15 High Technology High School students by asking the question: “Do current methods of turn signaling on bicycles pose potential risks to rider safety?” All 12 students preferred to remain anonymous, but 11 of the 15 answered “Yes.”

2. DESIGN BRIEF

Designers: Nikhil Osuri, Liam Hoffman, Animish Jain

Client: All bicycle riders who either ride at night, or cannot properly signal turns with their hands

Design Statement: Design, build, and test a \$50 or under device that allows bicyclists to indicate turning left and right without removing their hands from the brake bar, and turns the turn signal off once the turn is completed.

Measurable Constraints:

1. Must withstand 60 total minutes of sample bike rides.
2. Must be recognizable from a distance of up to 50 feet.
3. Must not extend more than 3" from the bike frame
4. Percentage of testers reporting a compromise of rider safety must be under 10%.
5. Cannot run out of power within 10 hours of usage.
6. Cannot weigh more than 3 pounds.
7. Must output at least 50 lumens of light.
8. Must be operable with 5 or less steps of instructions.
9. Must have no exposed electronic components.
10. Must not take more than 10 minutes to install on a bicycle.
11. Material costs cannot exceed \$60.
12. Turn signal must activate and deactivate within 2 seconds.

Prototype Testing and Performance Criteria:

1. With the device attached and turned on, the entire turn signal apparatus should be able to run for over 10 hours.
2. When placed in front of a Vernier lumen reader, the light panels output at least 50 lumens of light.
3. When placed 50 feet away from another user, the user behind can recognize each left and right turn signal.
4. When activated, the turn signal activates and deactivates within 2 seconds.
5. The total weight of the device cannot weigh more than 3 pounds.
6. Any user can assemble and take apart the device with 5 or less steps and also in less than 10 total minutes.

3. PROJECT MANAGEMENT

3.1. Team Management:

Project Manager: Animish Jain

Team Members: Nikhil Osuri, Liam Hoffman

3.2. Team Responsibilities:

Animish Jain:

- Establishing the Arduino codebase with multiple functions for blinking lights and turn signals
- Using I2C chip in Arduino to convert angular acceleration readings from the IMU into angular displacement readings
- Creating product packaging and the final operating instructions for consumers
- Creating all soldered connections between all electrical components based upon Nikhil's fritzing drawing
- Integrating the current Arduino codebase with the final soldered product so the lights properly turn off and blink at correct times

Nikhil Osuri:

- In charge of all documentation and the organization of all materials
- Contributing to the Arduino codebase that establishes functions for blinking lights, turn signal functionality
- Construction of mock-up with exacto knives, cardstock, and foam core
- Finding a list of testers and developing the testing process for product evaluation
- Construction of prototype with PVC pipes, bandsaw, and soldered arduino components

- Developing the testing process for product evaluation and testing with patients

Liam Hoffman:

- Construction of prototype and developing the mechanism for mounting the Arduino and battery pack to the bicycle
- Creating the circuit for the IMU's, buttons, and blinking lights based upon Nikhil's fritzing
- 3D printing of all containers for the lights and arduino/battery pack
- Developing the testing process for product evaluation and testing with patients
- 3D printing of all containers for the lights and arduino/battery pack

3.3. Gantt Charts

There were no changes in the proposed gantt chart throughout this project.

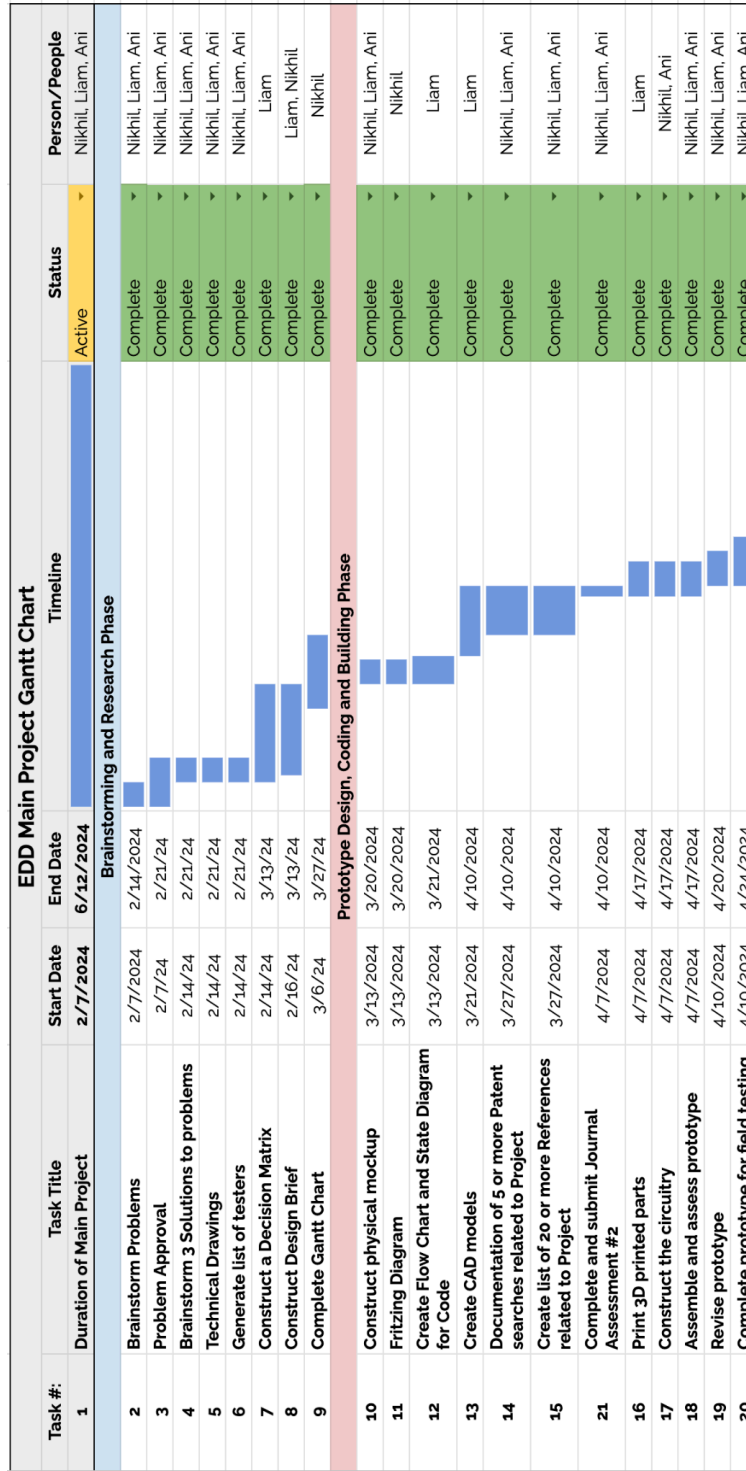


Figure 3.3.1: Final Gantt Chart and Timeline from February 7, 2024 to April 24, 2024

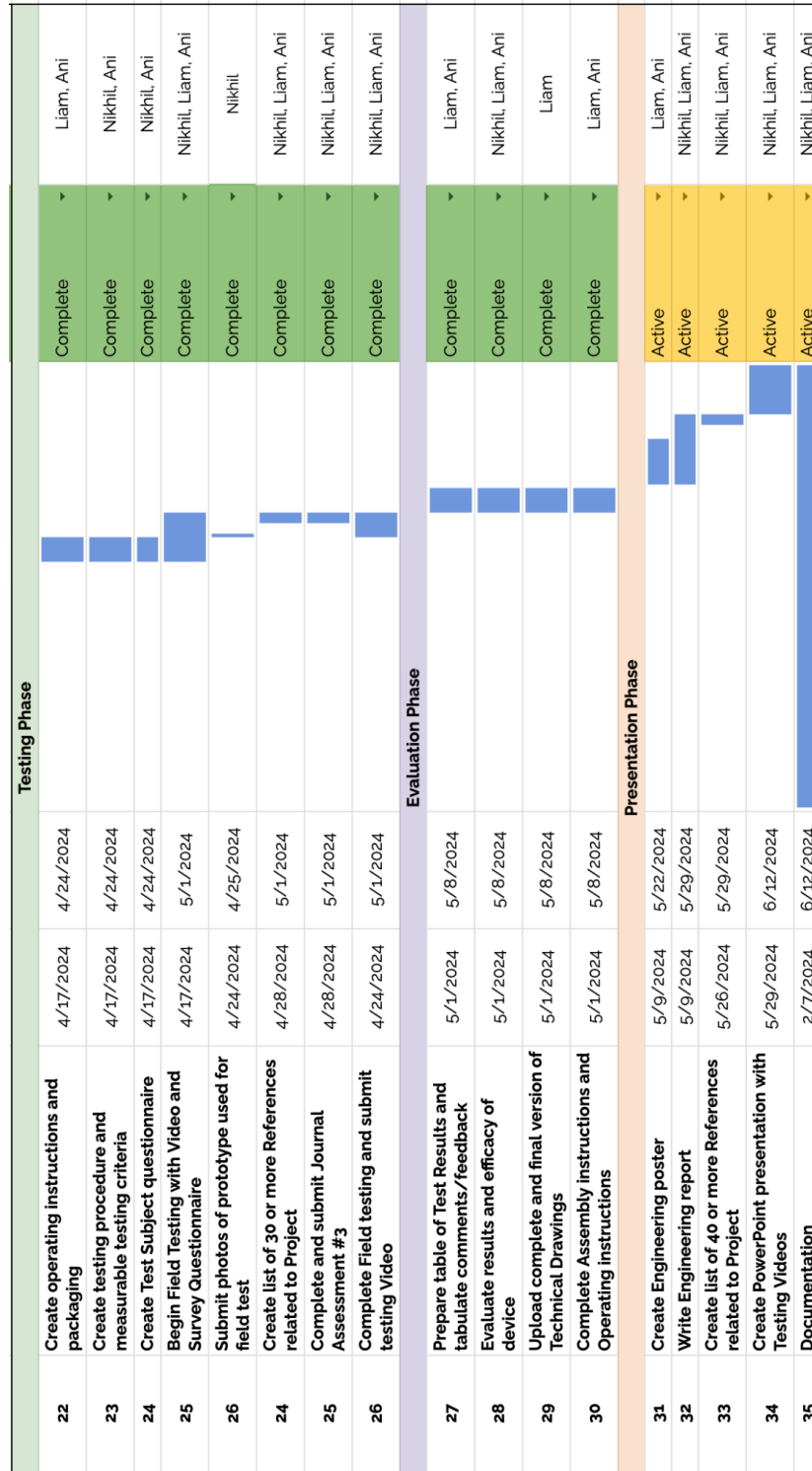


Figure 3.3.2: Final Gantt Chart and Timeline from April 17, 2024 to June 2, 2024

4. PAST AND CURRENT PRODUCTS

A number of patents have been filed that relate to various safety mechanisms on bicycles and current “smart” helmet designs. An analysis of some of the most relevant patents to the project’s problem statement and device are provided below.

4.1. Patent Abstracts and Analysis:

Patent 1: LED Smart Helmet for Wearing on a Bicycle

Patent Number: WO2020186771A1

Date: 11/04/2019

Authors: 郑佳源, 曹海涛

Abstract: Provided is an LED smart helmet for wearing on a bicycle. The LED smart helmet comprises a helmet body (1), wherein a rear warning light area (2) is provided on an upper portion of the back of the helmet body (1); a rear warning light group (3) is fixedly mounted in the rear warning light area (2); the left and right sides of a lower portion of the back of the helmet body (1) are provided with a left warning light area (4) and a right warning light area (5), respectively; a rear left turning light group (6) and a rear left brake light group (7) are fixedly mounted at an upper side and a lower side inside the left warning light area, respectively; a rear right turning light group (8) and a rear right brake light group (9) are fixedly mounted at an upper side and an lower side inside the right warning light area, respectively; and the left and right sides of the front of the helmet body (1) are provided with a front right light area (11) and a front left light area (12), respectively. The head of a user and bicycle movement are sensed by means of an angle sensor and a speed sensor, signals are fed back to an MCU module, and the MCU

module analyzes the information to control the light-up conditions of an LED light assembly, and gives prompts according to different light-up conditions.

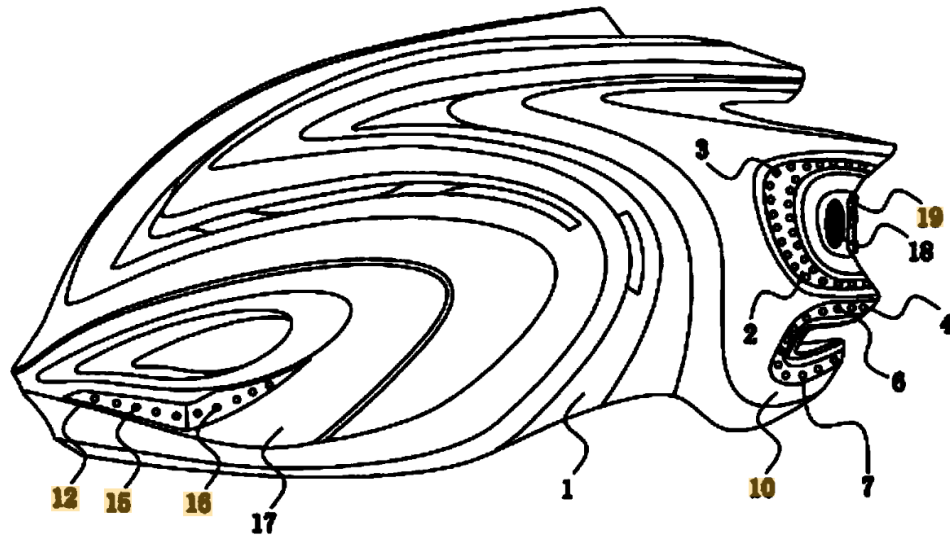


Figure 4.1.1: Left Side View of Smart Helmet

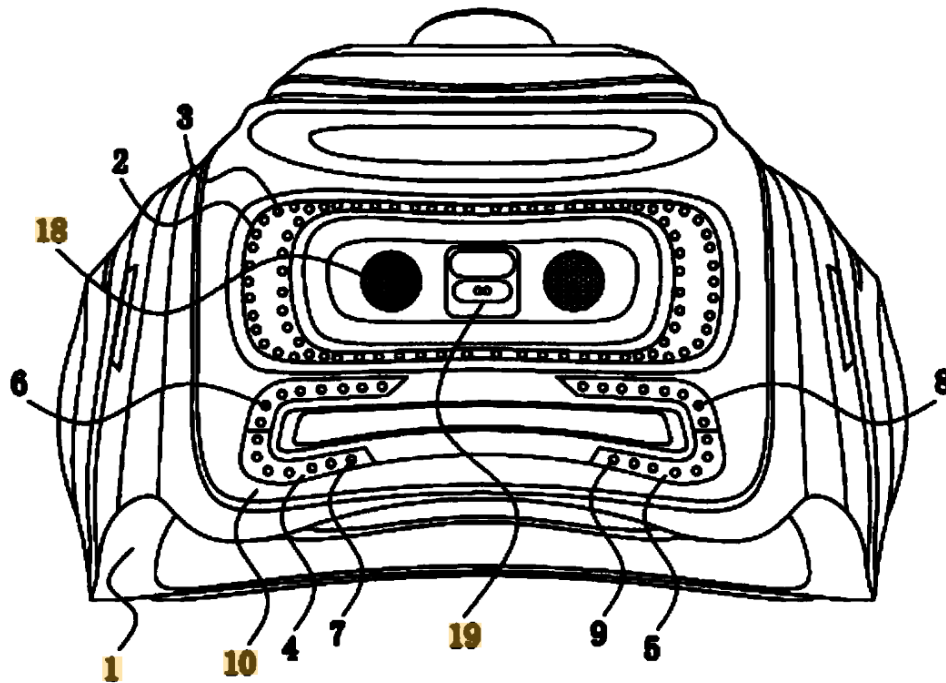


Figure 4.1.2: Back Side View of Smart Helmet

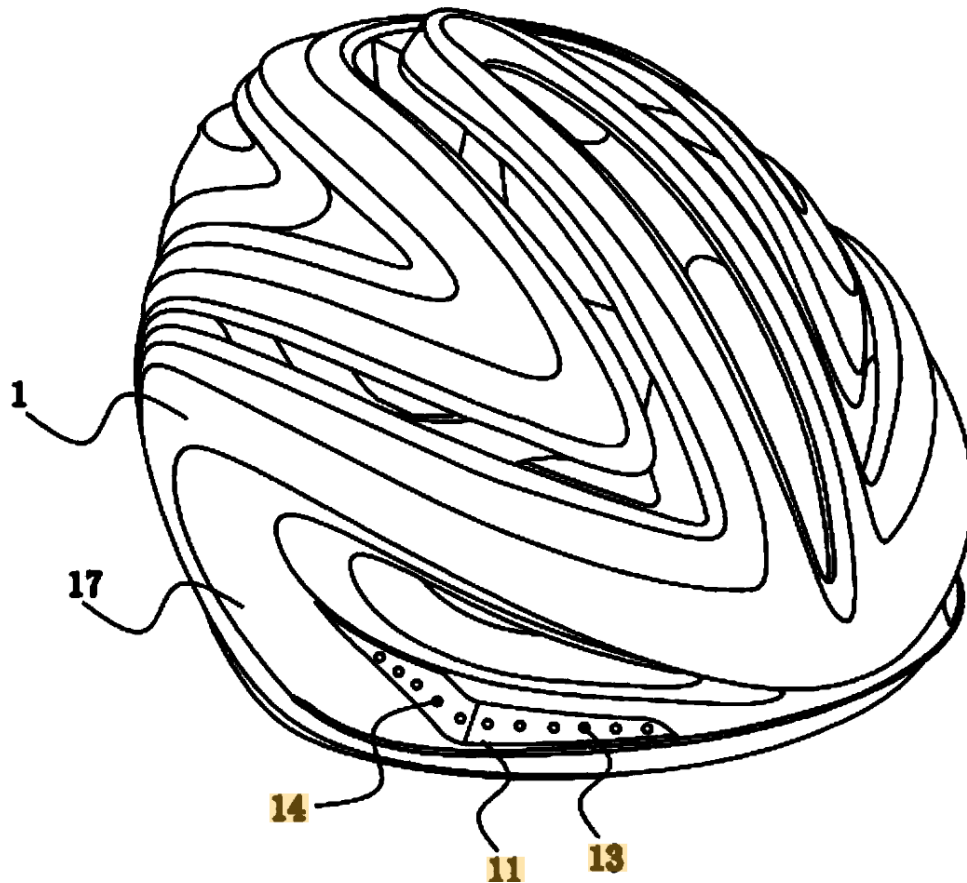


Figure 4.1.3: Isometric View of Smart Helmet

Analysis: This smart helmet's design is ergonomic and looks extremely similar to most bicycle helmets currently on the market. With the location of the lights surrounding the entire helmet, riders who wear this helmet will greatly enhance their rider visibility, especially at night. Furthermore, the addition of angle and speed sensors on the back of the helmet allow the smart helmet to properly signal turns and when the user is braking. However, the integration of electrical components into the helmet increases the overall weight and load this helmet places on the rider. Since this helmet relies on being charged through the outlet in the backside, it cannot be recharged in areas where there are no outlets or a continuous electrical source. Additionally, there are no covers over the outlet plug and other electrical components of the smart helmet on

the backside, which means that if this helmet were to be worn during any type of precipitation, it is possible that electrical components could be damaged.

Patent 2: Helmet with alarm indicator

Patent Number: CN201938457U

Date: 08/24/2011

Authors: 王一川

Abstract: A helmet with an alarm indicator relates to the improvement of a helmet structure.

The utility model provides a helmet with an alarm indicator, which has an alarm indication function and a simple structure, and comprises a signal generator and a motorcycle helmet, and the structural key points are that the top part of the motorcycle helmet is provided with a first alarm lamp, the middle of the motorcycle helmet is provided with a second alarm lamp, a brake lamp is arranged at the lower part of the motorcycle helmet, a left turning lamp is arranged at the left side of the motorcycle helmet, and a right turning lamp is arranged at the right side of the motorcycle helmet; and the first alarm lamp, the second alarm lamp, the brake lamp, the left turning lamp and the right turning lamp are respectively connected with a signal processor, and the signal processor is connected with a signal receptor.

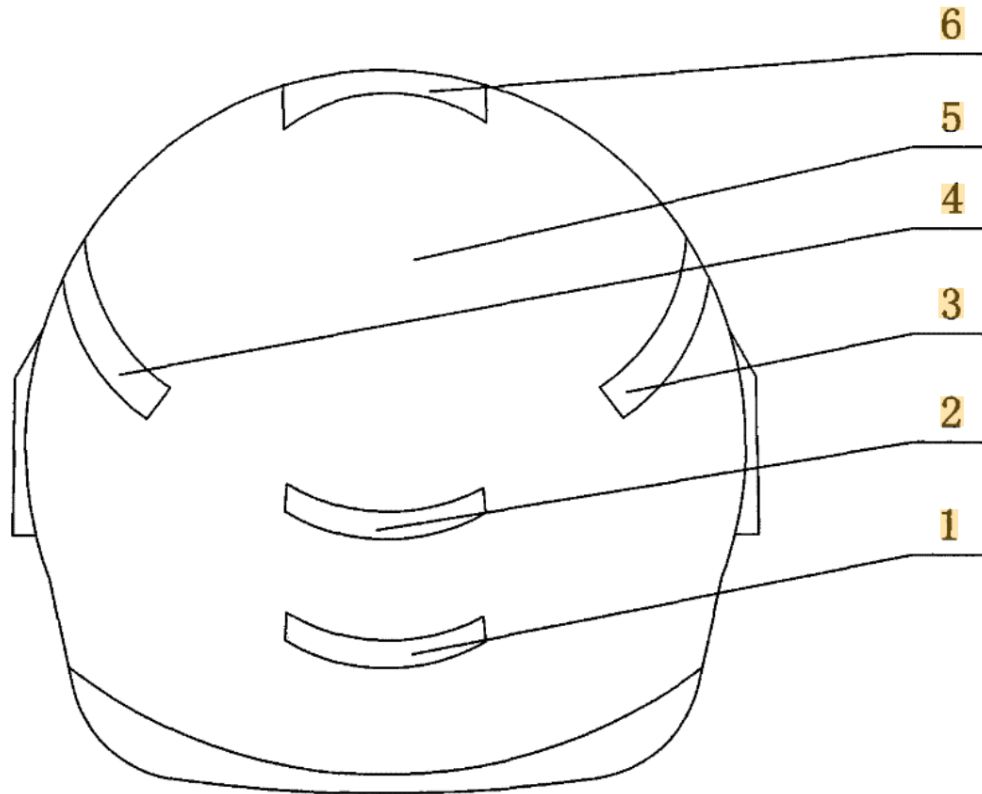


Figure 4.1.4: Back Side View of Helmet With Alarm Indicator

Analysis: Similar to the LED Smart Helmet, this motorcycle helmet looks extremely similar to most bicycle helmets currently on the market. On this helmet, there are a variety of alarm lamps placed on the front, top, sides, and back of the helmet. Each of these alarm lamps serves a specific purpose. For example, while the lights on the left and right (labeled 4 and 3 respectively) allow the rider to signal a left and right turn, the back light (labeled 1) signals when the user is trying to brake. Overall, the simplicity of this design enhances rider visibility at night while preventing the helmet from being weighed down with a variety of electrical components.

Patent 3: Improved communication system for vehicle hazard lights

Patent Number: ES2818568T3

Date: 04/23/2021

Authors: Daniel Tucker, John Cobb, Jonathan Torkelson, Denver Kimberlin, Devender Maurya

Abstract: Vehicle lighting safety device (300) comprising: at least one left turn signal input, at least one right turn signal input and at least one danger input, the at least one can be coupled hazard input (306; 408; 410) communicatively to a hazard light switch accessible to the existing driver (501; 701; 901; 1105; 1301; 1506) inside the vehicle, the at least one input of left turn signal and the at least one right turn signal input to a turn signal lever (204); a microcontroller (302) communicatively coupled to the at least one left turn signal input, at least one right turn signal input, and at least one danger input and operable to receive a voltage signal activation through the at least one hazard input, the activation voltage signal indicating activation of the hazard lights switch accessible to the driver to activate power to the hazard lights; and an output (446) communicatively coupled to the microcontroller and capable of driving a plurality of existing vehicle-mounted light-emitting diodes (102, 106, 108, 112), at least some of which selectively function as turn signal lights. based on manipulation of the signal light lever mounted on the steering column of a vehicle; wherein the microcontroller can be operated to generate a signal to drive the plurality of existing vehicle-mounted light-emitting diodes in a strobe manner having a repeating flash pattern comprising a portion having a cycle rate that is perceptibly faster than a turn signal light cycle rate in response to receipt of the drive voltage signal on the at least one hazard input.

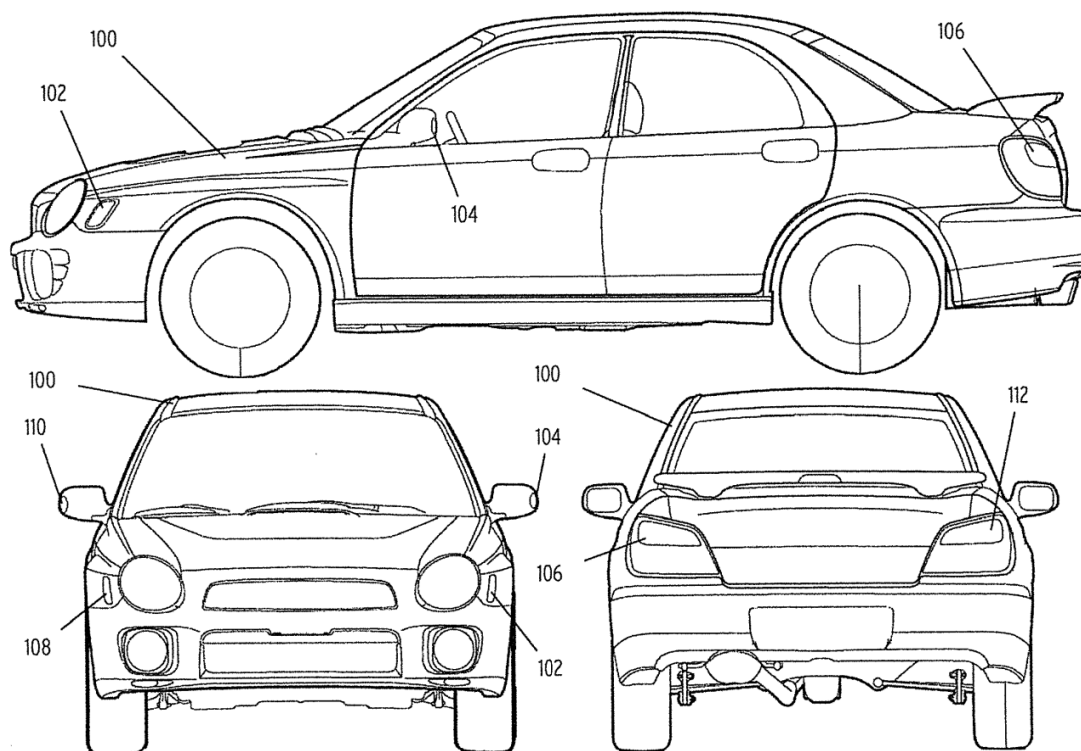


FIG. 1

Figure 4.1.5: Locations of Current Vehicle Hazard Lights

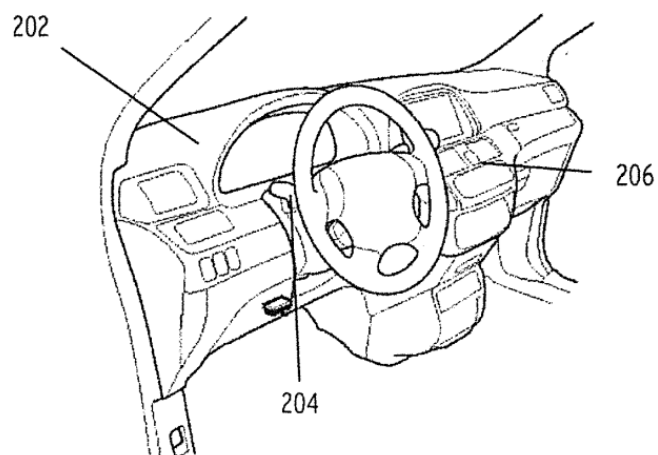


Figure 4.1.6: Location of Buttons and Handles to Activate Vehicle Hazard Lights

Analysis: As described in the patent's abstract and report, current hazard flashers and lights on automobiles and emergency vehicles do not provide a high enough level of clear communication to other drivers that there is a safety hazard ahead. The current double flashing light mechanism cannot be seen from far away, so the development of hazard lights that flash in a stroboscopic manner would improve visibility and safety on roadways. Some issues that arise from hazard lights that flash in a stroboscopic manner revolve around drivers who can become nauseous or feel disoriented after being exposed to strobe lights that flash between a frequency of 1-20 hertz. While these updated hazard lights may allow drivers from further away to be alerted to danger up ahead, there are some extremely photosensitive drivers who may become nauseous and disoriented while driving.

Patent 4: LED Illumination Pedal

Patent Number: CN219257613U

Date: 06/27/2023

Authors: 陈佳颖

Abstract: The utility model discloses an LED lighting pedal, which comprises a pedal main body and pedal shafts, wherein two sides of the pedal main body, which take the pedal shafts as symmetry centers, are provided with frame spaces with symmetrical positions, the frame spaces are hollow structures with openings at the front, rear, left, right, upper and lower sides, lighting mechanisms are arranged in the frame spaces, the lighting structures comprise opaque shells which are connected in the frame spaces in a sliding mode, one side of each shell, which is far away from each other, is provided with an opening structure, a light-transmitting plate is fixedly connected at one side of each shell, which is far away from each other, LED lamp tubes are

arranged in the shells, and the lighting mechanisms are arranged at the pedal positions, so that the front road can be illuminated during riding at night, and vehicles and pedestrians can be warned more safely, conveniently and practically.

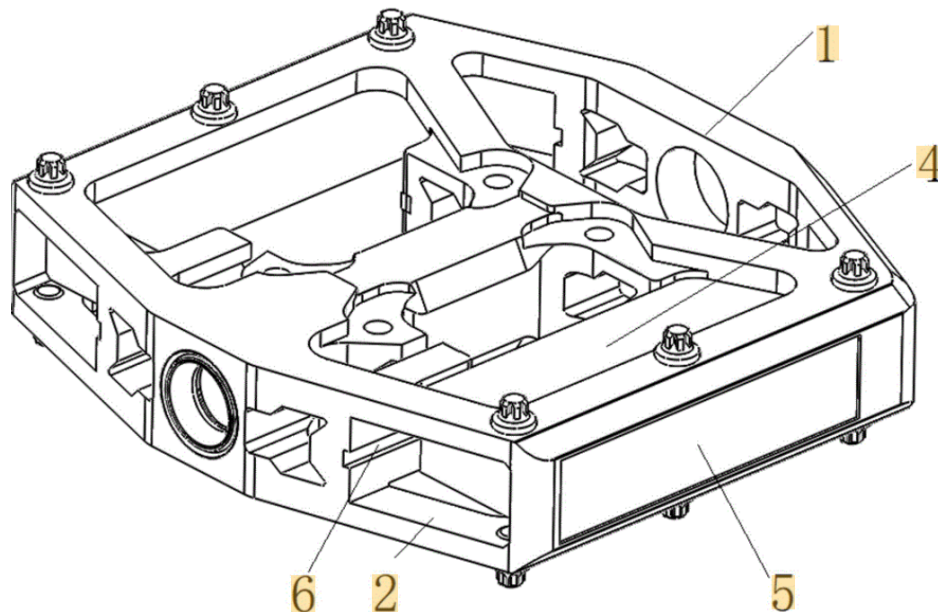


Figure 4.1.7: LED Illumination Pedal with Labeled Lights

Analysis: Integrating LED Panels into bicycle pedals provides a practical solution for increasing rider safety and visibility while biking. The lights being positioned on the front and back of the pedals allow for the light to naturally align with the rider's movement, ensuring consistent visibility without the need for additional equipment. Furthermore, this design is extremely easy to install compared to other products that may require a complicated setup or extra accessories. While this design is simple and extremely compact, the pedal light has the lowest luminance level of all other products. Moreover, it cannot signal when the user is trying to turn or brake. It acts as a reflective decal on the bike frame or tire except it requires a battery powered mechanism to illuminate the LED's.

Patent 5: Handlebar lights with turn actuator

Patent Number: US10618586B2

Date: 04/14/2020

Authors: Daniel Ebrahemi

Abstract: A bicycle including a handlebar attached to a frame at substantially a midpoint, a first set of light sources disposed to project light in a first forward direction, said first set of light sources including a fixed light source and a motor-controlled light source, disposed to project light in a second forward direction said second set of light sources including a fixed light source and a motor-controlled light source, a controller, said controller disposed on the handlebar, said controller coupled to the first set of light sources and the second set of light sources, a rotation sensor operable to sense movement of the handlebar relative to the frame, said rotation sensor coupled to the controller, wherein the motor-controlled light sources move in response to the position of the rotation sensor.

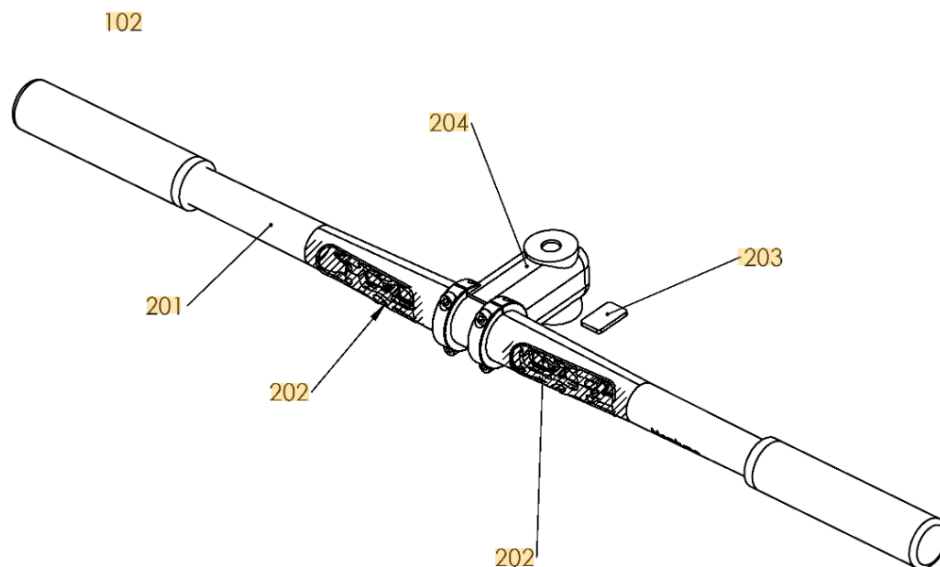


Figure 4.1.8: Isometric View of Handlebar Light Actuator Assembly

Analysis: This handlebar light actuator projects a beam of light forwards to enhance rider visibility at night. It contains multiple rotation sensors and a motor-powered light actuator so that it can properly track and illuminate the area when the user wants to turn with the light on. While this design properly illuminates the space in front of a rider, it fails to alert any drivers or other riders behind the user. Moreover, the lights in the handlebar project forwards, which may be a distraction to other riders or drivers coming towards the user.

4.2. Current Marketed Products and Analysis:

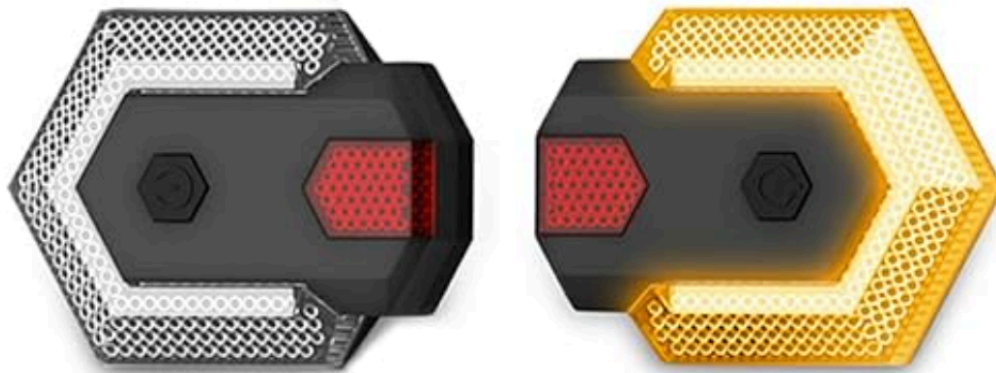


Figure 4.2.1: Wireless Bike Tail Light Turn Signal

Analysis: This wireless bike tail light turn signal has proved to be a sufficient turn signal with a myriad of different features. The material of the bike signal is plastic and is battery powered with a long total battery time. Furthermore, the entire product contains a 120 dB horn that beeps and effectively alerts riders and drivers behind the biker of when the user is about to turn. However, the price of this device (\$65.99) may prevent a lot of needy consumers from buying it. While this turn signal has a maximum brightness of 75 lumens, this may not be bright enough to still work during specific parts of the day.

5. PROPOSED ALTERNATIVES

5.1. Description of Proposed Alternatives

At the onset of this project, each team member created 3 ideas to solve our problem statement.

Below is a tabulated list of each team member's ideas:

Team member	Idea #	Method for detecting turns	Description
Liam	1	1 IMU on handlebars	An IMU is mounted on the handlebars of the bicycle. When a turn signal is initiated, the IMU sets its angle to 0. As the bicycle turns, the IMU continuously measures its angle relative to the starting angle. Once the angle reaches 90 degrees in the selected turning direction, the turn is complete. The turn signal deactivates and the IMU awaits the next turn signal.
	2	Rotational sensor on joint between handlebars and body	A rotational sensor is mounted such that it measures the rotation of the joint between the handlebars and the body. When a turn signal is initiated, the rotational sensor sets its angle to 0. As the bicycle turns, the angle between the handlebars and the body increases. The rotational sensor continuously measures the rate of change of the angle. Once the angle decreases back to 0, the rate of change is measured to have been positive, then negative, then zero. With this sequence, the turn is complete. The turn signal deactivates and the rotational sensor awaits the next turn signal.
	3	Ultrasonic sensors on body pointed at each handlebar	Two ultrasonic sensors are mounted, each pointing at one of the bicycle's handlebars. When the signal is initiated, the ultrasonic sensors record the distance to each handlebar. When one sensor begins to read a higher value than the other, the handlebar on that side is turned away from the bike body, so the turn is in progress. Once the values return to their original values, the turn is complete. The turn signal deactivates and the ultrasonic sensors await the next turn signal.
Nikhil	1	1 IMU on bicycle body	The IMU is placed inside a box connected to the main supporting bar of the bicycle. When the signal is initiated, the IMU measures its angular acceleration. As the bicycle handlebars continue to turn, the IMU reads the acceleration increase. Once the acceleration returns to its original value, the turn is complete. The light signal then switches from blinking to completely off.

	2	Tension cables between each handlebar and the bicycle body	Two tension sensors are mounted to two ropes that connect from the bicycle handlebars and the bicycle body. When the signal is initiated, the tension values in each cable are recorded. When one cable begins to experience more tension, the handlebar on that side is turned away from the bike body, so the turn is in progress. Once the tension returns to the original value, the turn is complete. The light signal then switches from blinking to completely off.
	3	1 IMU on bicycle body and 1 IMU on handlebars	When the signal is initiated, the IMUs both set their angles to 0. While the rider is turning, the IMU on the handlebar records its changing angle. By determining when this IMU value and the IMU value from the center of the bike are the same again (handlebar is perpendicular to bike), the turn is complete.
Animish	1	Camera mounted to handlebars with AI algorithm	When the signal is initiated, the computer vision algorithm will analyze the user's movements and once the rider is detected to be going back in a straight line, the turn is complete.
	2	Timer	When the signal is initiated, the timer waits a certain period of time before deactivating the turn signal.
	3	Microphone	When the signal is initiated, the microphone begins to listen for input. Once the rider says a predetermined key phrase, the turn is complete.

Each team member also created sketches to illustrate their ideas:

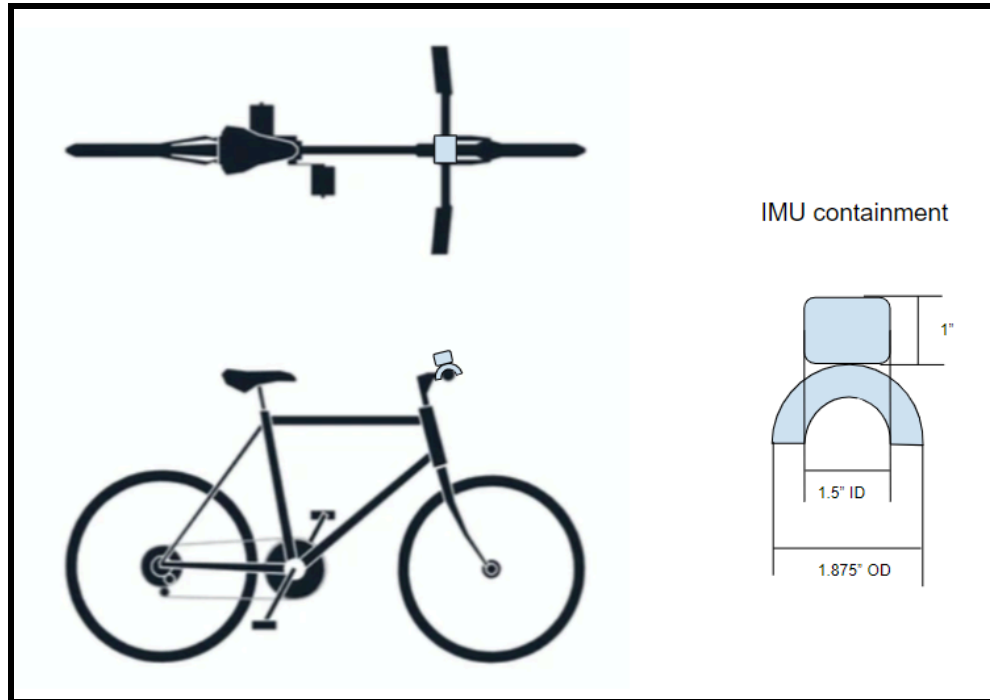


Fig. 5.1.1: Sketch of Liam's #1 Idea

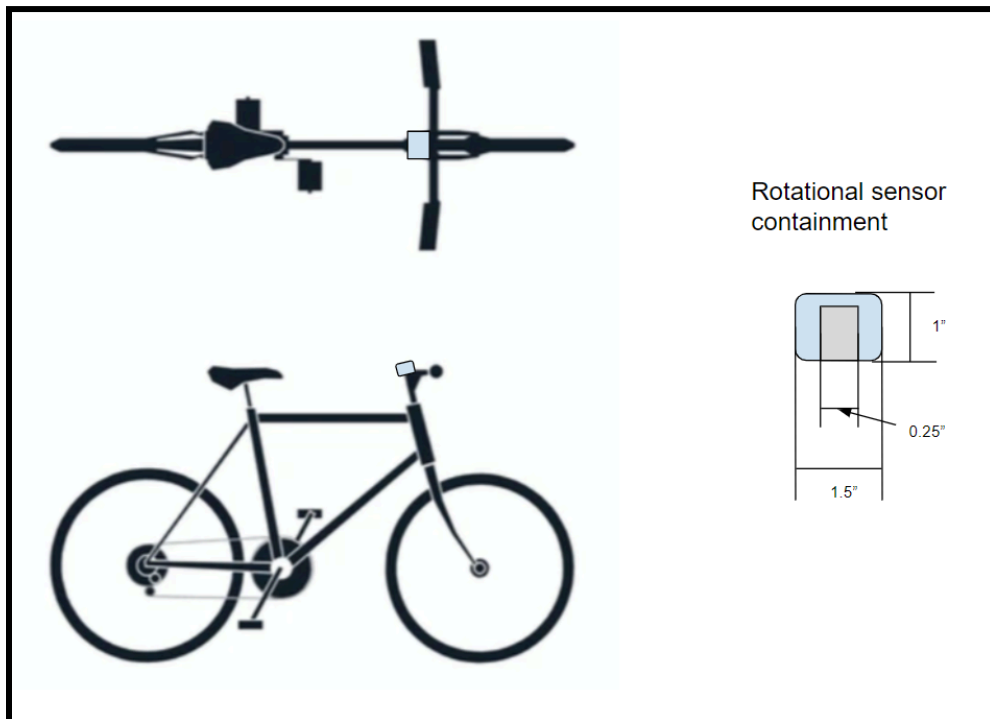


Fig. 5.1.2: Sketch of Liam's #2 Idea

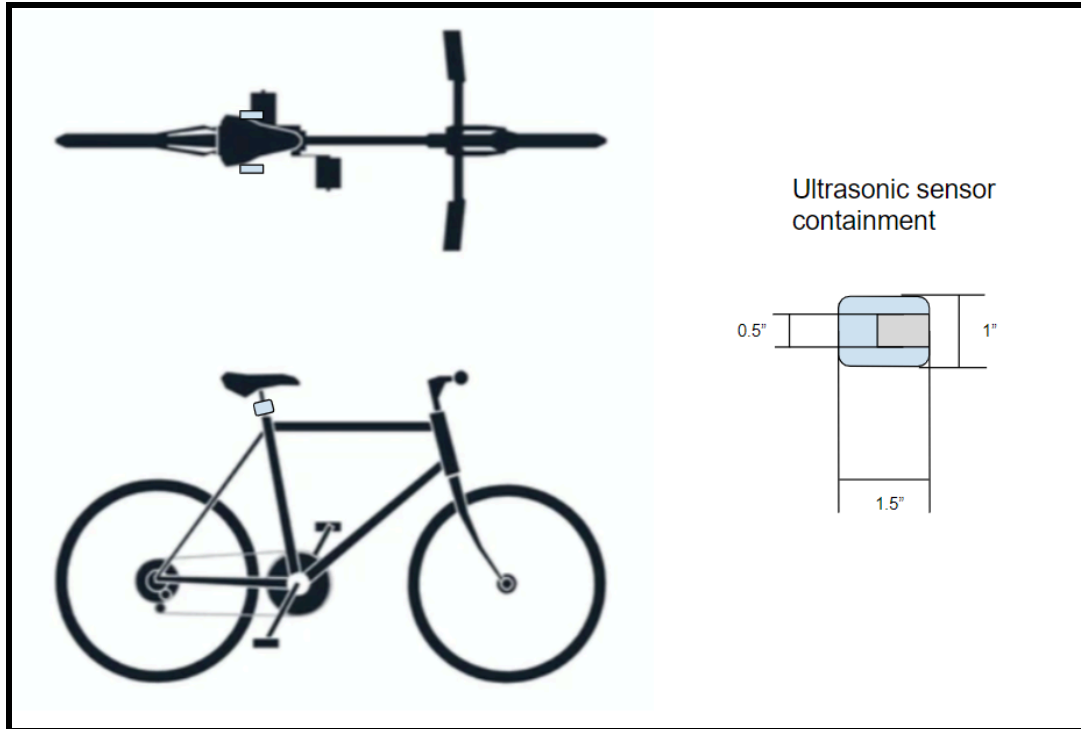


Fig. 5.1.3: Sketch of Liam's #3 Idea

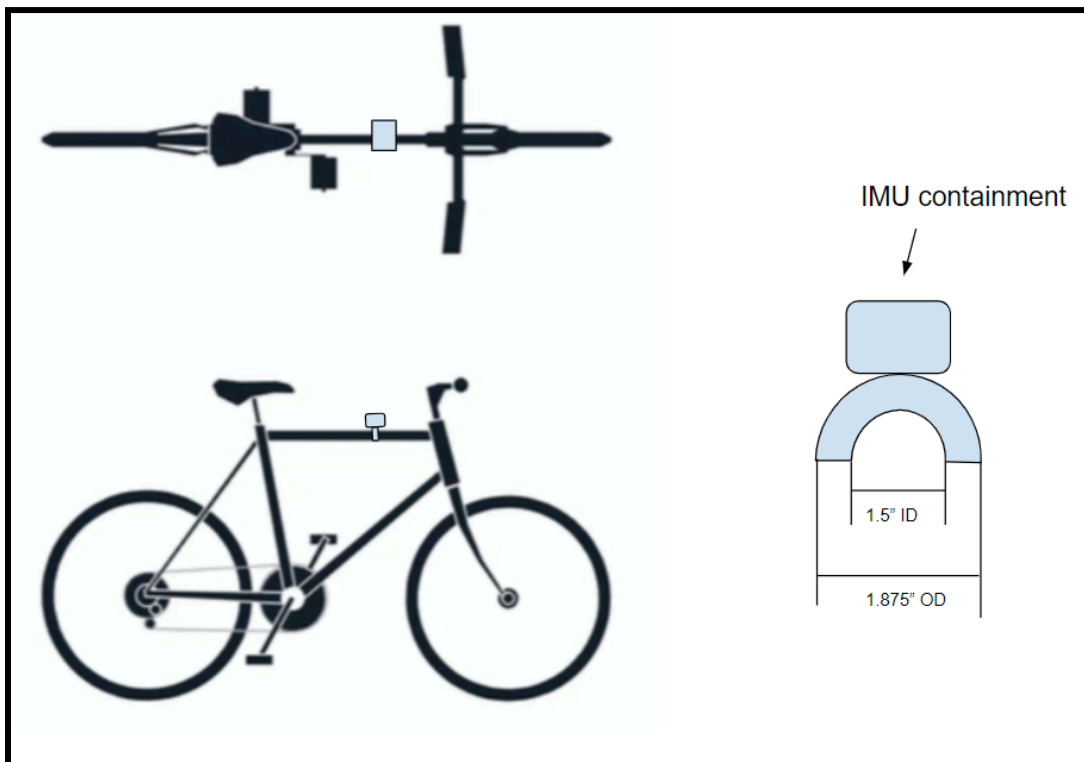


Fig. 5.1.4: Sketch of Nikhil's #1 Idea

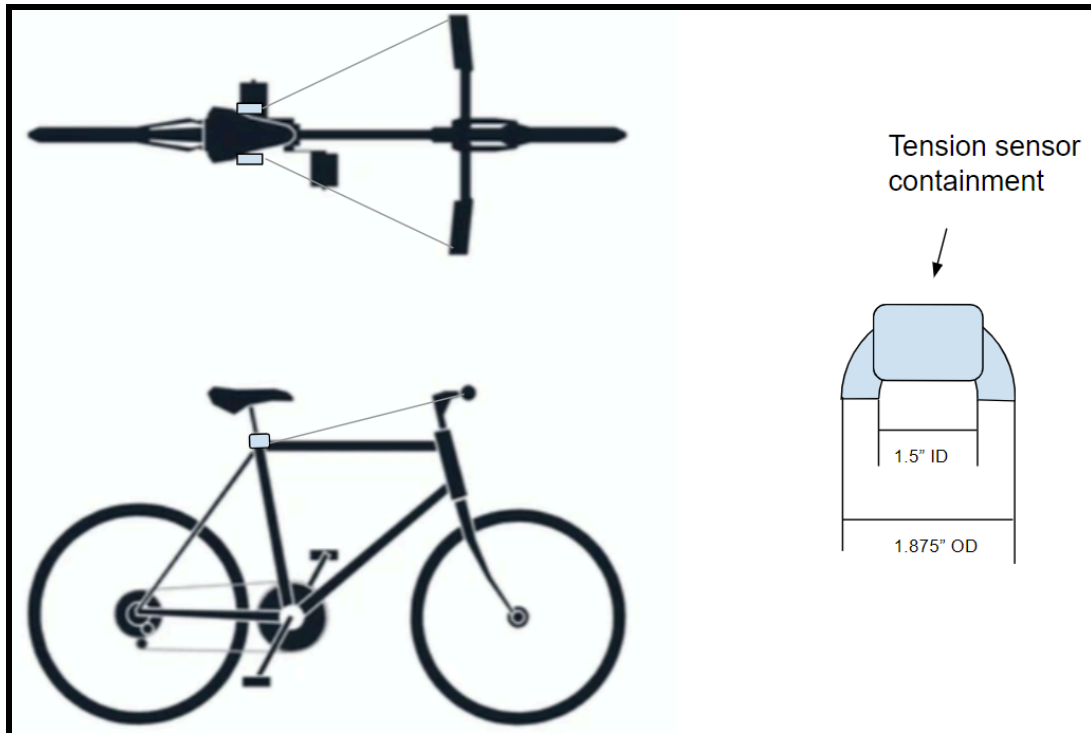


Fig. 5.1.5: Sketch of Nikhil's #2 Idea

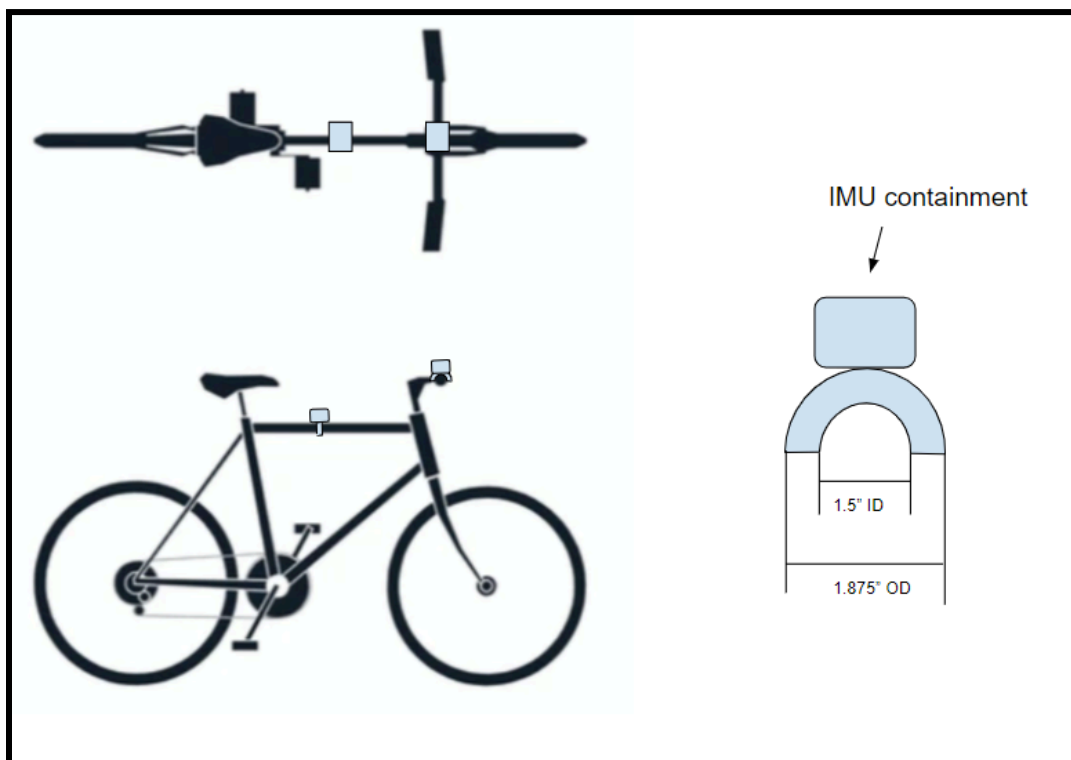


Fig. 5.1.6: Sketch of Nikhil's #3 Idea

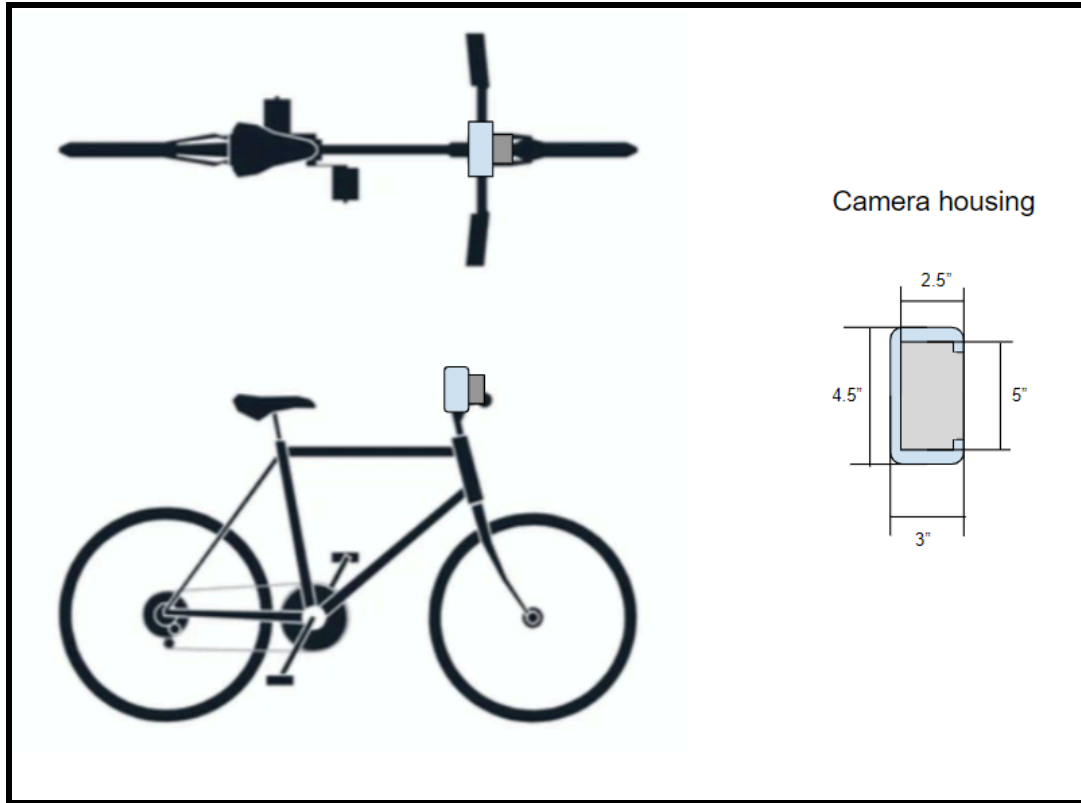


Fig. 5.1.7: Sketch of Animish's #1 Idea

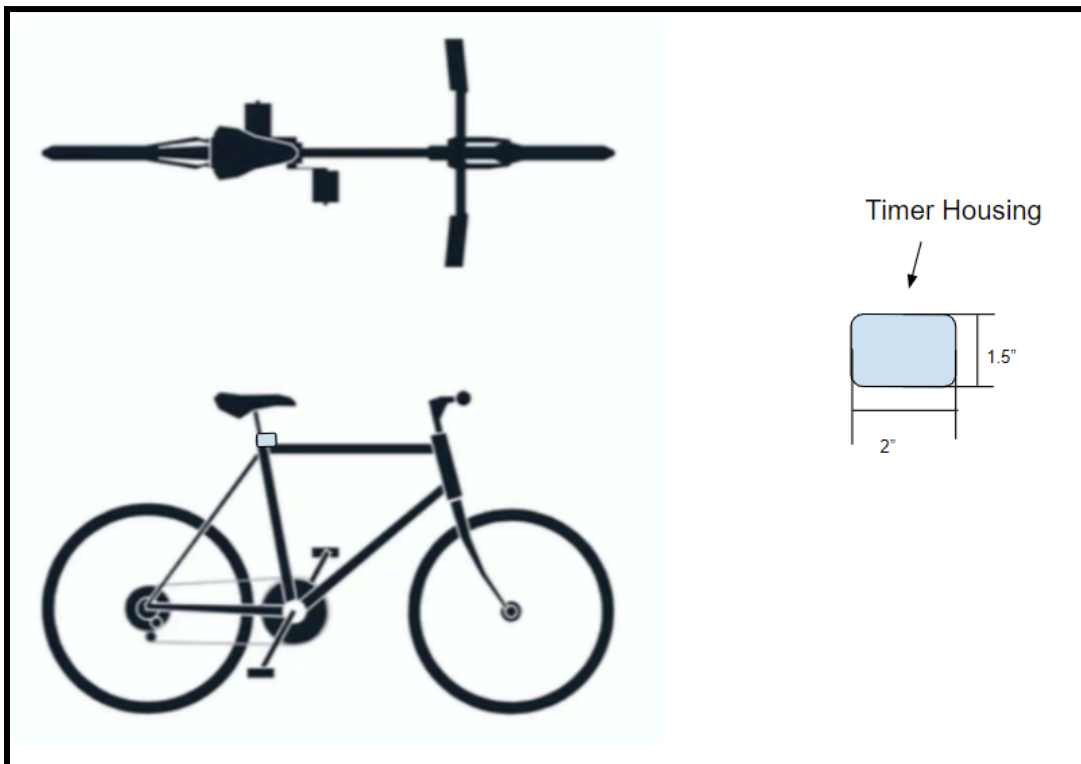


Fig. 5.1.8: Sketch of Animish's #2 Idea

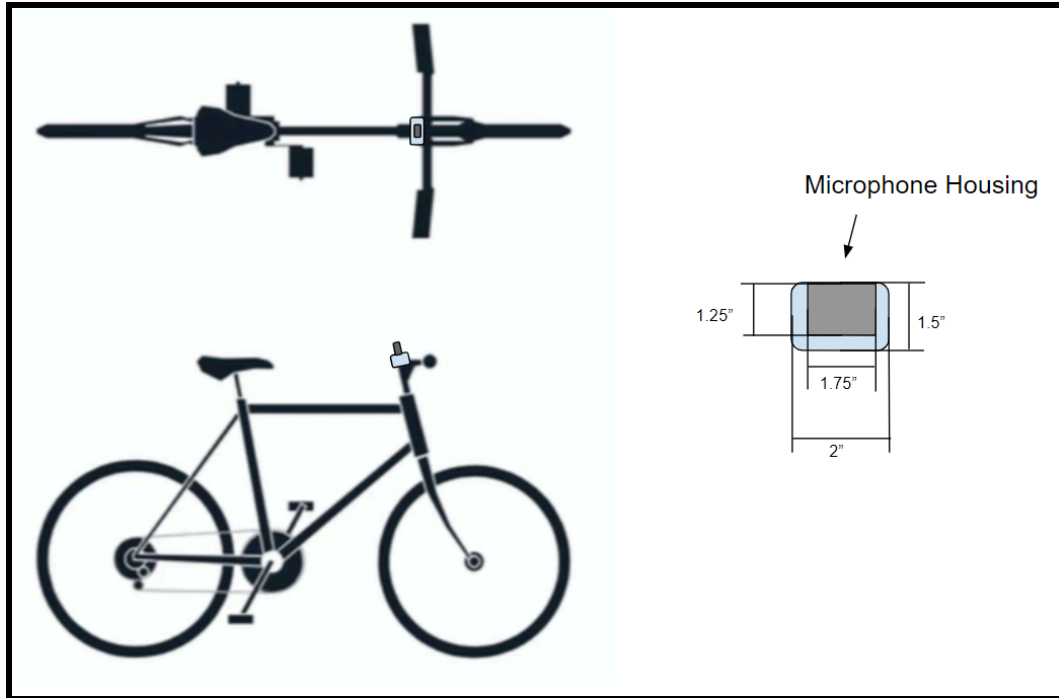


Fig. 5.1.9: Sketch of Animish's #3 Idea

5.2. Evaluation of Alternatives/Methodology

In order to evaluate our alternatives and select one to move forward with as our product design, we constructed a decision matrix. The categories we selected were based on our design brief, which was itself made to describe a product meeting all of the criteria that we believed a solution to our problem statement should incorporate:

- Durability is necessary for the product to withstand the vibrations and shocks experienced by any bicycle during use
- Minimum size ensures that the device will be visible to other riders and/or vehicles on the road
- Maximum size ensures that the device will not infringe upon the riding experience
- Safety is key to maintain the health of users
- Power must be sufficient enough that the device lasts as long as a reasonable bicycle ride
- Weight limits the impact of the device upon the rider's ability to ride over long distances

- Luminance aids in the visibility of the turn signal
- Simplicity makes assembly easy for both the manufacturer and the user
- Electrical safety protects the rider from electrical shocks and other circuit-related issues
- Time refers to the quick activation and deactivation time of the signal, which may be relevant in sequences of multiple close turns
- Material costs ensures that the device will not be too expensive as to be not worth using over alternative products

Below are the results for each alternative as determined by the decision matrix:

Idea	Liam 1	Liam 2	Liam 3	Nikhil 1	Nikhil 2	Nikhil 3	Ani 1	Ani 2	Ani 3
Durability	10	10	8	10	3	6	7	10	10
Min size	10	10	10	10	10	10	10	10	10
Max size	10	10	7	10	1	10	7	10	10
Safety	9	9	4	10	3	9	6	10	8
Power	9	9	8	8	9	9	6	8	9
Weight	10	10	10	10	9	10	10	10	10
Luminance	10	10	10	10	10	10	10	10	10
Simplicity	10	10	10	10	10	10	10	10	9
Electrical safety	10	10	10	10	10	10	10	10	10
Time	9	1	2	7	2	9	3	10	9

Material costs	8	3	5	6	4	10	1	8	5
Activation time	5	10	8	10	5	6	9	3	7
Total	110	102	92	111	76	109	89	109	107

5.3. Justification of Selected Alternative

The alternative that won was Nikhil's first idea. In this device, a single IMU is mounted to the body of the bicycle. When a turn signal is activated, the angular acceleration of the IMU is continuously measured, and the turn signal corresponding to the button pressed begins to blink. Once the acceleration passes above a certain threshold, the device evaluates that the turn has begun. After the acceleration passes back below the threshold, the device evaluates that the turn has ended, and the turn signal turns off.

Below are the justifications for each score that the alternative received:

- Durability: This idea gets a 10 for durability because the IMU, Arduino Uno, battery pack, and blinking lights all have cases that protect all electrical components from wear and tear.
- Min/Max Size: This idea gets a 10 for both minimum and maximum size because the one IMU and all other electrical components fit within the constraint given.
- Safety: This idea gets a 10 for safety because all electrical components will be out of the way for the user. This allows all testers to use the bicycle with no issues with the entanglement of electrical wires or any other parts.
- Power: This idea gets an 8 for power because the use of an IMU and the blinking lights draws more energy from the battery pack and decreases the total usage time.
- Weight: This idea gets a 10 for weight because the entire contraption weighs less than 3 pounds.

- Luminance: All ideas have the same score of 10 for luminance because all of the ideas use the same BTF-Lighting WS2812B light panels.
- Simplicity: This idea gets a 10 for simplicity because there are only 3 electrical components: one IMU, and two blinking lights. There is no need for any preliminary set up needed (no rope attachments/tension sensors).
Electrical Safety: This idea gets a 10 for electrical safety because all exposed wires from the electrical components will be covered and securely attached to the frame of the bicycle body. This will prevent any exposed wires or components from harming the user.
- Time: This idea gets a 7 on the time required to set up because this idea requires the user to attach the arduino/battery pack box to the frame of the bicycle right under the seat. Furthermore, the user must attach the two buttons on their handlebar to signal which direction they want to turn.
- Material Costs: This idea gets a 6 for material costs because there are a lot of electrical components that add to the total material cost. Furthermore, there are materials needed so that there are no exposed electronics or components that can harm the user.
- Activation Time: This idea gets a 10 on the activation time constraint because the turn signal will activate and deactivate within two seconds with the Arduino codebase. By reading the angular displacement and comparing it from the original value, the lights will automatically know when to turn off.

6. PROTOTYPE PLANNING AND CONSTRUCTION

6.1. Mockup Model Construction

The Mockup model was developed using the following materials:

- Foam core
- Cotton String
- Construction Paper

The Mockup model was developed using the following tools:

- Hot Glue Gun
- Scissors
- Ruler
- T-Square
- Exacto Knife
- Stick Glue
- Sand Paper
- Red Marker

The initial mockup model was developed by precisely cutting the foam core sheets using an Exacto Knife into various shapes. Our mockup model consisted of one central electrical housing box, 2 buttons, and 2 light panels. The central box was used to hold the electrical components, batteries, and circuitry. Next, two separate arrows signals were created. These arrows were made from paper and foam core and were attached to the central box using super glue. Two button cases/button clickers were developed using foam core to create a square base and circular button. A paper ring was created with the same diameter as the bike handle and was glued onto the foam

core button base. A cotton string was used to represent the wiring between the central box and the turn signal buttons.

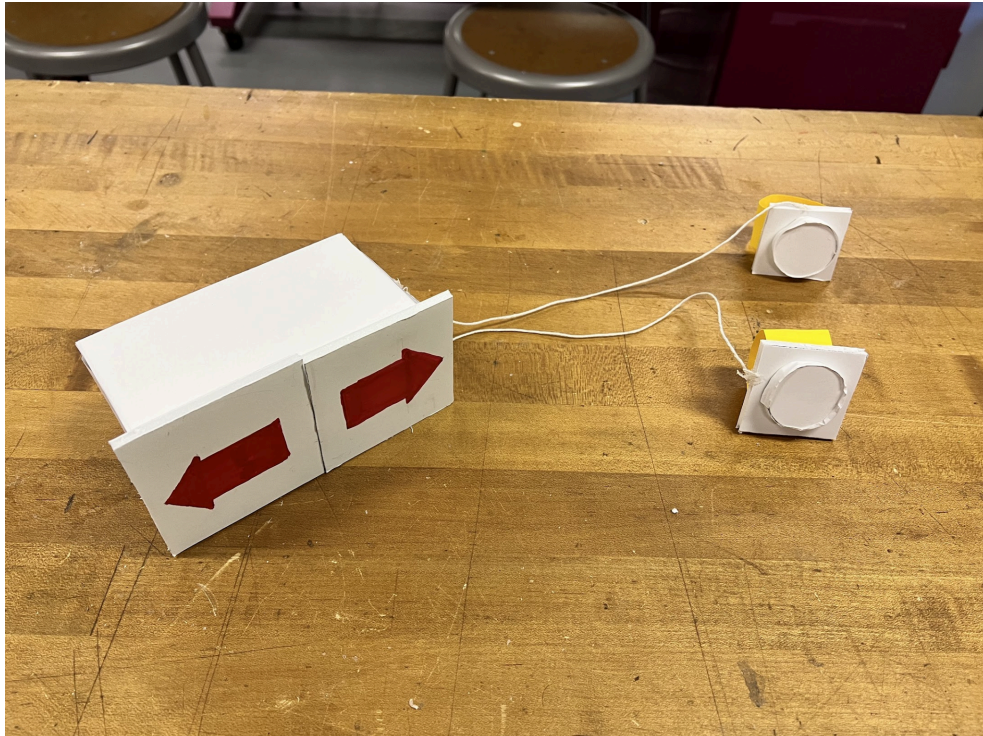


Figure 6.1.1: Isometric View of Completed Mockup

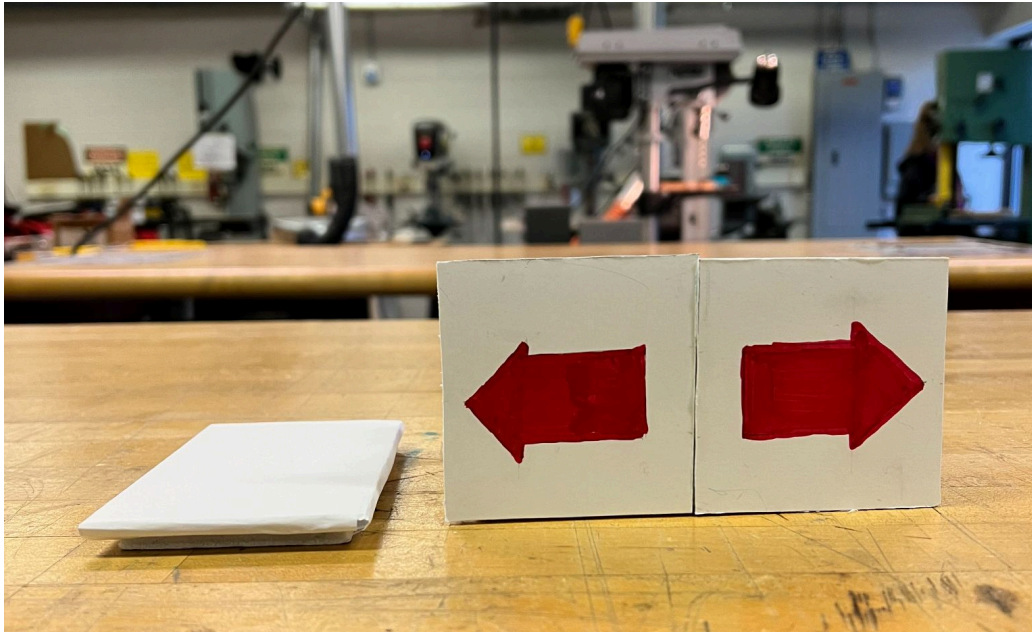


Figure 6.1.2: Front View of Completed Mockup



Figure 6.1.3: Top View of Completed Mockup

6.2. Post-Mockup Evaluation and Redesign

Redesign 1: The Electronics Casing

While considering the potential redesigns of our mockup, we realized that our central electrical housing box was limiting the users ease of use and assembly due to it's unnatural and uncomfortable shape. In order to create a more natural design, the decision was made to switch to a casing that would be tubular in shape and would be able to fit into the bottle holder of the bike. This not only makes it much easier to implement and assemble, but it also makes it much more practical and universally applicable. This not only simplified the mounting process but also streamlined the assembly, making the device more intuitive to install and integrate onto the bike frame. Moreover, the tubular design also was much more stronger than the rectangular box. This made the internal and electrical components less susceptible to damage and the overall design much more durable.

Redesign 2: The Light Panels

After developing the mockup model, it was decided that the light panels should not be directly attached to the electronics housing box. Instead, they should be designed to latch securely around the bike seat, making them much more visible and relatively central to the back of the bicycle. In addition, this makes the device much more durable as there are multiple components going into the structure of the light panels, and they are not just connected directly to the housing of the electronics. This not only optimized the visibility of the turn signals but it also helped to make the JigTurn a much more streamlined and functional design.

6.3. Detailed Construction/Assembly Plans of Components



Figure 6.3.1 Flowchart for Assembly Procedure

Electronics Housing Case

In order to develop the Electronics Housing Case, we first decided to use a PVC pipe as this would easily fit within the water bottle holder on a bicycle. A PVC pipe with a diameter of 4 inches was chosen as it ensured sufficient space for the internal components while also perfectly slipping into the holder. The length of the pipe was carefully measured and cut using a band saw. This was done to make the pipe match the maximum dimensions that a standard water bottle holder could accommodate. To secure the electronics within the pipe, we used PVC pipe caps on both sides of the pipe. This helped to not only make our device secure from the electronics falling out, but it also protected the components from water, dust, and dirt. This not only provided a high level of protection for the sensitive electronic components but also allows for

easy access in case the user would like to upgrade or fix his/her device.



Figure 6.3.2 Electronics Housing Case on Bike

Buttons Casing

To construct the casing for the buttons steel conduits were carefully clamped around the bike handles. This ensured that the casing would remain securely in place, which is especially important while riding a bike in extreme conditions or on uneven/bumpy surfaces.

Then, a custom button casing was designed and 3D printed to match the dimensions required for a snug fit. The design allowed the casing to screw directly into the steel conduit, creating a cohesive and secure unit that minimized any movement or rattling.

Finally, the buttons were installed into the casing using a friction fit. This was done by making the buttons slightly larger than the opening in the casing.



Figure 6.3.3: Button Casing on Bike

Light Panels Casing

The casing for the light panels and the supports were developed through CAD software and were 3D printed on a Makerbot. In order to create the supports specifically, we used preexisting screw holes on the bike that are commonly used to attach water bottle holders and cargo racks onto the

bukes main frame. This allowed for the user's to get an easy installation without the need for any additional modifications to the buke frame itself.

The casing for the light panels were made to sit on the supports mentioned above while also using the back of the main seat for support. This would allow for the light panels to be easily visible from the behind.



Figure 6.3.4: Light Panels Casing and Supports on Bike

6.4. Technical CAD Drawings, Flowcharts, Schematic Drawings

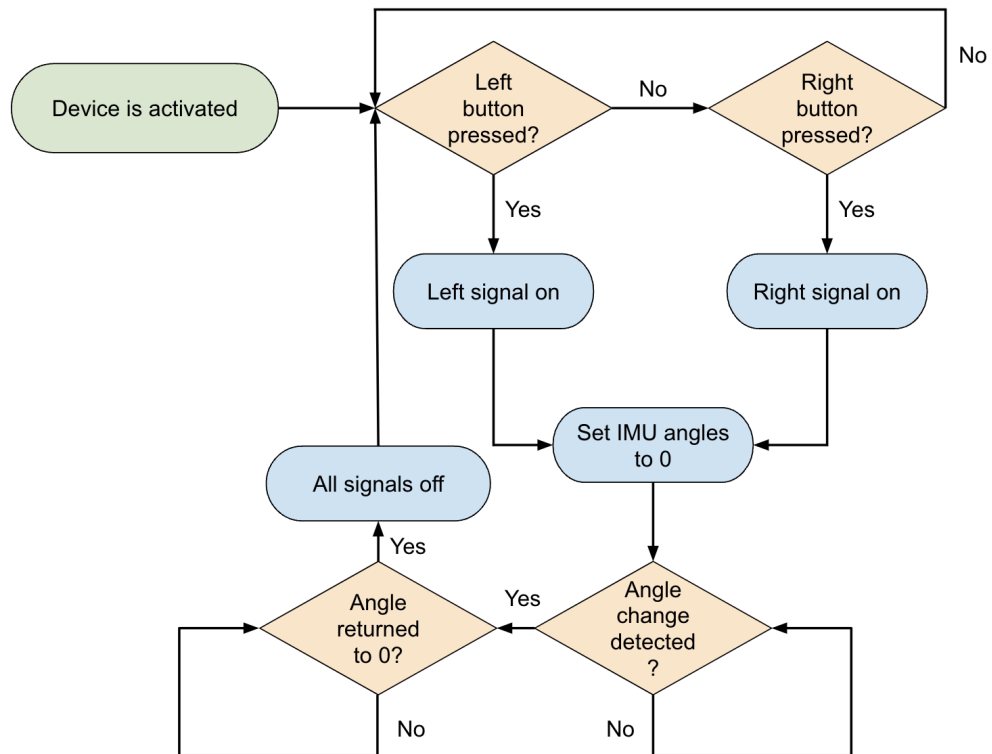


Figure 6.4.1 Flowchart for Circuit Logic

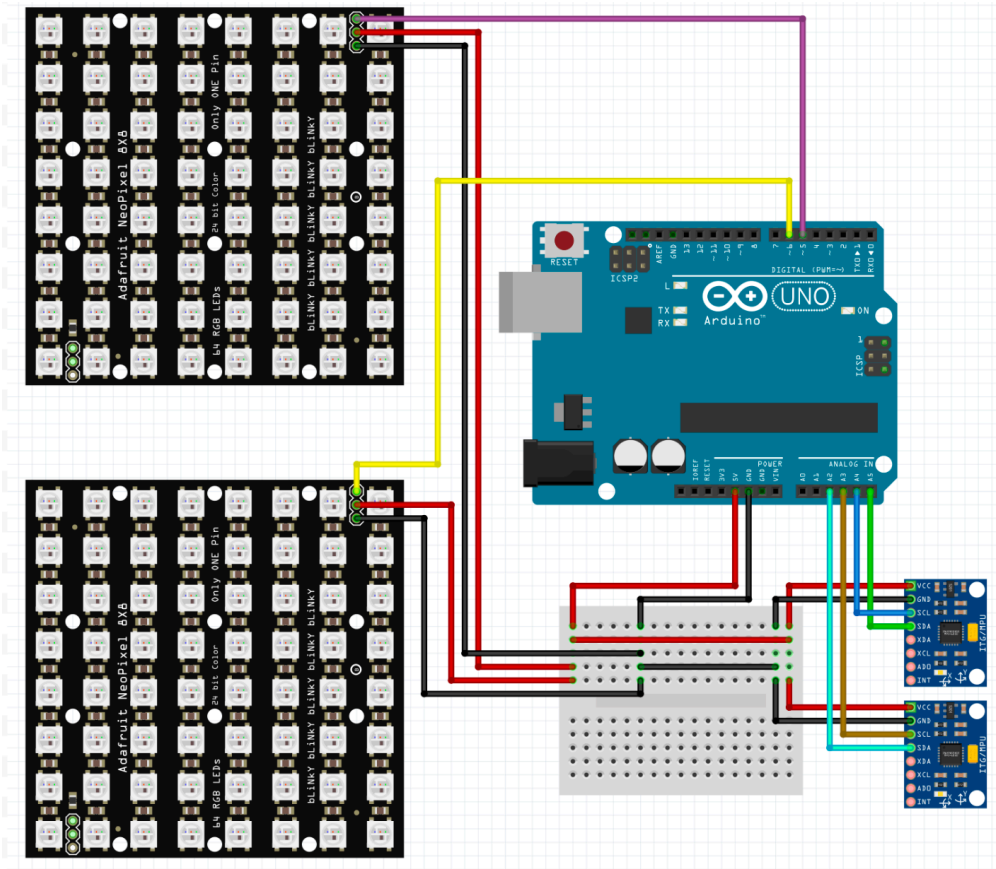


Figure 6.4.2 Fritzing Diagram for Circuit

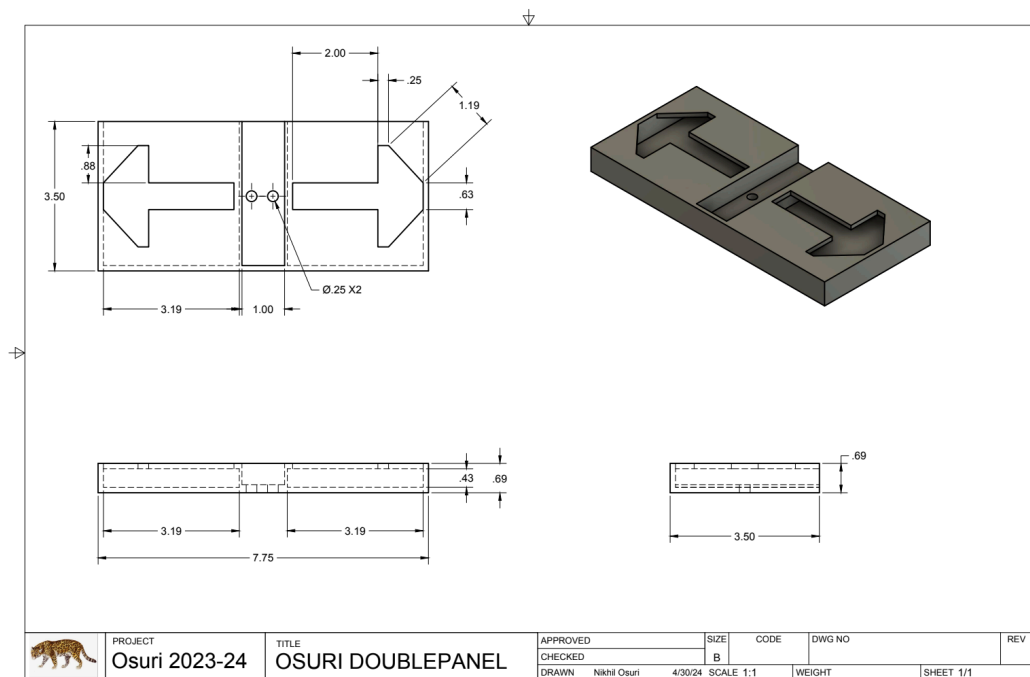


Figure 6.4.3 CAD Drawing for Light Panel

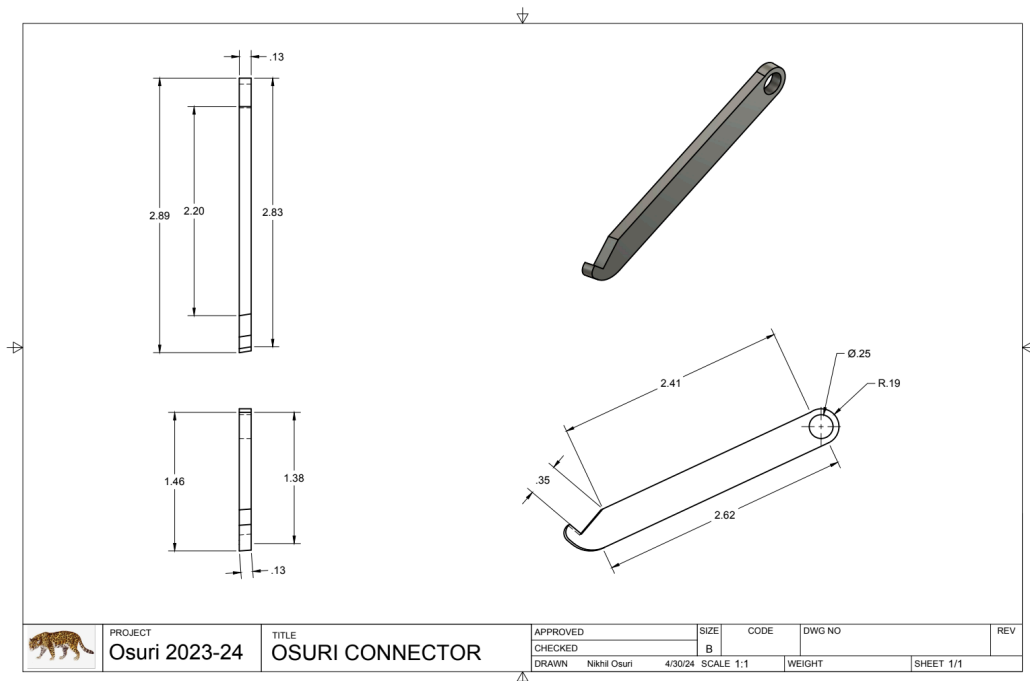


Figure 6.4.4 CAD Drawing for Light Panel Connector

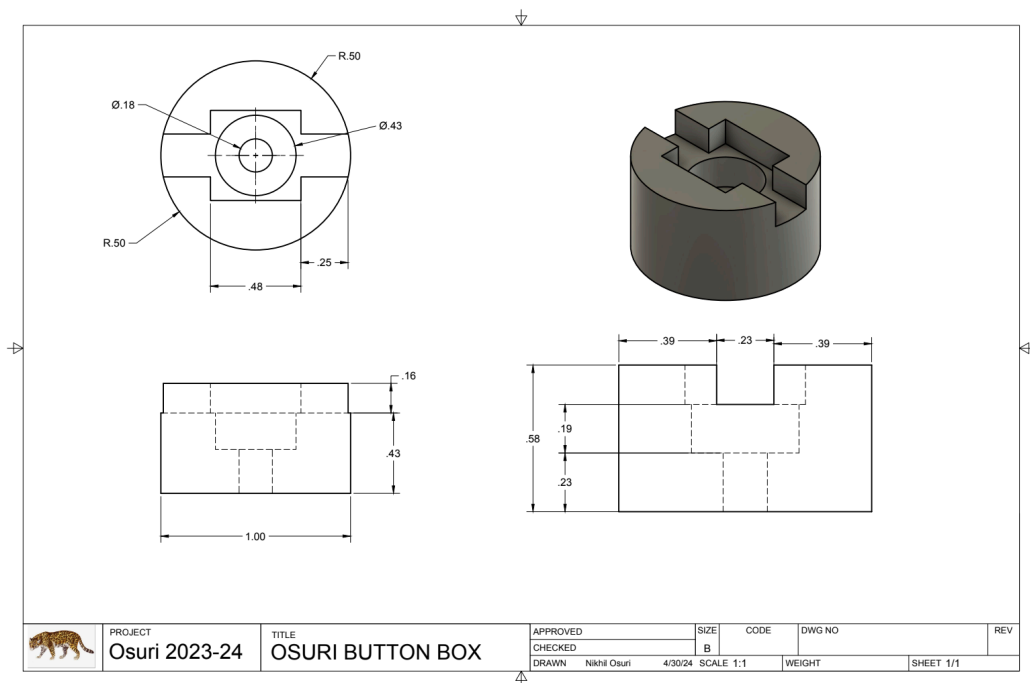


Figure 6.4.5 CAD Drawing for Button Casing

6.5. Materials List

- 5 Feet of 12 Gauge Electrical wire
 - Provided by HTHS (no additional cost)
 - \$5.99 Amazon
- 5.71 ounces MakerBot PLA 3D Print Filament, Blue
 - $\$0.83 / \text{Ounce Amazon} = \4.74
- 5g Tin/Lead Solder
 - Provided by HTHS (no additional cost)
 - $\$0.09 / 1\text{g} = \0.45 Amazon
- Arduino Nano
 - Pre-owned (no additional cost)
 - \$9.99 Amazon
- 4 Duracell AA Batteries
 - Pre-owned (no additional cost)
 - \$1.25 Amazon
- 1ft Electrical Tape
 - Pre-owned (no additional cost)
 - $\$0.03 / \text{Foot Amazon}$
- SHILLEHTEK MPU 6050 GY-521 (6 Axis Accelerometer)
 - \$4.95 Amazon
- 2 BTF-LIGHTING WS2812B ECO RGB LED Panels
 - \$11.98 Amazon
- 2 Four Pin Push Button

- Provided by HTHS (no additional cost)
- \$0.20 Amazon
- 2 330 Ohm Resistors
 - Provided by HTHS (no additional cost)
 - \$0.12 Amazon
- Adafruit 4AA Battery Holder
 - Provided by HTHS (no additional cost)
 - \$2.95 Amazon
- Double Sided PCB Board
 - \$0.10 Amazon
- 4" x 2ft PVC Piping
 - \$4.47 Home Depot

6.6. Equipment & Tools List

- MakerBot Replicator+ 3D Printer
 - Provided by HTHS (no additional cost)
 - MakerBot: \$2099
- K Kernowo 928D Soldering Iron
 - Pre-owned (no additional cost)
 - Amazon: \$19.99

6.7. Construction Cost of Prototype

Item	Pre-Owned?	Cost
SHILLEHTEK MPU 6050 GY-521 (6 axis accelerometer)	No	\$4.95
Arduino Nano	Yes	\$9.99
BTF-LIGHTING WS2812B ECO RGB (light panels)	No	\$11.98
4 pin push button	Yes	\$0.20
330 ohm resistor	Yes	\$0.12
Adafruit 4AA battery holder	Yes	\$2.95
Duracell AA batteries (4 pack)	Yes	\$1.25
Double Sided PCB Board	No	\$0.10
4" PVC Piping	No	\$4.47
1ft Electrical Tape	Yes	\$0.03
5g Tin/Lead Solder	Yes	\$0.45
5.71 ounces MakerBot PLA 3D Print Filament	Yes	\$4.74
10 Feet of 12 Gauge Electrical wire	Yes	\$5.99
Total: \$47.22		

Total 3D Printing Time: 14 hours

Total Labor Hours: 5 hours

7. TESTING AND RESULTS

7.1. Operating Instructions: Setup/Assembly for Manufacturer

The setup and assembly of our product consists of two phases: a build procedure and electrical wiring.

Build Procedure:

1. 3D print all 3D models
 - a. Hinge x2
 - b. Light Panel Bracket x1
 - c. Turn Signal Button Bracket x2

Electrical wiring:

1. Add 4 AA batteries to the battery pack with proper orientation
2. Switch wiring
 - a. Connect the positive terminal from the battery pack to the central pin on the Switch
 - b. Connect the negative terminal from the battery pack to GND on the Arduino Uno
 - c. Connect one side of the of the Switch to 5V on the Arduino Uno
3. Place the Arduino Uno inside of the Tube Casing
4. MPU6050 wiring
 - a. Connect VCC on the MPU6050 to 5V on the Arduino Uno
 - b. Connect GND on the MPU6050 to GND on the Arduino Uno
 - c. Connect SDA on the MPU6050 to A4 on the Arduino Uno
 - d. Connect SCL on the MPU6050 to A5 on the Arduino Uno
5. LED Panel wiring

- a. Connect DIN on LED Panel 1 to pin 6 on Arduino Uno
 - b. Connect DIN on LED Panel 2 to pin 7 on Arduino Uno
 - c. Connect both GND pins on LED Panels to GND on Arduino Uno
 - d. Connect 5V on both LED Panels to 5V on Arduino Uno
6. Button wiring
- a. Connect input pin on Button 1 to D2 on Arduino Uno
 - b. Connect input pin on Button 2 to D3 on Arduino Uno
 - c. Connect remaining pins on Buttons 1 and 2 to 10k Ω resistor then into GND on Arduino Uno

7.2. Operating Instructions: Setup/Assembly for User

Assembly is intended for use on the BIKE MODEL.

1. Unscrew the two screws at the top of the seat stay. Align each Hinge component to its respective screw hole and screw it in.



Figure 7.2.1: Hinge Components Attached Onto Bike

2. Run the Zip Tie through the holes in the back of the Light Panel Bracket and around the seat post. Tighten the Zip Tie as much as possible.



Figure 7.2.2: Zip Tie Around the Light Panel

3. Screw each button casing onto its respective conduit clamp
4. Screw each conduit clamp onto its respective bicycle handle.



Figure 7.2.3: Conduit Clamp and Button Casing on Bicycle Handle

5. Friction fit each button onto their respective button casings.
6. Slide each light panel into their respective casings.
7. Remove the water bottle holder from the down tube and reattach it to the seat tube, then slide the Tube Casing into the water bottle holder.



Figure 7.2.4: Tube Casing in Water Bottle Holder

7.3. Operating Instructions: Operation

1. Flip the Switch on top of the Tube Casing to “On.” Wait 3 seconds to ensure that the device is initialized and calibrated.
2. Ride the bicycle as usual. When initiating a turn signal, press the button corresponding to the direction of the turn.
3. After a turn, attempt to ride straight in order to ensure that the turn signal properly deactivates.

7.4. Operating Instructions: Disassembly

1. Remove the Tube Casing from the water bottle holder. Remove the water bottle holder from the seat tube and reattach it to the down tube.
2. Loosen the each Button Bracket’s screw and slide it off of its bicycle handlebar.
3. Cut the Zip Tie.
4. Unscrew the two screws at the top of the seat stay. Remove each Hinge component and screw the corresponding screw back in.

7.5. Testing Criteria

Our testing criteria were based on our design brief. They were a combination of qualitative and quantitative criteria:

1. Qualitative: Device durability
2. Qualitative: Minimum size

3. Quantitative: Maximum size
4. Qualitative: User safety
5. Quantitative: Power consumption
6. Quantitative: Maximum weight
7. Quantitative: Luminance
8. Qualitative: Simplicity
9. Qualitative: Electrical safety
10. Quantitative: Installation time
11. Quantitative: Material costs
12. Qualitative: Activation time

7.6. Testing Procedure

We determined methods of testing using a combination of our own measurements and analysis of the device, the market survey completed by our testers, and our analysis of videos of the testers:

1. Device durability - Operational test (check status after test subject use)
2. Minimum size - Volunteer study (question on market survey)
3. Maximum size - Dimensional measurement (measure with dial calipers)
4. User safety - Volunteer study (question on market survey)
5. Power consumption - Operational test (run device until time requirement)
6. Maximum weight - Weighing (weigh device on scale)
7. Luminance - Light sensor measurement (measure lux output)
8. Simplicity - Volunteer study (question on market survey)
9. Electrical safety - Visual observation (visually check all electrical components)

10. Installation time - Volunteer study (question on market survey)
11. Material costs - Cost evaluation (cost spreadsheet)
12. Activation time - Operational test (analysis of test subject videos)

Overall, our procedure for each tester was as follows:

1. Begin recording the tester.
2. Give the tester the user assembly instructions. Time the tester on their ability to assemble the device.
3. Give the user the operating instructions. Have the user perform a sample straight-line movement.
4. At the end of the straight-line movement, have the user activate the turn signal and stop. Have the user round the turn and perform another straight-line movement until the turn signal deactivates.
5. Have the user complete the market survey.

7.7. Photos of Testing Procedure



Figure 7.7.1 Anonymous User #1 Testing JigTurn



Figure 7.7.2 Anonymous User #2 Testing JigTurn



Figure 7.7.3 Anonymous User #3 Testing JigTurn



Figure 7.7.4 Anonymous User #4 Testing JigTurn



Figure 7.7.5 Anonymous User #5 Testing JigTurn

7.8. Selection of Test Subjects

In order to select our test subjects, we verbally asked students around High Technology High School two questions:

1. Can you ride a bicycle?
2. Do you feel comfortable removing your hands from the handlebars while riding a bicycle?
3. Would you like to participate in a volunteer study to test a bicycle turn signal?

Students who answered “Yes” to the first question but “no” to the second question met our device’s target demographic. Therefore, the first 12 students who met this demographic and answered “Yes” to the third question made up our body of test subjects.

7.9. Tabulation of Test Results

The LED Panels that create our device’s turn signal have variable brightness, determined by a set value within our code. Before testing the device for other criteria, we determined the approximate minimum brightness setting to meet our design brief’s luminance requirement.

Below is our testing data:

Brightness %	Trial 1	Trial 2	Trial 3	Avg
25	57	63	57	59
50	112	106	109	109
75	162	166	161	163
100	219	218	216	217.7
Brightness % is a measure of how high the brightness of the LED panels is set				

relative to its maximum value. All other data is measured in lumens.

We came to the conclusion that we only needed to set the brightness to 25% of its maximum value in order to satisfy the 50 lumen threshold.

After testing the device with our 12 testers, we had each tester complete a market survey. This survey included questions with three purposes: (1) data collection, (2) to satisfy certain requirements from our design brief, and (3) to gain a better understanding of the potential performance of our device as a real product. The questions were as follows:

1. Name (Write “Anon” if you wish to remain anonymous) (*Data collection*)
2. Phone Number (*Data collection*)
3. Were you able to recognize the turn signal from a distance of 50 feet or more? If not, how many feet could you see it from? (*Design brief - Minimum Size*)
4. Were you able to operate the device with the four instructions given? Are there any unclear or confusing instructions? (*Design brief - Simplicity*)
5. How long did it take you to install the device onto the bicycle? (*Design brief - Time*)
6. Do the light panels or any other part of the device impede your ability to ride the bicycle? (*Device performance*)
7. On a scale of 1-10, how safe did you feel using this device? (*Design brief - Safety*)
8. On a scale of 1-10, how comfortable were your hands while riding the bicycle with the button holder on the handlebars? (*Device performance*)
9. On a scale of 1-10, how easy was it to press the button? (*Device performance*)
10. On a scale of 1-10, how likely would you be to buy/use this device and recommend it to someone else? (*Device performance*)

11. On a scale of 1-10, how satisfied were you with the user experience? (*Device performance*)

12. What potential changes, if any, do you think could improve this device? (*Data collection*)

7.10. Tabulation of Market Survey Results

Below are the results of the market survey as completed by our 12 testers. The questions are labeled with numbers 1-10, with the questions corresponding to each number listed below the results:

Question #	1	2	3	4	5	6	7	8	9	10
Tester 1	Yes	Yes	8 min	No	7	8	10	8	8	Make the signals smaller to avoid brushing legs against them
Tester 2	Yes	Yes	7 min	No	7	9	9	8	9	Make the device work for smaller bicycle sizes
Tester 3	Yes	Yes	10 min	No	8	9	10	9	9	Make the turn signals studier
Tester 4	Yes	Yes	8 min	No	9	10	10	10	10	Don't change the device
Tester 5	Yes	No	12 min	No	8	8	10	9	9	Make the buttons smaller so my hands have more room
Tester 6	Yes	Yes	9 min	No	9	8	10	9	9	Add another water bottle holder so I can also have a water bottle
Tester 7	Yes	Yes	9 min	No	8	9	10	8	9	None
Tester 8	Yes	No	11 min	No	8	9	9	9	8	No changes
Tester 9	Yes	Yes	7 min	No	7	7	10	8	7	Prevent legs from touching device

Tester 10	Yes	Yes	10 min	No	8	9	10	7	8	Make the supports stronger
Tester 11	Yes	Yes	7 min	No	9	8	10	8	8	Make the bicycle smaller
Tester 12	Yes	Yes	8 min	No	9	10	10	10	10	None

Question key:

1. Were you able to recognize the turn signal from a distance of 50 feet or more? If not, how many feet could you see it from?
2. Were you able to operate the device with the four instructions given? Are there any unclear or confusing instructions?
3. How long did it take you to install the device onto the bicycle?
4. Do the light panels or any other part of the device impede your ability to ride the bicycle?
5. On a scale of 1-10, how safe did you feel using this device?
6. On a scale of 1-10, how comfortable were your hands while riding the bicycle with the button holder on the handlebars?
7. On a scale of 1-10, how easy was it to press the button?
8. On a scale of 1-10, how likely will you be to buy/use this device and recommend it to someone else?
9. On a scale of 1-10, how satisfied were you with the user experience?
10. What are some potential changes, if any, do you think could improve this device?

After our testing was complete, we performed some basic data analysis to understand how the average tester felt about the device. Below are our observations:

- 12/12 users were able to recognize the turn signal from a distance of 50 feet

- 10/12 users were able to operate the device with the instructions given
- The average time to install the device was 8 minutes and 50 seconds
- No users felt that the device impeded their ability to ride the bicycle
- The average user gave a safety rating of 8.1/10
- The average user gave a comfortability rating of 8.7/10
- The average user gave an ease of use rating of 9.8/10
- The average user gave a recommendation likelihood rating of 8.6/10
- The average user gave an overall satisfaction rating of 8.7/10

8. CONCLUSION

Overall, the JigTurn performed very well across many key metrics including visibility, usability, safety, and user satisfaction. First off, all of the participants within our testing were able to recognize the turn signals from a minimum distance of 50 feet. This shows that the JigTurn is effective in providing clear and visible signaling which is very crucial for night-time riders or bike rides taken in adverse weather conditions. With an average installation time of approximately 8 minutes and 50 seconds, the JigTurn was shown to be incredibly user-friendly. In fact, 10 out of 12 testers successfully operated it with the provided instructions. The JigTurn also did not impede the bicycle's operation. This shows that the riders felt much more safe without compromising the riding experience. Testers also felt significantly safer and comfortable while using the device, with an average safety rating of 8.1 out of 10, and an average comfort rating of 8.7 out of 10. Furthermore, since there was a high likelihood of recommendation (8.6 out of 10) and high overall satisfaction (8.7 out of 10) we can conclude that there was an overall positive reception among users.

In the original design brief, we were tasked with developing a turn signal device that's less than \$50 and allows users to automatically deactivate the turn signal after the turn is completed without removing their hands from the handlebars. The JigTurn prototype was incredibly simple and effective in solving the problem with ease. The JigTurn was very successful during testing as users were able to easily use the automatic turn-off feature and had overall positive feedback on ease of use and quick installation.

9. REDESIGN

In the future, we will redesign the JigTurn by placing the light panels not only at the back of the bike but also at the front. This will ensure that oncoming traffic can clearly see the turn signals, thus improving both the safety and effectiveness of the signaling system in all traffic conditions.

In addition, we will change our design to include adjustable and modular components. This will allow the device to be easily customized to fit securely on any bike frame, from large to compact sizes, without compromising stability or aesthetics. Currently, the JigTurn only works for larger bike frames. We plan to use sliding and telescoping mounts that can accommodate different types of frame dimensions and attachment points.

Moreover, to enhance the durability of the JigTurn, we will redesign using metal components for the main structural elements, including the button and circuit casings and light panel supports. This will also allow for more precise components and a higher quality of engineering. This will not only provide a sleeker and more streamlined appearance but also will maintain functionality and increase the product's longevity.

10. ACKNOWLEDGEMENTS

We would like to thank Ms. Linda Grunthaner and Dr. Raymond Eng for their continued supervision and guidance throughout the course of this project. Additionally, we would like to thank the High Technology High School administrators for supporting the Engineering Design & Development program each year and the Parent Faculty Association for giving us the funds necessary to complete this project. Finally, we would like to thank Mr. Borchardt and Dr. Ellsworth for providing us with a variety of resources to build and test our prototype design.

11. APPENDICES

11.1. Annotated Software Code

```
// Include necessary libraries for communication with the hardware

#include <Wire.h>           // Include the Wire library for I2C communication

#include <Adafruit_NeoPixel.h> // Include the Adafruit NeoPixel library for controlling the LED
strip

#include "I2Cdev.h"         // Include I2Cdev library for I2C device control

#include "MPU6050.h"         // Include MPU6050 library for accelerometer and gyroscope


// Definitions for the pin numbers and the number of LEDs in each strip

#define PIN_RIGHT 6         // Define the pin number connected to the right LED strip

#define PIN_LEFT 7          // Define the pin number connected to the left LED strip

#define NUMPIXELS 128       // Define the number of pixels (LEDs) in each strip


// Initialize MPU6050 and NeoPixel strip objects

MPU6050 accelgyro;         // Create an object for the MPU6050 sensor

Adafruit_NeoPixel stripRight = Adafruit_NeoPixel(NUMPIXELS, PIN_RIGHT, NEO_GRB +
NEO_KHZ800); // Initialize the right LED strip

Adafruit_NeoPixel stripLeft = Adafruit_NeoPixel(NUMPIXELS, PIN_LEFT, NEO_GRB +
NEO_KHZ800); // Initialize the left LED strip


// Button pins

const int buttonPinRight = 2; // Define the digital pin number for the right button
```

```

const int buttonPinLeft = 3; // Define the digital pin number for the left button

// Constants for turn detection and blinking

const int startTurnThreshold = 20000; // Define the acceleration threshold to start a turn
const int endTurnThreshold = 19500; // Define the deceleration threshold to end a turn
const int blinkInterval = 500; // Define the interval (in milliseconds) for blinking the LEDs

// Struct to manage turn signal state
struct TurnSignal {
    bool turning; // Flag to check if the turn signal is active
    bool hasTurned; // Flag to check if a turn has occurred
    unsigned long lastStableTime; // Timer to track stability duration after a turn
    unsigned long lastBlinkTime; // Timer to track last blink event
    bool ledState; // State of the LED (on or off)
    Adafruit_NeoPixel& strip; // Reference to the associated LED strip
};

// Initialize turn signal data for both right and left signals
TurnSignal rightSignal = {false, false, 0, 0, false, stripRight};
TurnSignal leftSignal = {false, false, 0, 0, false, stripLeft};

void setup() {
    Serial.begin(9600); // Start serial communication at 9600 baud

```

```

Wire.begin();           // Initialize I2C communication

accelgyro.initialize(); // Initialize the MPU6050 sensor

stripRight.begin();     // Prepare the right LED strip for use

stripLeft.begin();      // Prepare the left LED strip for use

stripRight.show();      // Initialize all pixels to 'off' on the right strip

stripLeft.show();       // Initialize all pixels to 'off' on the left strip

pinMode(buttonPinRight, INPUT_PULLUP); // Set the right button pin as input with internal
pull-up resistor

pinMode(buttonPinLeft, INPUT_PULLUP); // Set the left button pin as input with internal
pull-up resistor

Serial.println("Setup complete. Waiting for input..."); // Print setup completion message
}

void loop() {

    checkTurnSignal(buttonPinRight, rightSignal); // Check the right turn signal

    checkTurnSignal(buttonPinLeft, leftSignal); // Check the left turn signal
}

// Function to check and manage turn signals based on button press and acceleration

void checkTurnSignal(int buttonPin, TurnSignal& signal) {

    int buttonState = digitalRead(buttonPin); // Read the current state of the button (pressed or
not)

```



```

    if (buttonState == LOW && !signal.turning) { // If button is pressed and signal is not already
active

        signal.turning = true; // Activate the signal

        signal.hasTurned = false; // Reset the turn completion flag

        signal.ledState = true; // Turn on the LEDs

        signal.lastBlinkTime = millis(); // Reset the blink timer

        Serial.println((buttonPin == buttonPinRight ? "Right" : "Left") + String(" button pressed.
Turn signal activated."));

        displayArrow(signal.ledState, signal.strip); // Display the arrow on the LEDs
    }

    if (signal.turning) { // If the signal is active

        int16_t ay = accelgyro.getAccelerationY(); // Get the Y-axis acceleration from the sensor

        double lateral_acceleration = abs(ay); // Take the absolute value of the acceleration

        Serial.print("Y-axis lateral acceleration: ");

        Serial.println(lateral_acceleration);

        if (!signal.hasTurned && lateral_acceleration > startTurnThreshold) { // If a turn is
detected

            signal.hasTurned = true;

            Serial.println((buttonPin == buttonPinRight ? "Right" : "Left") + String(" turn in
progress."));

        }

```

```

    if (signal.hasTurned && lateral_acceleration < endTurnThreshold) { // If the turn is
completed
        if (millis() - signal.lastStableTime > 2000) { // Check if 2 seconds have passed since turn
completion
            signal.turning = false; // Deactivate the signal

            signal.strip.clear(); // Turn off the LEDs

            signal.strip.show();

            Serial.println((buttonPin == buttonPinRight ? "Right" : "Left") + String(" turn
completed. Turn signal deactivated.));

        }
    } else {
        signal.lastStableTime = millis(); // Reset the stability timer if still turning
    }

    if (millis() - signal.lastBlinkTime > blinkInterval) { // If it's time to blink
        signal.ledState = !signal.ledState; // Toggle the LED state

        displayArrow(signal.ledState, signal.strip); // Update the LED display

        signal.lastBlinkTime = millis(); // Reset the blink timer
    }
}
}
}

```

```

// Function to display or clear the arrow on the LED strip

void displayArrow(bool on, Adafruit_NeoPixel& strip) {

    strip.clear(); // Clear all LEDs

    if (on) { // If turning the arrow on

        int arrowPixels[] = {13, 17, 18, 45, 46, 50}; // Define the LED positions for the arrow

        for (int i = 24; i < 40; i++) {

            strip.setPixelColor(i, strip.Color(255, 0, 0)); // Set the middle row LEDs to red

        }

        for (int i = 0; i < sizeof(arrowPixels) / sizeof(arrowPixels[0]); i++) {

            strip.setPixelColor(arrowPixels[i], strip.Color(255, 0, 0)); // Set the arrow tip LEDs to
red

        }

    }

    strip.show(); // Update the LED strip to show changes

}

```

11.2. Test Subjects

Tester Number:	Phone Number:	Date:	Testing Location:
Tester 1:	732-242-2640	5/1/2024	Senior Lounge
Tester 2:	732-858-2130	5/1/2024	Senior Lounge
Tester 3:	732-285-2638	5/1/2024	Senior Lounge

Tester 4:	908-627-3948	5/1/2024	Senior Lounge
Tester 5:	732-285-5024	5/1/2024	Senior Lounge
Tester 6:	917-724-7714	5/1/2024	Senior Lounge
Tester 7:	732-535-1860	5/1/2024	Senior Lounge
Tester 8:	609-619-1070	5/1/2024	Senior Lounge
Tester 9:	512-705-7811	5/1/2024	Senior Lounge
Tester 10:	732-610-1207	5/1/2024	Senior Lounge
Tester 11:	650-213-2310	5/1/2024	Senior Lounge
Tester 12:	908-770-8144	5/1/2024	Senior Lounge

11.3. References

Ahmadizade, C., Ahrabi, A., Appiah, I., Jendli, W., & Medhioub, A. (2014). Functional Specification for a Bicycle Smart Helmet. Simon Fraser University.

- The specifications outlined in this document contributed to our understanding of the integration of smart technology in cycling equipment, specifically helmets. By analyzing their approach to incorporating sensors and communication tools into a helmet, we were able to extract valuable insights that informed the development of our turn signal device. This included how to effectively combine safety features with user-friendly design,

ensuring that our product not only enhances safety but does so with minimal disruption to the cyclist's experience.

Beck, B., Blomberg, R. D., Dozza, M., Johansson, O., Kim, J. K., Lacherez, P., Rasanen, M., Shackel, S. C., Twisk, D. A., & Wood, J. M. (2020, June 12). *Effects of night-time bicycling visibility AIDS on vehicle passing distance*. Accident Analysis & Prevention. <https://www.sciencedirect.com/science/article/abs/pii/S000145751931752X>

- This study investigates the impact of various visibility aids on the distance vehicles maintain from bicyclists during night-time. It provided evidence that certain types of visibility aids can significantly increase safety by encouraging drivers to give more space to cyclists. This research informed our project's emphasis on incorporating features that enhance cyclist visibility at night, which could potentially influence the design and functionality of our signaling device.

Bicycle crash statistics. Bicycle Safety Guide and Countermeasure Selection System. (n.d.).

http://www.pedbikesafe.org/bikesafe/guide_statistics.cfm#:~:text=Night%20bicycle%20riding,a n%20education%20issue%20for%20bicyclists.

- This source offers statistics on bicycle accidents, notably underlining the dangers of nighttime riding. We used these statistics to underline the necessity for effective signaling devices that enhance cyclist visibility and safety, particularly after dark. This information substantiated the need for our project, aiming to mitigate these risks with improved technology.

Brown, B. B., Smith, K. R., Hanson, H., Fan, J. X., Kowaleski-Jones, L., & Zick, C. D. (2013, March). *Neighborhood design for walking and biking: Physical activity and body mass index*. American journal of preventive medicine. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3690570/>

- The research explores how neighborhood design affects physical activity such as walking and biking, and the implications on body mass index and safety. It provided context for understanding how our signaling device could be utilized in various urban environments. The insights helped inform the design requirements to ensure the device would be versatile and effective in different settings.

Chan, B. H., & Duran, R. A. (2014). *Bike Safe: An Automatic Turn Signal System*. California Polytechnic State University - San Luis Obispo.

- Their research, conducted as part of their undergraduate thesis, explored the technical requirements and potential implementations of such systems, offering critical insights into the integration of electronic and mechanical components. Leveraging their findings, our team was able to develop a more sophisticated, user-friendly design that incorporates automatic signaling based on real-time cycling dynamics. This prior research was pivotal in helping us address technical challenges and refine our design to ensure reliability and ease of use in our turn signal device.

Day, G. A. (n.d.). *US9210771B2 - vehicle exterior lighting system*. Google Patents. <https://patents.google.com/patent/US9210771B2/en?q=%28hazard%2Blights%2Bcar%29&oq=hazard%2Blights%2Bcar>

- This patent outlines a sophisticated vehicle lighting system that automatically responds to environmental inputs. It served as an inspiration for incorporating similar automatic features in our bicycle signaling device, particularly the mechanism for turning off the signal post-turn to simplify the user experience and enhance safety.

Dev, R. (2023, January 19). *Thermal flasher: Automobile turn signal flashers - AMPERITE*.

Amperite Co. <https://amperite.com/blog/automobile-turn-signal-flashers/#:~:text=The%20resistance%20to%20the%20current,signal%20bulb%20to%20stop%20glowing>.

- Discusses how thermal flashers work in automotive turn signals, utilizing resistance changes to automatically switch off the signal. We considered this mechanism as a potential low-cost solution for automating the turn-off feature in our bicycle signals, enhancing usability and safety without manual intervention.

Doyan, A. (n.d.). (PDF) Arduino-based light intensity measurement. https://www.researchgate.net/publication/362164168_Arduino-Based_Light_Intensity_Measurement

- This publication describes the development and application of an Arduino-based system for measuring light intensity. The methodology and findings from this study were used to explore potential sensor integration in our bicycle turn signal device, particularly for automatically adjusting the signal brightness based on ambient light conditions to optimize visibility.

Ebrahemi, D. (n.d.). *US10618586B2 - handlebar lights with turn actuator*. Google Patents.

<https://patents.google.com/patent/US10618586B2/en?q=%28bicycle%2Blights%29&oq=bicycle%2Blights>

- This patent involves handlebar lights with a built-in turn actuator, directly relevant to our project's goals. It was studied to understand existing solutions and to find ways to innovate beyond the manual aspects of these systems, particularly aiming to automate the signaling process.

Elsevier. (2023, December 9). *Road lighting and cycling: A review of the Academic Literature and Policy Guidelines*. Journal of Cycling and Micromobility Research. <https://www.sciencedirect.com/science/article/pii/S2950105923000086>

- Reviews the impact of road lighting on cycling safety, with a focus on how visibility can be optimized through artificial lighting. This source was instrumental in designing our device to function effectively under various lighting conditions, ensuring cyclist visibility is maximized during night rides.

Eric. (2022, June 24). *Real-time rendering*. RealTime Rendering. <https://www.realtimerendering.com/blog/physical-units-for-lights/>

- This article covers the principles of real-time rendering with a focus on the physical units used for lighting in visual simulations. Understanding these principles helped us in designing the visual output of our turn signals to ensure they are clearly visible in real-time to other road users during both day and night, optimizing safety.

Franček, P., Jambrošić, K., Horvat, M., & Planinec, V. (2023, January 12). *The performance of inertial measurement unit sensors on various hardware platforms for binaural head-tracking applications*. MDPI. <https://www.mdpi.com/1424-8220/23/2/872>

- This research evaluates the performance of inertial measurement unit (IMU) sensors across different hardware platforms, specifically for head-tracking applications. Insights from this study were applied to consider the use of IMU sensors in our device to detect the orientation and completion of turns, potentially automating the turn signal deactivation process.

Gao, Y., Schwebel, D. C., Zhang, L., Xiao, W., & Hu, G. (2020, May 7). *Unsafe bicycling behavior in Changsha, China: A video-based observational study*. International journal of environmental research and public health. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7246696/>

- This observational study assesses unsafe bicycling behaviors in Changsha, China, using video data. The findings underscored common risky behaviors that could be mitigated by improved signaling devices, influencing our project's approach to enhancing cyclist behavior and safety through better design.

Gelb, J. (n.d.). *US20150327615A1 - Helm Light*. Google Patents. <https://patents.google.com/patent/US20150327615A1/en?q=%28smart%2Bbike%2Bhelmet%29&oq=smart%2Bbike%2Bhelmet>

- Describes a smart bike helmet equipped with integrated lights for signaling. This patent was relevant for exploring alternative, wearable signaling solutions that could inform our design of a non-wearable device, especially to enhance intuitive use and safety.

Google. (n.d.-a). *CN201210881Y - Illumination Helmet*. Google Patents. <https://patents.google.com/patent/CN201210881Y/en?q=%28smart%2Bbike%2Bhelmet%29&oq=smart%2Bbike%2Bhelmet>

- Details a helmet with integrated illumination, adding a layer of visibility and safety for cyclists. This design was analyzed to explore possibilities of incorporating light-based signaling directly into cyclist gear, though our focus remained on bicycle-mounted solutions.

Google. (n.d.-b). *CN201938457U - helmet with alarm indicator*. Google Patents. <https://patents.google.com/patent/CN201938457U/en?q=%28smart%2Bbike%2Bhelmet%29&oq=smart%2Bbike%2Bhelmet>

- This patent introduces a helmet with an alarm indicator, aimed at improving cyclist safety through visual and possibly auditory alerts. It was considered to understand how integrated safety features could be adapted for our more cost-effective, bicycle-mounted signaling device.

Google. (n.d.-c). *CN212697868U - helmet with warning function for night driving*. Google Patents. <https://patents.google.com/patent/CN212697868U/en?q=%28smart%2Bbike%2Bhelmet%29&oq=smart%2Bbike%2Bhelmet>

- Focuses on a helmet designed for enhanced safety during night driving through the use of warning lights. This idea was evaluated to glean insights into the use of warning signals that could be applicable to our project, particularly in terms of automatic activation and deactivation.

Google. (n.d.-d). *CN219257613U - LED illumination pedal*. Google Patents. [https://patents.google.com/patent/CN219257613U/en?q=\(bicycle+lights\)&oq=bicycle+lights](https://patents.google.com/patent/CN219257613U/en?q=(bicycle+lights)&oq=bicycle+lights)

- This patent covers an LED illumination pedal which aims to improve bicycle visibility. The concept of integrating lighting into different parts of the bicycle, such as pedals, was explored as a potential additional feature for our signaling system to ensure all-around visibility.

Google. (n.d.-e). *WO2020186771A1 - led smart helmet for wearing on a bicycle*. Google Patents. <https://patents.google.com/patent/WO2020186771A1/en?q=%28smart%2Bbike%2Bhelmet%29&oq=smart%2Bbike%2Bhelmet>

- Outlines a LED smart helmet specifically designed for bicycle use, incorporating both safety and communication features. While focusing on wearable tech, this patent provided insights into user interface design that could enhance the ease of use and integration of our signaling device.

Hou, M., Mahadevan, K., Somanath, S., Sharlin, E., & Oehlberg, L. (2020). Autonomous Vehicle-Cyclist Interaction: Peril and Promise. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (pp. 1–12). <https://doi.org/10.1145/3313831.3376884>

- Their findings influenced our project's approach to developing a bicycle turn signal system that could be readily identified not only by human drivers but also by autonomous vehicle systems. This alignment ensures that our device contributes effectively to reducing accidents and misunderstandings in mixed traffic environments. By integrating

these insights, our design aims to enhance the visibility and predictability of cyclists, thereby fostering safer interactions between cyclists and autonomous vehicles.

Hunter, W. W., Stewart, J. R., & Stutts, J. C. (1995). Study of Bicycle and Pedestrian Programs in United States Cities. U.S. Department of Transportation, Federal Highway Administration.

- This source was used to substantiate the claim that removing one hand from the handlebars to signal a turn compromises a bicyclist's control and safety. The study provides evidence that the design and execution of bicycle safety programs focus on addressing such risks.

JD, L., & SM, W. (n.d.). *Cycling Health Beliefs, crash experiences and night cycling behaviour of 13 year olds*. Journal of paediatrics and child health. <https://pubmed.ncbi.nlm.nih.gov/1605974/>

- This article explores the health beliefs, crash experiences, and night cycling behavior of young adolescents. It provided context on the psychological and behavioral aspects of cycling safety, which were considered in developing a user-friendly and highly visible signaling system that appeals to younger cyclists.

Kim, J. K., Kim, S., & Ulfarsson, G. F. (2007). Bicycle traffic injuries and fatalities: A review of risk factors and risk distributions. *Accident Analysis & Prevention*, 39(6), 1120-1128.

- This source is used to provide a broader context on how one-handed riding, often necessitated by hand signaling, increases the risk of accidents, particularly in complex traffic situations or on uneven terrains.

The Great Bike Light Problem. BikePortland. (2008, October 21). <https://bikeportland.org/2008/10/21/the-great-bike-light-problem-9660>

- Discusses issues faced by cyclists regarding inadequate bike lighting solutions. This article underscored the common problems our project aims to solve, such as reliability and visibility, and motivated the development of a more dependable signaling device.

Lahrman, H. (n.d.). Safety effects of permanent running lights for bicycles: A controlled experiment | request PDF. https://www.researchgate.net/publication/230653054_Safety_effects_of_permaent_running_lights_for_bicycles_A_controlled_experiment

- A study on the safety effects of permanent running lights on bicycles, highlighting their potential to reduce accidents. This research supported the idea that continuously visible signals could significantly enhance cyclist safety, influencing our design to include features that ensure constant visibility.

Macarthur, C., Parkin, P. C., Sidky, M., & Wallace, W. (1998). Evaluation of a bicycle skills training program for young children: a randomized controlled trial. *Injury Prevention*, 4(2), 116-121.

- This study by Macarthur et al. was crucial in informing the educational aspect of our bicycle turn signal device, specifically targeting the training of young cyclists. The research provides evidence on the effectiveness of structured bicycle skills programs in enhancing the safety and proficiency of young riders. Drawing from these insights, our product development focused on creating a device that not only improves physical signaling but also complements educational programs by reinforcing safe cycling habits

through intuitive use and reliable performance. This alignment ensures that our device supports the foundational safety skills taught in such training programs, making it a valuable tool for enhancing young cyclists' safety on the road.

McLaughlin, K. A., & Glang, A. (2010). The Effectiveness of a Bicycle Safety Program for Improving Safety-Related Knowledge and Behavior in Young Elementary Students. *Journal of Pediatric Psychology*, 35(4), 343-353. <https://doi.org/10.1093/jpepsy/jsp076>

- This article was instrumental in the development of our bicycle turn signal device as it provided crucial insights into the safety-related behaviors and knowledge among young bicyclists. McLaughlin and Glang's research highlighted the significant impact of educational interventions on improving young cyclists' safety practices. By understanding these foundational safety principles and the effectiveness of structured safety programs, our design team was able to tailor the device to enhance intuitive use and maximize safety benefits, particularly focusing on the younger segment of the cycling community.

National Highway Traffic Safety Administration (NHTSA). (2013). Traffic Safety Facts 2012 Data: Bicyclists and Other Cyclists. U.S. Department of Transportation.

- The NHTSA report is referenced to discuss the limitations of current market solutions for electronic turn signaling devices, particularly their high costs and the distraction caused by manual deactivation requirements.

Riya, J. F. (n.d.). *A Smart Helmet: Ensuring Safety of Bike Riders*. IEEE Xplore. <https://ieeexplore.ieee.org/Xplore/home.jsp>

- Describes a smart helmet concept aimed at improving cyclist safety through integrated technology. Although focusing on helmets, this work was used to extract applicable ideas for our bicycle-mounted system, particularly in terms of incorporating smart, responsive features.

Rodgers, G. B. (1995). Bicyclist deaths and fatality risk patterns. *Accident Analysis & Prevention*, 27(2), 215-223.

- Rodgers' research is cited to emphasize the increased risks associated with hand signaling, especially under poor visibility conditions such as at night or during adverse weather, where the effectiveness of hand signals significantly decreases.

Russell, S. (1959, September 1). *Why do consumer battery powered led Lights Fail Mid Ride*. Bicycles Stack Exchange. <https://bicycles.stackexchange.com/questions/18574/why-do-consumer-battery-powered-led-lights-fail-mid-ride>

- Analyzes why consumer battery-powered LED lights often fail during rides, addressing reliability issues. Insights from this discussion helped us design a more reliable and durable signaling system that avoids common pitfalls of battery-operated bike lights.

Sherman, C. &. (2023, July 24). *Dangers of riding a bicycle at night*. Chaikin, Sherman, Cammarata & Siegel, P.C. <https://www.chaikinandsherman.com/blog/2023/07/dangers-of-riding-a-bicycle-at-night/>

- Highlights the increased dangers of riding a bicycle at night and the need for effective lighting and signaling. This article reinforced the importance of our device being highly visible and reliable in low-light conditions, driving key aspects of our design criteria.

Tucker, D. (n.d.). *ES2818568T3 - improved communication system for vehicle hazard lights*.

Google Patents. <https://patents.google.com/patent/ES2818568T3/en?q=%28car%2Bturn%2Bsignal%29&oq=car%2Bturn%2Bsignal>

- A patent on an improved communication system for vehicle hazard lights, providing ideas for enhancing signal visibility and recognition. We drew on this patent to explore sophisticated signaling methods that could be adapted for bicycles, enhancing communication with other road users.

Uttley, J., Fotios, S., & Lovelace, R. (2020, May 15). *Road lighting density and brightness linked with increased cycling rates after-dark*. PloS one. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7228109/>

- This study links increased cycling rates after dark with better road lighting density and brightness. It supported our rationale for integrating high-visibility features into the signaling device, showing that enhanced illumination can encourage cycling by making it safer and more comfortable.

Wolfe, E. S., Arabian, S. S., Breeze, J. L., & Salzler, M. J. (2016). *Distracted biking: An observational study*. Journal of trauma nursing : the official journal of the Society of Trauma Nurses. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4785823/>

- Focuses on the prevalence of distracted biking and its consequences. This research highlighted the need for our signaling system to be simple and intuitive to use, aiming to reduce distractions and enhance focus, particularly in urban environments where distraction-related accidents are more common.

Wu, C., & Chen, D. (2019, December 9). *The difference in night visibility between shared bikes and private bikes during night cycling with different visibility aids*. MDPI. <https://www.mdpi.com/2071-1050/11/24/7035>

- This research compares the visibility of shared versus private bicycles under different night-time visibility conditions. It influenced our project by highlighting the importance of effective visibility aids, which helped guide the development of a signaling system that is effective across various bicycle types and lighting conditions.

Wu, X., Xiao, W., Deng, C., Schwebel, D., & Hu, G. (n.d.). *Unsafe riding behaviors of shared-bicycle riders in urban China: A retrospective survey*. Accident; analysis and prevention. <https://pubmed.ncbi.nlm.nih.gov/31228635/>

- This survey assesses unsafe riding behaviors among users of shared bicycles in urban China. The insights from this study were used to tailor our signaling system to address specific behaviors noted as risky, such as improper signaling before maneuvers, enhancing the overall safety of shared bicycle systems.

Yiqi, X., & He, R. (2018). The Handlebar as an Input Field: Evaluating Finger Gestures Designed for Bicycle Riders. In Proceedings of the Conference (pp. 648–659).

- Their research into finger gesture recognition on handlebars informed the ergonomic design of our turn signal device, ensuring that it is both accessible and intuitive for cyclists. By integrating gesture-based inputs that align with natural hand positions on the handlebars, our product not only improves safety but also enhances the overall user experience. This approach ensures minimal distraction, allowing riders to communicate

effectively with both the device and the surrounding traffic without compromising their control or attention.

Youssef, A., Colon, J., Mantzios, K., Gkiata, P., Mayor, T. S., Flouris, A. D., De Bruyne, G., & Aerts, J.-M. (2019, August 4). *Towards model-based online monitoring of Cyclist's head thermal comfort: Smart helmet concept and prototype*. MDPI. <https://www.mdpi.com/2076-3417/9/15/31>

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- Discusses the development of a smart helmet that monitors the thermal comfort of cyclists, using sensors and responsive technology. Although focused on comfort, the integration of sensors provided a model for incorporating similar technology in our signaling device to adjust to environmental conditions.

Велислав Димитров СТОЯНОВ. (n.d.). *WO2014209159A1 - illumination device for wheels of two-wheeled vehicle, such as a Bicycle*. Google Patents. <https://patents.google.com/patent/WO2014209159A1/en?q=%28bicycle%2Blights%29&oq=bicycle%2Blights>

- This patent details an illumination device for the wheels of two-wheeled vehicles, like bicycles, to improve visibility and safety. It inspired us to consider additional lighting features that could complement our main signaling system, potentially integrating wheel lights for enhanced side visibility.