Helmet Safety Indicator

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1 Introduction

1.1 Objective

In 2017 the number of bicyclists hit a staggering 47.5 million individuals [17], or about 12% of the total American population [10]. With this many bicyclists, cities have taken notice to accommodate cycles through separated bike lanes and paths. Even then, a vast majority of cities do not accommodate bikes and bikes are forced to ride alongside vehicles on the open road. In these situations, bicyclists are placed in a position of elevated risk and require more measures to ensure their safety. The two most risky situations are turning at intersections and getting overtaken by vehicles or other bicyclists [2]. Bicyclists are expected to indicate speed changes and turns via their arms, but many drivers are not aware of these signals, and at high speeds, extending one arm out of the bike is less than ideal for the bicyclist. These arm signals ultimately fail at providing a safe and effective method of indicating messages to car drivers or other bicyclists. In addition, bicyclists ride very close to cars and can only be aware of cars near them by physically turning their head, which can also be a potentially risky maneuver which will leave them unaware of potential threats in front of them.

Our proposal is to create a safety system that is simple for riders to use and can be installed on a variety of bikes. The safety system will comprise two parts: indicators for other drivers and indicators for the bicyclists. The indicators for the driver would work by having attachable triggers the user could attach to their handlebars and brakes which will send signals via bluetooth to a light attachment on the user's helmet. The lights would be placed on the back of the user's helmet to be directly in the line of view for cars behind the rider and they will display left and right turns as well as braking. For the bicyclist's indicators, in order to provide the rider feedback of approaching cars or other bicyclists from behind, there will be an ultrasonic sensor on the back of the helmet. This sensor will alert the bicyclist via a light up indicator the user can attach to the handlebars.

1.2 Background

In 2018, 2% of motor vehicle crash fatalities in the United States were bicyclists, resulting in 857 deaths. There were in total 45,000 reported bicycle accidents [2]. Many of these motor vehicle accidents were preventable as two of the primary causes for these accidents were drivers not properly acknowledging the bicyclists and the cities not being properly planned for bicyclists and drivers to share the road. This shows that at least until American cities reach a higher safety standard for bicyclists, there needs to be a method that bicyclists can elevate their safety on their cycles. We believe that by allowing bicyclists to attach indicators to their helmets and handles bars, the product can ensure that there is adequate signalling to both other cars on the road and bicyclists as well as also promoting the usages of helmets by bicyclists.

As urban infrastructure still lags behind the growth of bicycling, there are many solutions for providing light indicators for cycles. A vast majority exist more as a passive indicator that simply flashes to grab the attention of motorists but still relies on the bicyclist to use their arms to indicate changes in speed or direction. Even for solutions that exist to indicate turning and braking, these indicators are placed underneath the saddle of the bike, putting it in a position that is not directly in the view of a driver of a motorized vehicle. *Lumos* is one company that does provide a solution where the indicators are attached to the helmet [12]. *Lumos,* though, is a very expensive solution and, unlike our proposal, they do not offer any form of indication to the cyclist themselves. Our solution provides unparalleled safety for the bicyclist as they are able to provide clear indication to surrounding motorists, while also being able to receive information pertaining to whether vehicles are close behind them or not. In addition, by having a system that is primarily wireless, we have designed a system that is simple to install and remove. Our project was inspired by Project 8 from Fall 2017, the Bicycle Street Notification System. By being able to provide a simple to install and use system, with turn signals mounted to the user's helmet and a rider warning indicator, our solution provides safety and simplicity that eclipses the Bicycle Street Notification System.

1.3 Visual Aid

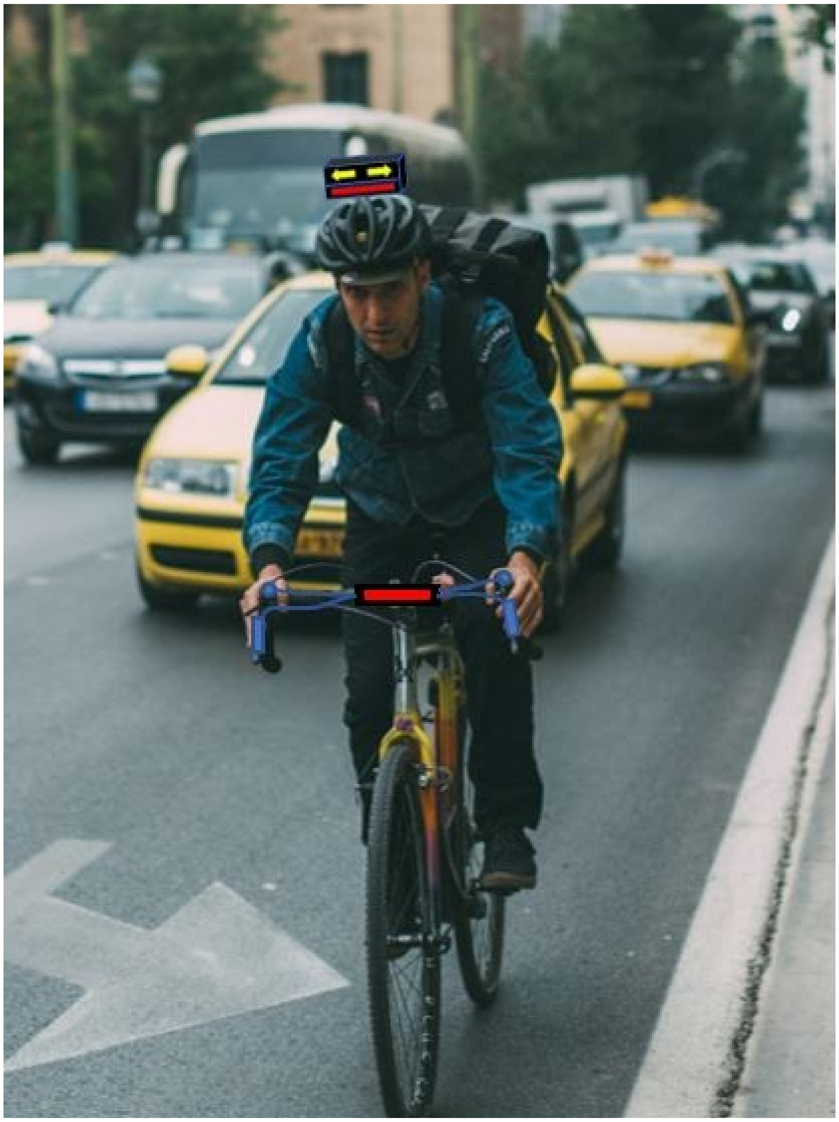

Figure 1. Visual aid of a bicyclist using the Helmet Safety Indicator at a busy intersection.

As shown in Figure 1, the user has a component of the device attached to the top of the user's helmet as well as a component that attaches to the user's handlebars. The helmet component has LED lights that indicate the direction the bicyclist is turning to vehicles and other bicyclists in front and behind the user. The helmet component also has a red LED bar that would indicate when the cyclist is braking. The handlebar component has a red LED panel fastened to the handlebar to indicate when an object is within 3 m behind the cyclist. The handlebar component also has turn signal and brake triggers.

1.4 High-level requirements list

- Helmet LED indicators must be activated when turning or braking based on the trigger inputs on the handlebar and the handlebar LED indicator must be activated based on the input from the ultrasonic sensor on the helmet.
- Light indicators and buttons must be easily attachable and stay securely fixed to the bicycle and helmet when attached.
- The ultrasonic sensor mounted on the helmet must be able to pick up objects and vehicles that are within 3 m behind the bicyclist.

2 Design

2.1 Overview

The device is designed with four primary submodules, as shown in Figure 2, which will be spread over two separate devices. The first submodule is the input module, this consists of the buttons to indicate braking and turning as well as the ultrasonic sensor on the helmet. These input modes will communicate with the control unit module. Both of the devices which are attached to the handlebars and the helmet will have their own control unit components. The inputs on the handle bar will communicate with the control unit component that is within the handlebar attachment and the sensor will communicate to the helmet's control unit component. From the control unit RF transmitters will be used to send data between the two separate devices which will then be relayed to the indicator submodule which will illuminate the appropriate indicators on the device. Finally, there is the power submodule, both of the components will have a 3.3 volt lithium ion battery which can be charged via a Micro-USB port.

2.2 Block Diagram

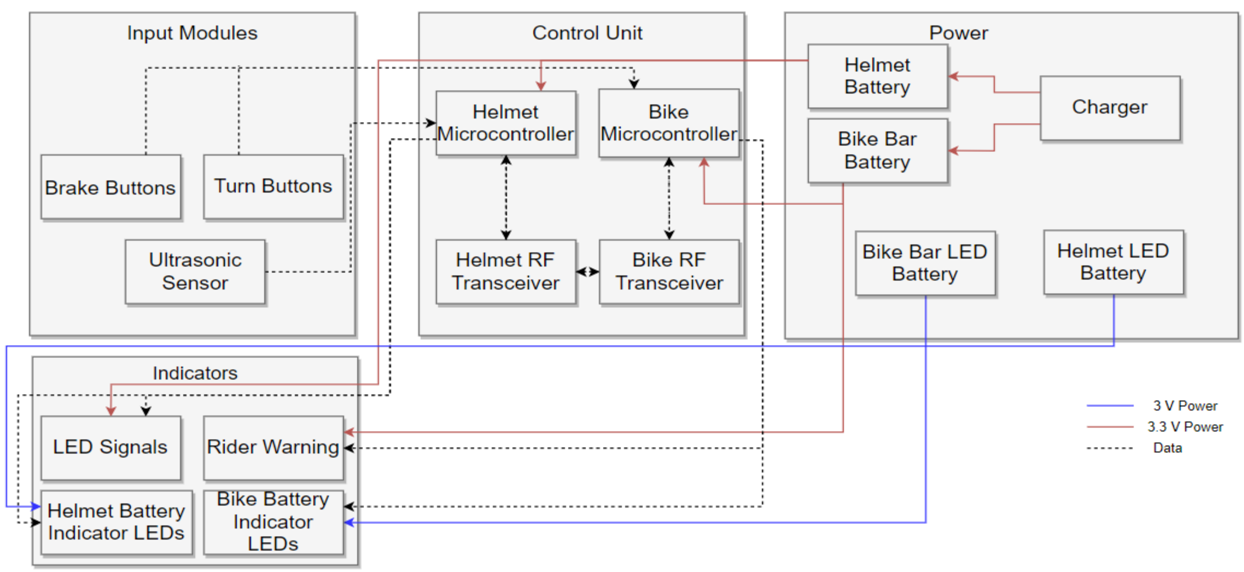

Figure 2. Overall block diagram showing power and data connections between functional units.

As can be seen in Figure 2, the device is spread over two separate devices as helmet and bike in all submodules except the charger. Brake and turn buttons send the input from the bike through the LED signals for the output on the helmet. Similarly, the ultrasonic sensor sends the input from the helmet through the rider warning for the output on the bike.

2.3 Physical Design

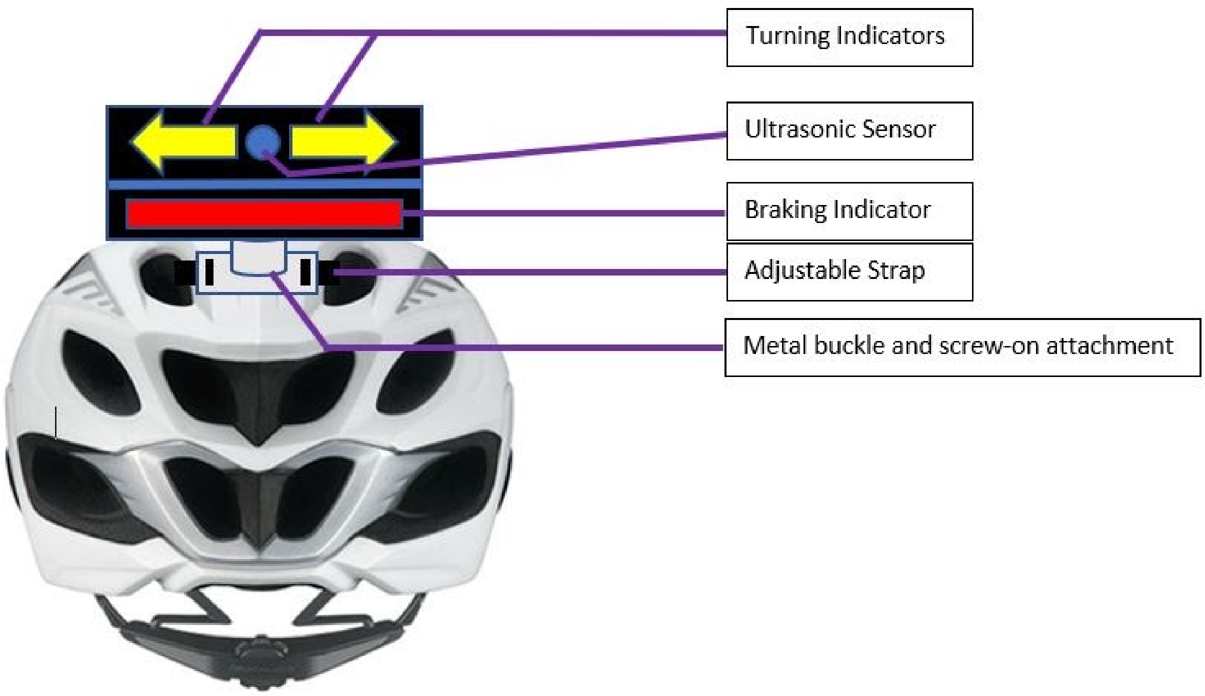

Figure 3. Rear view of placement of LED box and attachment to helmet.

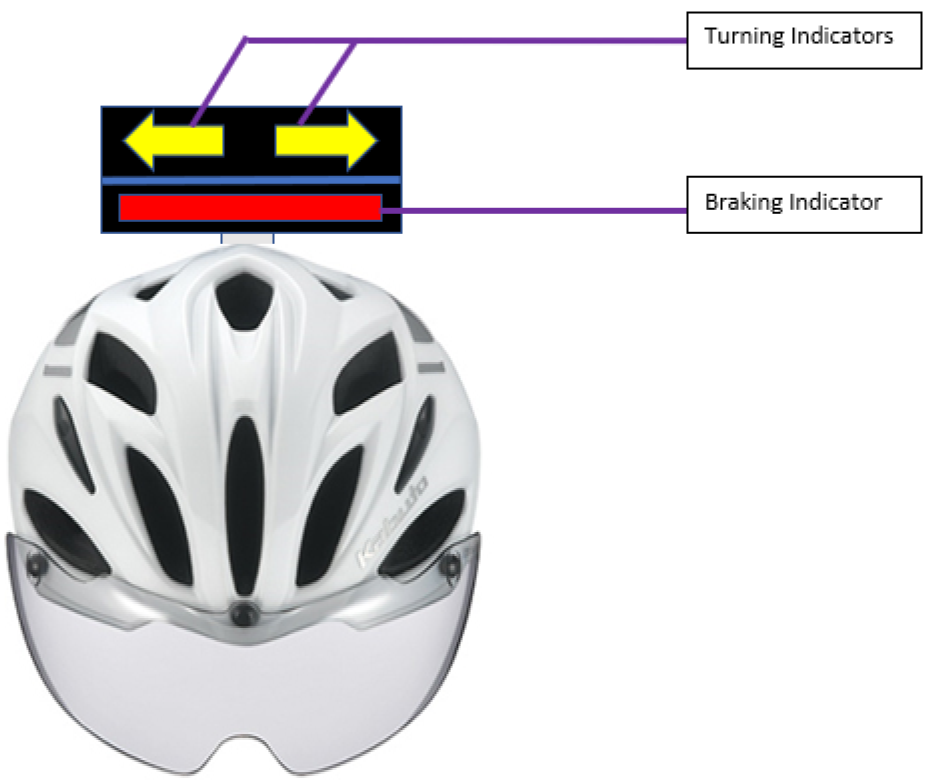

Figure 4. Front view of placement of LED box and attachment to helmet.

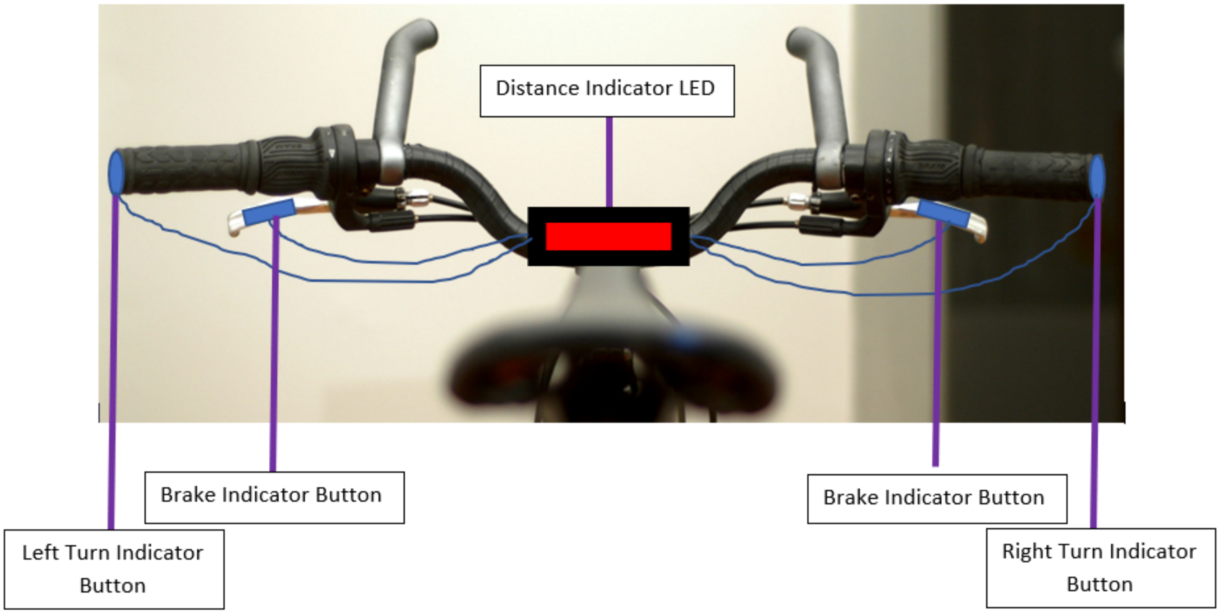

Figure 5. User view of placement of distance indicator LED, brake and turn indicator buttons on traditional bicycle handlebars.

The physical design of the product will consist of two separate parts. The first part will be attached to the top of the rider's helmet through an adjustable strap as shown in Figures 3 and 4. The turning and brake indicators on the helmet attachment will screw onto a metal plate attached to the adjustable strap for secure attachment. The handlebar design shown in Figure 5 will be strapped in a similar fashion to the rider's handlebar and will have four wires coming out of it for the brake and turn indicator buttons. The brake button will be on the front of the brake where the user's hand will go when braking. In Figure 5, the brake indicator buttons would actually appear on the other side of the brake lever, but we have included a box for it so the location of it is understood. The helmet and handlebar designs will be enclosed and weather resistant, including the exposed wires.The battery, microcontroller, etc. will be stored in the large boxes in both parts.

2.4 Functional Overview

2.4.1 Input Modules

The input modules take data from the user and ultrasonic sensor to provide the right signals and data to the microcontroller. The user input data comes from the two triggers on the right and left brakes as well as the two triggers on the ends of the handlebars that indicate a right and left turn respectively. The ultrasonic sensor located on the helmet will send distance data to the helmet microcontroller for when an object is within 3 m behind the user.

2.4.1.1 Brake Buttons

As seen in Figure 5, our design will include brake buttons for the user to attach to their braking system on their bicycle. This allows for easy accessing, in order to trigger the light. Both buttons will trigger the brake lights on the back of the helmet. The signals from these buttons are relayed to the control unit located on the device attached to the handlebars which will then relay the signal to the LED indicators on the helmet. The brake lights must remain on for as long as the brakes are engaged by the user and must turn off immediately after the user has released the brakes and this will be achieved using a monostable switch. The requirements for the brake buttons are listed in Table 1 along with their appropriate verifications.

Table 1. RV table for the brake buttons.

Requirements	Verifications
1. When the monostable button is engaged power must be delivered and power must stop being delivered immediately after the button is disengaged.	1A. Will hook up monostable switch input to a voltmeter. when engaging the switch, measure that voltage is delivered to the voltmeter 1B. Once the monostable switch is disengaged ensure that the voltage drops to 0 V immediately.

2.4.1.2 Turn Buttons:

As seen in Figure 5, there are two buttons that can be placed anywhere on left and right handlebars, by the bicyclists, wherever is most convenient for them. The left button activates the left turn signal and the right button activates the right turn signal. The signals from these buttons are relayed to the control unit located on the device attached to the handlebars which will then relay the signal to the LED indicators on the helmet. As shown in Table 2, it is important for the switches to be bistable so that the user can turn off the indicator after they have completed the turn. In addition the turn button will illuminate an LED on the rider warning, to allow the user to be aware that the turn signal is on, in the situation that the rider has forgotten and left it on.

Table 2. RV table for the turn buttons.

Requirements	Verifications
1. Turning on the left switch illuminates the left turn signal and the right switch turns on the right turn signal.	1A. Assure that when the left signal button is pressed the LED indicator for the left signal immediately turns on and stays on indefinitely. Replicate this test with the right signal.
2. Pressing the switch when the turn signal is on will turn off the turn signal.	2A. Turn on both of the signals. With them illuminated, press both of the turn buttons and ensure that both the turn signals immediately turn off.
3. When the switch is turned on it illuminates the appropriate LED on the rider warning to let the rider know that the turn indicator is on.	3A. Turn on both of the signals and ensure that the appropriate LEDs are illuminated on the rider warning LED array, and when they switch is pressed when the LED is on, the LED turns off.

2.4.1.3 Ultrasonic Sensor

There will be one ultrasonic sensor placed at the rear of the helmet that will detect the objects and vehicles that are close to the bicyclist. This sensor will provide data regarding the distance of objects behind the bicyclist to the control system which can be processed and determine whether there is an approaching bicyclist or motor vehicle within the threshold distance. As shown in Table 3, the sensor must be able to notify the rider of motorists and other bicyclists that are within 3 m behind the user.

Table 3. RV table for the ultrasonic sensor.

Requirements	Verifications
1. Must be capable of detecting objects at a distance less than or equal to 3m away from the bicyclist and as close as 20 cm from the bicyclist.	1A. Place sensor at the end of measuring tape and at various distances between 3 m and 20 cm from the bicyclist place large objects and ensure that the ultrasonic sensor is capable of picking up the distances accurately. 1B. With the same setup as stated above, ensure that if the object is placed in distances less than 20 cm or greater than 3 m a null distance is recorded.
2. Must indicate to the bicyclist when an object is within 20 cm to 3 m of the bicyclist	2A. Using the arduino, check that if there is a large object between 20 cm and 3 m that the arduino sends an output stating that there is an object behind the bicyclist and powers the output pin responsible for illuminating the bicyclist indicator LED.
3. Is not sensitive to small objects such as leaves when making measurements	3A. Using the arduino, throw small objects in the range of the device and ensure that no output is generated indicating that an object is in the way.
4. Measurement period must be greater than 60 ms.	4A. Use the arduino to set the measurement period to 80ms.

2.4.2 Indicators

The indicators will be used as the outputs from the microcontrollers. The battery indicator LEDs will show the current battery level of each battery to the user. The LED signals will be turned on in appropriate fashion when the user is signalling left, right, or is braking. The rider warning LEDs will also turn on when there is an object detected within 3 m behind the bicyclist.

2.4.2.1 LED Signals

Three separate LED arrays will be placed at the top of the helmet to indicate if the bicyclist is turning or braking. This will caution other bicyclists and drivers with clear, visible signals to prevent accidents. These LEDs will be attached to the helmet mounted device which will be in the line of sight of anyone behind the user and will clearly relay to them if the bicyclist has triggered the left or right turn signals or the brake. The design of the LED must ensure that it is very clear to observers whether the bicyclist is braking or turning and the LED must be clearly visible from 100 ft away. These requirements are discussed in Table 4.

Table 4. RV table for the LED signals.

Requirements	Verifications
1. LED must be clearly visible in any light conditions up to 100 ft away.	1A. In sunlight two individuals will hold timers standing at a distance of 100 ft. Have the person that is holding the indicator turn on the LEDs at irregular intervals, and have the individual that is standing at a 100 ft distance note the time that the indicators were lit. Ensure a 100% accuracy between the times noted and the times that the indicator was illuminated.
2. LED must blink to one side for turn indication.	2A. Illuminate the LED with the programming for both right and left signals and ensure that only the appropriate half of the LED is illuminated and is blinking.
3. Entire LED strip must be lit for braking indication.	3A. Illuminate the LED with the programming for braking. Ensure that the entire LED holds a solid glow for the entire duration that the LED's are switched on.
4. At a distance of 100 ft, the difference between turn signals and brake should be clearly visible in any light conditions.	4A. In sunlight two individuals will stand at a distance of 100 ft with one holding the indicator LEDS. Have the person that is holding the indicator randomly switch between braking LEDs and illuminating LEDs for the turn signals at irregular intervals. Have

Table 4. RV table for the LED signals (continued).

	the individual that is standing at a 100 ft distance note the order of which type of indicators were lit. Ensure a100% accuracy between the recorded order and what was being illuminated.
5. The LED must be clearly visible for other riders in cars.	5A. Repeat tests 1 & 4 with the recorder recording from within a car.

2.4.2.2 Battery Indicator LEDs

Four LED lights which are placed on both the helmet attachment and the bike will indicate the charge level of the device to the user. These LEDs will connect to the corresponding battery in order to be able to display the current charge value for that device. This indication will be possible using a four-channel voltage monitoring chip for each battery. This requirement and its appropriate verification is shown in Table 5.

Table 5. RV table for the battery indicator LEDs.

Requirements	Verification
1. LED lights attached to the four-channel voltage monitoring chip are able to accurately display how much battery life the device has to the nearest 25% for each battery.	1A. Use a voltage meter to detect both the fully charged and discharged voltages of the battery then validate that at the appropriate intervals of voltage the appropriate LEDs which are attached to the voltage monitoring chip are glowing to indicate remaining charge.

2.4.2.3 Rider Warning:

This will be an LED indicator array containing 10 LEDs that the rider can place in front of them on the handlebars in order to be able to receive the information provided by the ultrasonic sensor attached to the helmet. It will show a solid red light to clearly inform the rider of approaching traffic. It will also show whether the turn indicators are on with individuals LEDs placed at the right and left side of the array. These requirements are shown below in Table 6.

Table 6. RV table for the rider warning.

Requirements	Verification
1. LED array indicator illuminates when an object is detected to be within the range of 20 cm to 3 m.	1A. When the sensor and LED are set up, ensure that when an object is placed anywhere within the range of 20cm to 3 m that the LED indicators illuminate.
2. When the right or left turn signal is turned on the right or left most LED will be illuminated in green to indicate that the turn signal is on to the bicyclist.	2A. Connect Arduino to both turn signal buttons. Ensure that when either of the turn signals are on the pin to the RF transmitter is on and an additional one to supply power to the respective LED is powered.

2.4.3 Control Unit

The Control Unit comprises the microcontrollers and transceivers of the system. This unit is responsible for deciphering the data that is sent to it from the input system and will either relay the data to the other component, either helmet or handlebar component, or will output a signal to the appropriate indicator on the device.

2.4.3.1 Helmet Microcontroller

The helmet microcontroller has two responsibilities: being able to decipher signals from the ultrasonic sensor and illuminate LEDs based on the bicyclist's inputs. It will receive the data from the turn/brake buttons on the bike handlebar component via the transceiver. Based on the data that it receives, the microcontroller must turn on the correct indicator LEDs. It will also receive the signal from the ultrasonic sensor on the helmet and determine based on the signal whether the distance threshold has been breached by an incoming vehicle and then transmit the response to the transceiver so that it can be sent to the transceiver on the handlebar component to illuminate the rider warning. In order to be able to handle their various inputs and outputs, we have elected to utilize an arduino mini which can compute the calculations needed while also sending data to the other components efficiently. These requirements and their verifications are presented in Table 7.

Table 7. RV table for the helmet microcontroller.

Requirements	Verifications
1. Based on input given by an ultrasonic sensor, it must be able to determine whether an object is within the 3 meter threshold or not, and send the appropriate signal to the LED indicators.	1A. When a large object is placed within the 20 cm to 3 meter range, the microcontroller must produce an output indicating that the rider is warned is illuminated. 1B. When a large object is placed outside the 20 cm to 3 meter range, the microcontroller must not produce an output.
2. Must be able to encode received data from turn and brake buttons into the appropriate outputs to illuminate the correct lights in the correct fashion.	2A. For each of the inputs (brake, left and right signal) the appropriate output must be powered by the Arduino microcontroller.

2.4.3.2 Bike Microcontroller:

The bike microcontroller has two responsibilities: being able to relay inputs based on the type of button pressed and illuminate the rider warning LED array based on a given signal. Once a turn or brake button is pressed, the microcontroller will decipher which button the signal is coming from and send the appropriate signal to the transceiver. This signal will then be converted to the LED output on the helmet and after a time interval will indicate that the LED must be turned off. In addition, based on the data it receives from the transceiver, the microcontroller must be able to turn on the rider warning, if a vehicle is within the three meter threshold. As with the helmet microcontroller, these computations will also be driven by an Arduino mini. The requirements and respective verifications are presented in Table 8.

Table 8. RV table for the bike microcontroller.

Requirements	Verifications
1. Based on input given by an ultrasonic sensor, it must be able to determine whether an object is within the 3 meter threshold or not, and send the appropriate signal to the bicyclist's LED indicator.	1A. When a large object is placed within the 20 cm to 3 meter range, the microcontroller must produce an output indicating that the rider is warned is illuminated. 1B. When a large object is placed outside the 20 cm to 3 meter range, the microcontroller must not produce an output.
2. Must be able to encode received data from turn and brake buttons into the appropriate outputs to illuminate the correct lights in the correct fashion.	2A. For each of the inputs (brake, left and right signal) the appropriate output must be powered by the Arduino microcontroller.

2.4.3.3 RF Transceiver

RF transceivers will be used to connect both the helmet and handlebar components using radio signals. As shown in Table 9, inputs processed in the microcontrollers of each of the components must be relayed via these RF transceivers to the other microcontroller so that the appropriate indicator can be illuminated. The RF transceivers will use General ISM with 433 MHz frequency, which is suitable for short range connections.

Table 9. RV table for the RF transceiver.

Requirements	Verifications
1. RF transceivers are able to send packets of data to indicate which of the inputs have been pressed, which can be received by the other RF transceiver and decoded into which button was pressed.	1A. Have the RF transceiver that is connected to the input buttons and another RF transceiver that is connected to the Arduino device. Validate that when either the right or left button is on, the arduino turns on the output pin for the respective LED. 1B. Replicate the set up from test 1A. Press the brakes and ensure that the Arduino device attached to the second

Table 9. RV table for the RF transceiver (continued).

	RF transceiver is able to turn on the output pin for the brake LED, and turn it off instantly after the brake button has been released.
2. RF transceivers are able to send data to indicate when there is an object within 3 m of the ultrasonic sensor which is able to be received by the other RF transceiver.	2A. Have the RF transceiver attached to the ultrasonic sensor and the other RF transceiver attached to the Arduino device. Ensure that the Arduino turns on the output pin for the driver warning LED when large objects are placed within 3 m of the ultrasonic sensor.
3. Data is sent only over 433 MHz frequency.	3A. Using the Arduino set the output and receiving frequency of the RF transceiver to 433 MHz.

2.4.4 Power

The power will be provided to the remaining subsystems through two separate lithium ion batteries. Both these batteries operate at 3.3 volts and provide data to the LED battery indicators. The batteries will be chargeable through a Micro-USB connection. In addition for extra power to the LED's we will use AA batteries to add extra power for the LED's.

2.4.4.1 Helmet Battery

The helmet battery consists of a lithium ion battery with a charging circuit and USB-to-serial converter. The battery will power the components of the helmet mounted device, which includes the helmet microcontroller, LEDs, transceiver and ultrasonic sensor. The requirement for this battery is presented in Table 10.

Table 10. RV table for the helmet battery.

Requirements	Verification
1. Battery should supply voltage at 3.3V and at a rate of 500 mA.	1A. Use a voltmeter and ammeter to verify the supplied voltage and current values.

2.4.4.1 Helmet LED Battery

To limit significant drain of the rechargeable li-ion batteries, the user will provide 2 AA batteries to power the Helmet LED light. By providing a significantly higher mAh output compared to the li-ion, it will allow the user to use the device much longer between charges.

Table 11. RV table for the helmet LED battery.

Requirements	Verification
1. Battery should supply voltage at 3V and with an energy capacity more than 4000 mAh.	1A. Use a voltmeter to verify the supplied voltage.

2.4.4.2 Bike Bar Battery

The bike bar battery consists of a lithium ion battery with a charging circuit and USB-to-serial converter. The battery will power the components of the bike handlebar mounted device, which includes the bike microcontroller, transceiver and rider warning indicator. The requirements for this battery is shown in Table 11.

Table 12. RV table for the bike bar battery.

Requirements	Verification
1. Battery should supply voltage at 3.3V and at a rate of 500 mA.	1A. Use a voltmeter and ammeter to verify the supplied voltage and current values.

2.4.4.3 Bike Bar LED Battery

To limit significant drain of the rechargeable li-ion batteries, the user will provide 2 AA batteries to power the Bike Bar LED light. By providing a significantly higher mAh output compared to the li-ion, it will allow the user to use the device much longer between charges.

Table 13. RV table for the bike bar LED battery.

Requirements	Verification
1. Battery should supply voltage at 3V and with an energy capacity more than 4000 mAh.	1A. Use a voltmeter to verify the supplied voltage.

2.4.4.4 Charger

A Micro-USB charging wire will be used to charge the lithium ion batteries in the helmet and handlebar devices. The requirement for this charger is shown in Table 12.

Table 14. RV table for the charger.

Requirements	Verification
1. Charger should charge the battery at a rate of 100 mA.	1A. Use an ammeter to verify the charging current while charging the discharged battery.

2.5 Schematics

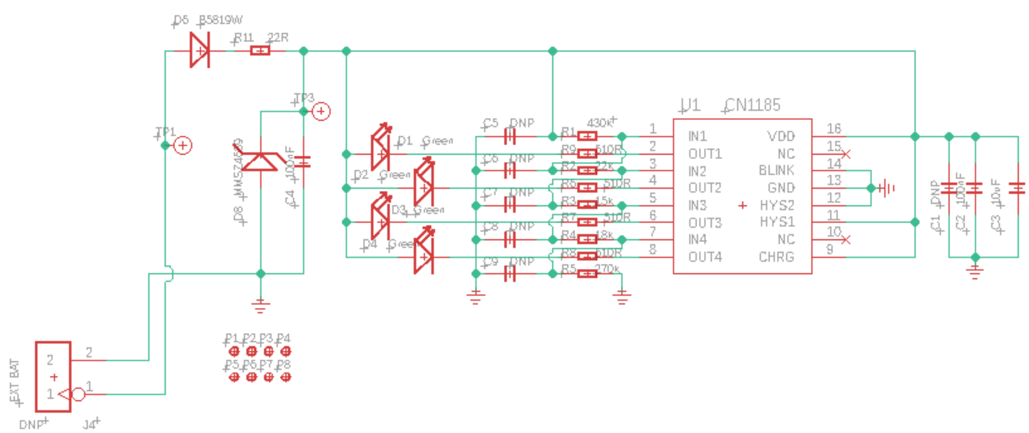

Figure 6. Voltage indicator circuit.

The voltage indicator circuit works with CN1185, which is a four-channel voltage monitoring chip that gives a quantized output depending on the input coming from the battery. The schematic for this component is visualized in Figure 6.

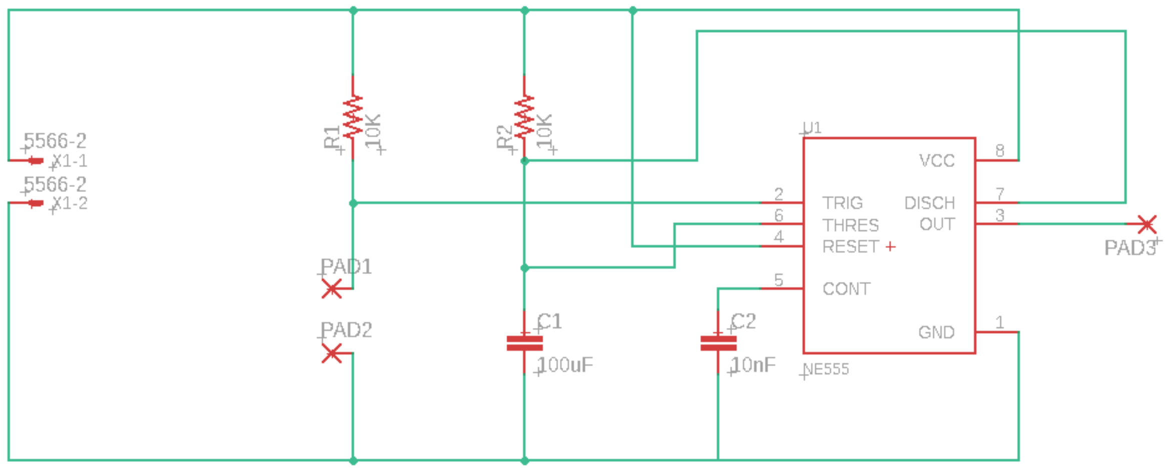

Figure 7. Brake button circuit.

As shown in Figure 7, the brake button circuit works with NE555, which is a 555 timer IC that helped to build up the monostable multivibrator circuit. To keep the brake indicator on for around a second, we decided to build the monostable circuit. C1 and R2, which are capacitance 1 and resistance 2 respectively, are used to set the time constant, which is shown in equation (1). Briefly, the circuit keeps the output on for 1.1 seconds after the button is released.

$$1.1\ X\ C1\ X\ R2\ = �� \qquad (1)$$

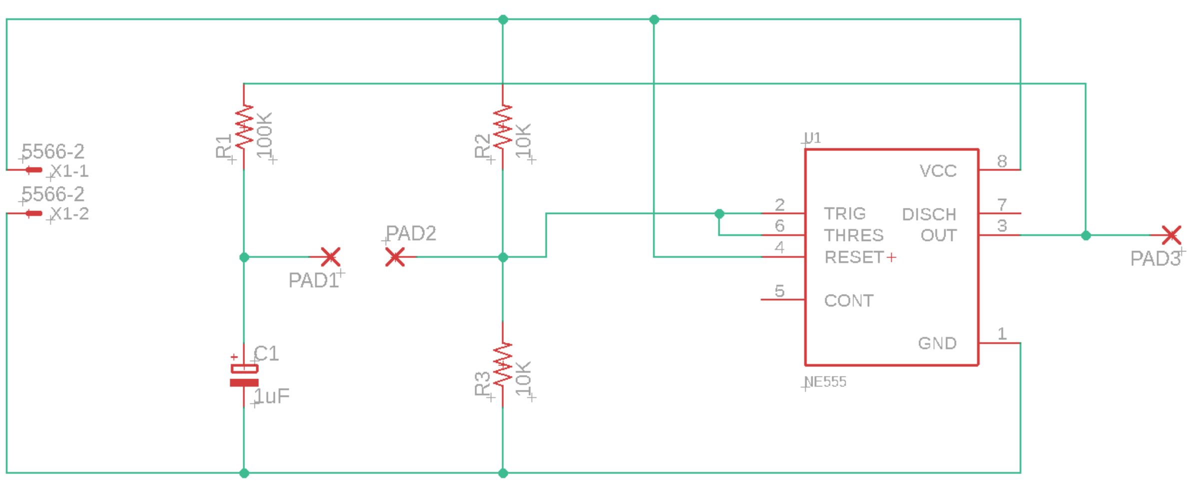

Figure 8. Turn button circuit.

The turn button circuit shown in Figure 8 also works with NE555. However, this time, trigger and threshold pins are connected to each other in order to make the circuit a toggle switch circuit. In order to make a better quantization between supply voltage, threshold voltage and trigger voltage, R2 and R3 are set at the same value, which is 10 kΩ. Briefly, this circuit makes output on when the button is pushed and released and off when button is pushed and released again.

2.7 Tolerance Analysis

In this project, there are two physically separated devices that both need to send and receive input data to and from the other device to process it for displaying the output. In order to make this connection wirelessly we had opted to use radio-frequency transceivers as they were the best option for making a short range connection without interruptions or requirement of pairing.

2.7.1 RF Transceivers

The RF transceivers that are going to be used in the project have a communication range of 1000 m and have a range of transfer rate of 1.2-115.2 kBps, as stated in the datasheet of the transceivers [8]. Since the placement of the two transceivers is going to be between the helmet and the handlebars, the distance between them during usage it's going to be much less than 1000 m. The transfer rate is expected to be at least the default rate which is 9.6 kBps, if not faster due to their proximity, and this should be fast enough for functionality as the data being transferred wirelessly should be no more than a few bits.

The sensitivity of the transceiver was also a major consideration in this design. Sensitivity affects the transmission while receiving, and it's defined as the power of the weakest signal the receiver can detect. The minimum sensitivity can be calculated using Equation (2) where S/N is signal-noise ratio and NF is noise factor [7].

$$S_{min}(dBm) = (S/N)\, kTB(NF) \tag{2}$$

It's also known that sensitivity is affected by the air baud rate. The air baud rate is the rate at which information can travel through a certain channel. Depending on the air baud rate, sensitivity of the RF transceivers for our project can differ in the range of -100 dBm and -124 dBm. Information about how air baud rate affects the sensitivity is included at the datasheet of the transceiver, which is also shown at Figure 9.

air baud rate	500bps	5000bps	15000bps	58000bps	236000bps/250000bps
receiving sensitivity	-124dBm	-116dBm	-111dBm	-106dBm	-100dBm

Figure 9. Air baud rate vs. receiving sensitivity [15].

2.7.2 Ultrasonic Sensor

The other component that posed a major consideration was the ultrasonic sensor we used. We need to ensure that the sensor is able to effectively detect within the necessary range. We are utilizing the HCSR-04 sensor, which is placed atop the helmet, and has a detecting range between 2 cm and 400 cm. The requirement for the sensor is that it is able to detect objects, primarily vehicles and other bicyclists that enter within 3 m of the rear of the bike.

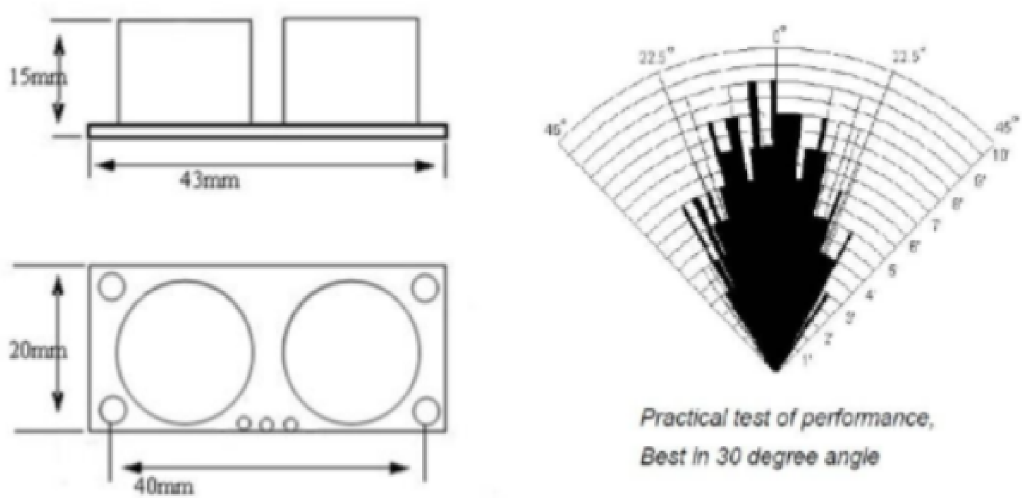

Figure 10. Performance vs. angle of the HC-SR04 ultrasonic sensor [14].

A large factor that will affect the detection range of the ultrasonic sensor is the detecting angle. Since the helmet and the approaching object for the ultrasonic sensor to detect won't stay at the same angle as the bicyclist might be moving their sitting position or head, the performance of the ultrasonic sensor should be considered at the possible range of angles. Figure 10 illustrates the performance testing graph of the sensor at different angles. It shows that ideal detection can be done best at 30 degree angle, but also still good at the range between 20-40 degrees. Keeping the sensor's detection within this range will be achieved via the helmet mount. The design will optimize maintaining the detection angle between the 20 - 40 degree range while the rider is sitting on their cycle saddle.

The final consideration of this project is the data collection and transmission rate of the ultrasonic sensors. As can be seen in Figure 11 below, one cycle of triggering the sensor, picking up the data and sending it to the microcontroller will take 50 ms. In order to allow for sufficient time, the collection rate will be set 80ms to ensure the proper collection and transmission of data.

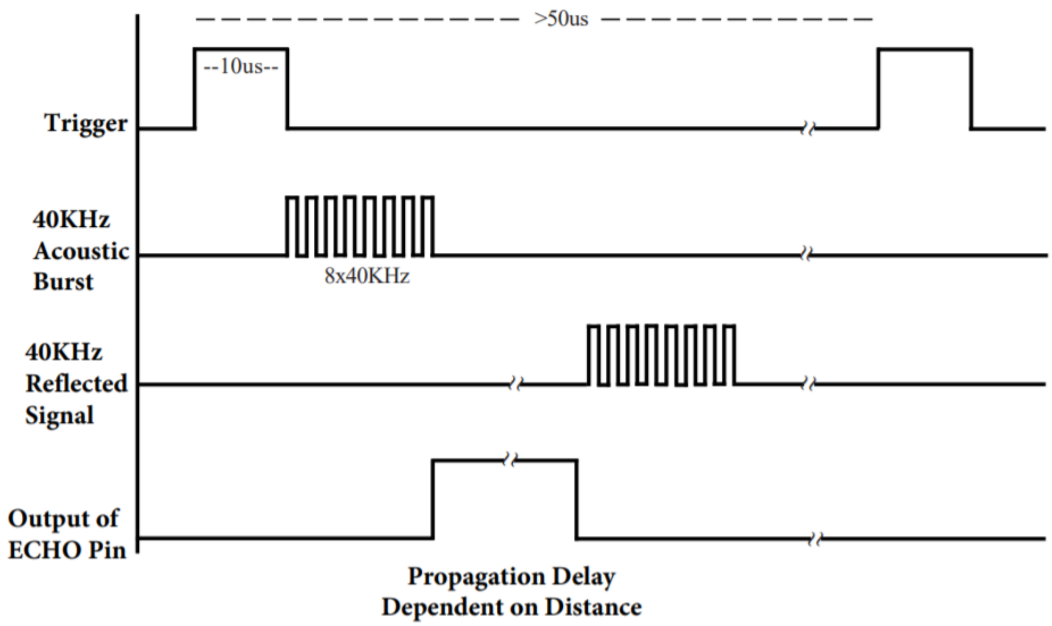

Figure 11. One cycle of the HC-SR04 ultrasonic sensor [9].

This ensures that objects that enter close behind the cyclist will be detected even if they are there for extremely short durations of time, but also will ensure that there will be no loss of data that will be collected from the ultrasonic sensors.

2.8 Differences

2.8.1 Overview

The proposed solution looked into the problem explored by Project 8 from Fall 2017, the Bicycle Street Notification System. In their solution they sought to create a design that encapsulates a wide range of motorized vehicle features on bicycles. These features included a speedometer, automatic lights, as well as braking and turning signals. Their system was intended to be a permanent fixture on the cycle, where the components derived power from AA batteries. The construction of their project was successful and they were able to demonstrate the success of their project. As explained in previous parts of this report, we had opted to create a more lightweight solution. Our solution was targeted at individuals that rode a variety of bikes for various purposes. Its small footprint design meant it would have less components and wires for the user to worry about as a majority of the system communicates wirelessly. It also focuses primarily on providing safety to the rider without worrying about other things such as speed. As the original solution came with a dense list of features, our solution aims to be far easier to use and install and ultimately be a better product for the average bicyclist looking for an unobtrusive solution with a lot of flexibility.

2.8.2 Analysis

There are two primary technical differences that our design is offering. The first benefit is that we are placing the indicators in a position that is going to be directly in the line of sight of car drivers. The second benefit is that we are providing a distance indicator for the user, so that they will be aware of cars that are close and approaching them.

2.8.2.1 LED Indicators

The first difference is that we provide a helmet mounted indicator as opposed to indicators mounted under the saddle. This allows the indicators to be higher up, and more in the line of view of drivers that may be in cars and trucks. Of all types of cycle fatalities, 45% occur from vehicles travelling in the same direction of the bicyclist [13]. This means that it is imperative to have an attention grabbing source of light for the indicators placed squarely in the line of sight for the driver. The average driver has an eye level at 1.25 m [5]. With the average saddle height being approximately 0.75 m off the ground, there is a significant disparity from the line of sight of the driver. Our design on the other hand places the lights above the rider’s helmet, which would give it an average height of 1.5 m [3]. As shown in Figure 12, this placement is much closer to the riders line of sight, and is much more likely to grab the attention of the driver, letting them know of any slowing of the cycle or if the cycle is going to change direction. In addition as opposed to lights placed under the seat, there is no chance of the helmet mounted indicators being obstructed by long, loose clothing or backpacks that the bicyclist might be wearing.

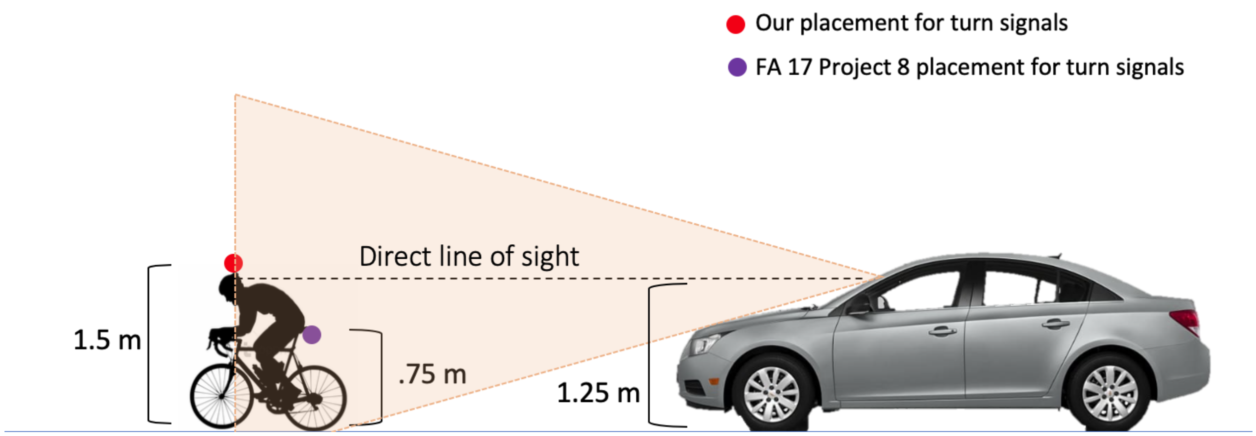

Figure 12. Comparing the proximity of our solution to a car driver's direct line of sight against the Bicycle Street notification System (FA 17 Project 8).

2.8.2.2 Rider Warning

The second technical difference is that our solution includes indicators for the bicyclist themselves. This comes in the form of an indicator to let the bicyclist know if there is a car within 3 m behind them. As stated before a majority of bicyclist deaths come from rear end collisions from motor vehicles. Motor vehicles passing bicyclists are legally mandated to allow at least 3 ft between them and the bicyclist when passing [16]. By allowing the bicyclist to know beforehand if a car is near to the bicycle, they will not have to turn their head as far or for as long to observe other vehicles. A UK study had shown that 43% of motor vehicle collisions with bicyclists was a result of the bicyclist "failing to look properly" [6]. Unfortunately at the speeds that bicyclists go, there is not enough of a time window to properly look.

$$Distance\ (meters) = [Speed\ (mph) \ / \ 2.237] * Duration\ (seconds) \qquad (3)$$

Using Equation (3), given that the average road-cyclist rides at a speed around 15 mph, if they turned their heads for just a second they would have moved 6.7 m, and in order to get a sufficient look at their surroundings, they might need to take a glance for longer than that. By including the Rider Warning, the bicyclist is able to acquire valuable insight into their surroundings, reducing the amount of time that is needed for them to glance at their blindspot. In addition the sensors can provide very beneficial information for the bicyclist in certain dangerous situations such as a car that is passing the bicyclist too close or a car that is tailing the bicyclist from too close of a distance. In these situations any movements by the bicyclist can prove to be dangerous, so by being aware of any nearby vehicles the bicyclist can ensure that they do not move in a sudden or unpredictable fashion that can lead to a collision. We believe that compared to speed, this is a far more necessary indicator for the bicyclists and thus have made this inclusion to the front console.

3 Cost and Schedule

3.1 Cost Analysis

Our fixed cost analysis is separated into labor and parts. Labor will be calculated assuming an hourly rate of 35$ an hour for each of the team members. We will also assume a ten hour work week for a total of 14 weeks. In Equation (4), we utilize these numbers along with a factor of 2.5 to get a total cost of $36,750.

$$Total\ Salary\ cost = 3 * 35 * 10 * 14 * 2.5 = \$36,750 \tag{4}$$

In Table 13, we itemize each part and its associated cost to calculate the total material cost of our prototype. The total parts cost is $188.48.

Table 15. Total cost of components for the Helmet Safety Indicator design.

Part name	Manufacturer	Part number	Cost per Unit ($)	Quantity	Total Price ($)
Lithium Ion Polymer Battery - 3.3v 500mAh	Adafruit	1578	7.95	2	13.90
Adafruit Micro Lipo - USB LiIon/LiPoly charger - v1	Adafruit	1304	5.95	2	11.90
FT232RL FTDI USB To TTL Serial Converter Adapter Module	HiLetgo	3-01-0661-1	5.68	2	11.36
RF Transceiver Module 433MHz Integrated, Helical Surface Mount	Seeed Technology Co., Ltd	113990039	13.16	2	26.32
Arduino Pro Mini 328 - 3.3V/8MHz	Adafruit	2378	9.95	2	19.90
555 Type, Timer/Oscillator (Single)	Texas Instruments	NE555DR	0.36	2	0.72

Table 15. Total cost of components for the Helmet Safety Indicator design (continued).

Chanzon 100 pcs 5mm Warm White LED Diode	Chanzon	100F5T-YT-WH-WW	6.25	1	6.25
Ultrasonic Sensor Sonar Distance 4cm-4m	Adafruit	3942	3.95	1	3.95
Duracell – 396/397 1.5V Silver Oxide Button Battery – long-lasting battery	Duracell	AA-Rechx4	14.05	2	28.10
GFORTUN 2PCS Black Plastic 2 x 1.5V AA Battery Box Case	GFORTUN	B06XW891WK	6.86	3	20.58
Pushbutton Switch SPST-NO Standard Panel Mount	Adafruit	473	5.95	2	11.90
Digi-Key Resistors	Yageo	RC0402JR-070RL	0.10	20	2.00
Force Sensing Resistor	Ohmite	FSR05BE	7.23	2	14.46
Estimated tax (10%)					17.134
Total parts cost					188.48

For our total cost, we add the total cost of parts calculated in Table 13 and the total cost of salary in Equation 3. This calculation is shown in Equation (5) and equals $36,938.48

$$Total\ cost = 36,750 + 188.48 = \$36,938.48 \quad (5)$$

3.2 Schedule

In Table 16, we outline the projected schedule for completion of the project within the next 11 weeks of the semester. This includes deadlines for completion of PCB designs and order, hardware and software debugging, and other tasks essential for successful product completion

Table 16. Schedule of work for the rest of the semester.

<table>
<tr><th>Week</th><th>Bhavish</th><th>Berk</th><th>Santan</th></tr>
<tr><td>Week 1</td><td colspan="3">Work on and complete Design Document and order all parts</td></tr>
<tr><td>Week 2</td><td>Meet with workshop professionals and complete design for helmet component fastener</td><td colspan="2">Complete PCB design and order for voltage indicator circuit, brake button circuit, and turn signal circuit</td></tr>
<tr><td>Week 3</td><td colspan="2">Complete PCB design and order for ultrasonic sensor and arduino code for ultrasonic brake detection</td><td>Complete arduino code for indicator, brake, and turn signals</td></tr>
<tr><td>Week 4 (break)</td><td colspan="3"></td></tr>
<tr><td>Week 5</td><td>Complete design and order of overall PCB for helmet and h</td><td colspan="2">Complete test of hardware and software integration of indicator, brake, and turn signal</td></tr>
<tr><td>Week 6</td><td>Complete blueprint design for helmet component including all physical and electrical components</td><td>Complete testing of helmet component fastener on helmet</td><td>Complete blueprint design for handlebar component including all physical and electrical components</td></tr>
<tr><td>Week 7</td><td>Complete CAD design and printing of outer casing of helmet component for 3D printing and printed mold completed.</td><td>Complete testing of ultrasonic sensor PCB with completed arduino code</td><td>Complete CAD design and printing of outer casing of handlebar component for 3D printing and printed mold completed.</td></tr>
<tr><td>Week 8</td><td colspan="3">Prepare Mock Demo by completing hardware debugging for subsystems</td></tr>
<tr><td>Week 9</td><td colspan="3">Complete soldering of PCBs and all hardware subsystems.for helmet and handlebar components and assembled final product</td></tr>
<tr><td>Week 10</td><td colspan="3">Complete user acceptance testing with diverse use cases</td></tr>
<tr><td>Week 11</td><td colspan="3">Complete final presentation and report</td></tr>
</table>

4 Ethics and Safety

When working on developing this device, our group will take many precautions to ensure our safety and the safety of those around us. All members of the group have completed and passed the required lab safety training and will follow Campus Environmental Health and Safety policy #RB-13, in which we will be responsible for maintaining and creating a healthy and safe environment for our team and the UIUC community [4]. We will make sure to not modify circuits while the power is connected, as well as be vigilant of any burning parts to make sure we do not start a fire. The lab will also be equipped with a fire extinguisher in case of emergency. Additionally, our group will have at least two members present when working in the lab to help prevent accidents. In the situation the group needs to work with equipment that the members of the group are unfamiliar with, we will ensure that there will be the necessary supervision to validate the proper usage of the equipment. Finally, the group will not use other individual's work without the proper citations, and certify that the idea and design of the project is original and unique [1].

Since this device will be used outdoors and can potentially have close contact with the human body, extra precautions are necessary to protect the user. The outside of the helmet LED box and the handlebar LED box will have insulating, waterproof, heat-resistant casing that will make sure no water can come in contact with the electrical components stored inside. Heat resistant plastic will be used to prevent the casing from warping under heat from the sun. This will minimize the risk the user faces when using the device while it is raining outside as well.. Although lithium ion batteries have become the standard in rechargeable consumer products, there is still a level of risk that must be mitigated when using them. The battery will be purchased from a reputable company with a protection circuit built into the battery. The protection circuit will prevent the battery voltage from getting too high or too low and will cause the battery to cut out at 4.0V. This also prevents the other circuitry in the device from shorting or being damaged by improper power input. The noise susceptibility of the 5.0V battery will also be lower than a 3.3V battery, making it more stable. The manufacturer recommended charger for the battery will also be used to prevent malfunctions in the battery. The charging will have three stages: a preconditioned charge, constant-current fast charge, and a constant-voltage trickle to top the battery off. These stages prevent overcharging of the battery. There will also be a voltage detection circuit that can visibly notify the user when the battery has charged. The exposed wires on the handlebar will also have weatherproof, heat resistant insulation so that there will be no exposure to the elements.

Since we are promoting this product as a replacement to traditional hand signals, it is imperative that our product works under duress and can work for up to eight hours. Rigorous testing will be conducted on prototypes to ensure consistent results. Bicycle signaling is required by law in the United States. In order to prevent situations where the device has lost battery and signals are not being output, visible battery indicators will be on the handlebars. Riders will be encouraged to monitor the battery levels of both the helmet and handlebar components to ensure that the device is still charged and responding. This is in accordance with #5 in the IEEE Code of Ethics in which we are urged to improve the understanding of individuals on the societal implications of our technology [11]. Additionally, in compliance with #1 in the IEEE Code of Ethics, we will ensure that all safety precautions are taken in the construction of the device to ensure that there is very minimal risk of harm to the user [11]. If any such risk exists, information would be provided to the user to inform them of the proper usage to avoid said risk.

References

[1] “Article 1, Part 4 - Academic Integrity Policy and Procedure.” *Part 4, Article 1 " Student Code " Illinois*, Illinois.edu, studentcode.illinois.edu/article1/part4/1-402/. [Accessed: April 2, 2020]

[2] Bicycle Accidents in the United States. (2019, December 1). [Online]. Available: https://www.peoplepoweredmovement.org/bicycle-accidents-in-the-united -states/ [Accessed April 2, 2020]

[3] Blocken, B., Druenen, T. van, Toparlar, Y., Malizia, F., Mannion, P., Andrianne, T., … Diepens, J. (2018, June 30). Aerodynamic drag in cycling pelotons: New insights by CFD simulation and wind tunnel testing. [Online]. Available: https://www.sciencedirect.com /science/article/pii/S0167610518303751. [Accessed April 17, 2020]

[4] “Campus Environmental Health and Safety,” Campus Administrative Manual. [Online]. Available: https://cam.illinois.edu/policies/rp-13/. [Accessed April 17, 2020]

[5] Capaldo, Francisco Saverio. (2012). Road Sight Design and Driver Ride Height. [Online]. Available: https://pdf.sciencedirectassets.com/277811/1-s2.0-S1877042812X0 0247. [Accessed April 17, 2020]

[6] Cycling Accidents Factsheet, Royal Society for the Prevention of Accidents. [Online]. Available: https://www.rospa.com/rospaweb/docs/advice-services/road-safety/cyclists/ Cycling-accidents-factsheet.pdf. [Accessed April 2, 2020]

[7] Department of Physics and Astronomy. (n.d.).[Online] Accessed: https://www.phys. hawaii.edu/~anita/new/papers/militaryHandbook/rcvr_sen.pdf. [Accessed April 2, 2020]

[8] Digikey Media. (n.d.). [Online] Available: https://media.digikey.com/pdf/Data%20 Sheets/Seeed%20Technology/113990039_Web.pdf. [Accessed: April 17, 2020]

[9] Electronic Components and Accessories. (n.d.). [Online] Available: https://www. mpja.com/download/hc-sr04_ultrasonic_module_user_guidejohn.pdf. [Accessed: April 17, 2020]

[10] Fuller, S. (n.d.). Topic: Cycling. [Online].Available: https://www.statista.com/topics /1686/cycling/. [Accessed April 2, 2020]

[11] Ieee.org, "IEEE IEEE Code of Ethics", 2020. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: April 2, 2020]

[12] Lumos Helmet - A Next Generation Bicycle Helmet. (n.d.). [Online]. Available: https://lumoshelmet.co/. [Accessed: April 2, 2020]

[13] “The Most Common Serious Bike Accidents and How to Avoid them”, 2020. [Online]. Available https://fortifiedbike.com/pages/the-most-common-serious-bike-accidents-and-how-to-avoid-them. [Accessed: April 16, 2020]

[14] Raspoid API. (n.d.).[Online]. Available: http://raspoid.com/download/datasheet/HCSR04. [Accessed: April 17, 2020]

[15] Seeed Studio. (n.d). [Online]. http://statics3.seeedstudio.com/assets/file/bazaar/product/HC-12_english_datasheets.pdf. [Accessed: April 17, 2020]

[16] Shinkle, D., & DuBois, G. (n.d.).[Online]. Available: https://www.ncsl.org/research/transportation/safely-passing-bicyclists.aspx. [Accessed: April 17, 2020]

[17] Walljasper, J. (2018, February 19). 10 Reasons Bicycling Will Continue to Soar in Popularity. [Online]. Available: https://www.strongtowns.org/journal/2018/2/9/12-reasons-bicycling-will-continue-to-soar-in-popularity. [Accessed: April 2, 2020]