Traffic Sensing Bicycle Light

ECE 445 Design Document

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1 Introduction

1.1 Objective

Despite the increased awareness and improved visibility of bike lanes, there were still about 840 bicyclist death in motor vehicle accidents in the United States in 2016. It was 2.2 percent of total motor vehicle traffic fatalities. Within these cases, there were 58% of bicyclists fatalities who did not occur at intersection locations, which was 28% more than accidents occurred at intersections [1]. For this reason, it would be extremely beneficial to have a device located at the back of the bike to alert both bicyclists and drivers, and to prevent potential accidents.

Our intention is to design a device to sense traffic coming up from behind. It is able to operate under three different modes to warn the drivers behind based on the relative distance and the approaching speed of the vehicle. In this way, the drivers are able to pay attention that there is a bicyclist in front. Therefore, it is able to reduce the possibility of accidents occurrence.

1.2 Background

There are several different types of devices in the market related to bicycle safety. Some devices only flash red light when the bicyclists hit the brake. Some devices are able to warn the bicyclists through compatible Edge bike computers. In general, their functionalities are single and simple. In the case of preventing accidents, multiple use of various equipments would be more efficient. Moreover, the capability of operating under different modes would be suitable under different situations.

Having such traffic sensing bicycle light is able to not only heighten the bicyclists awareness of potential accidents of approaching vehicles coming up behind but also have the drives to pay extra attentions to the bicyclists. And there would be three alarm modes for various situations. When either the relative distance gets closer or the speed increases over the certain velocity, the device is able to start from flashing red light, to a high-intensity white strobe light, and eventually loud audible alarm based on how serve it is. The determinant parameters such as distance ranges and relative speed are able to be adjusted via bluetooth using a Android devices. With such setting, it would be more effective to reduce the chance of accidents under various situations,

1.3 High-Level Requirements

- The device must be able to distinguish between vehicles coming up from behind and those parking beside, passing by and passing in the opposite direction, and it could recognize whether a car behind or a cyclist behind.
- The device must be able to have 4 modes of operation to alarm approaching drivers, as *Table 1* shown below, for specific information for each mode.
- The cost of the device must not exceed $150.

2 Design

The sensing light requires five sections for a successful operation: a power supply unit, a control unit, a sensor unit, output devices units, and a software unit. The power supply unit includes 27 V voltage source using NiMH batteries, and several voltage regulator for different modules of the device. Such that, the device could run a sufficient amount of time. The control unit contains a microcontroller (Atmega328p), which has 32 KB flash memory and is able to handle the incoming data continuously from the sensor module. Then the control unit would determine which output device are to be activated. The user can change the parameters of distance and velocity threshold for the sensor via their Android device.

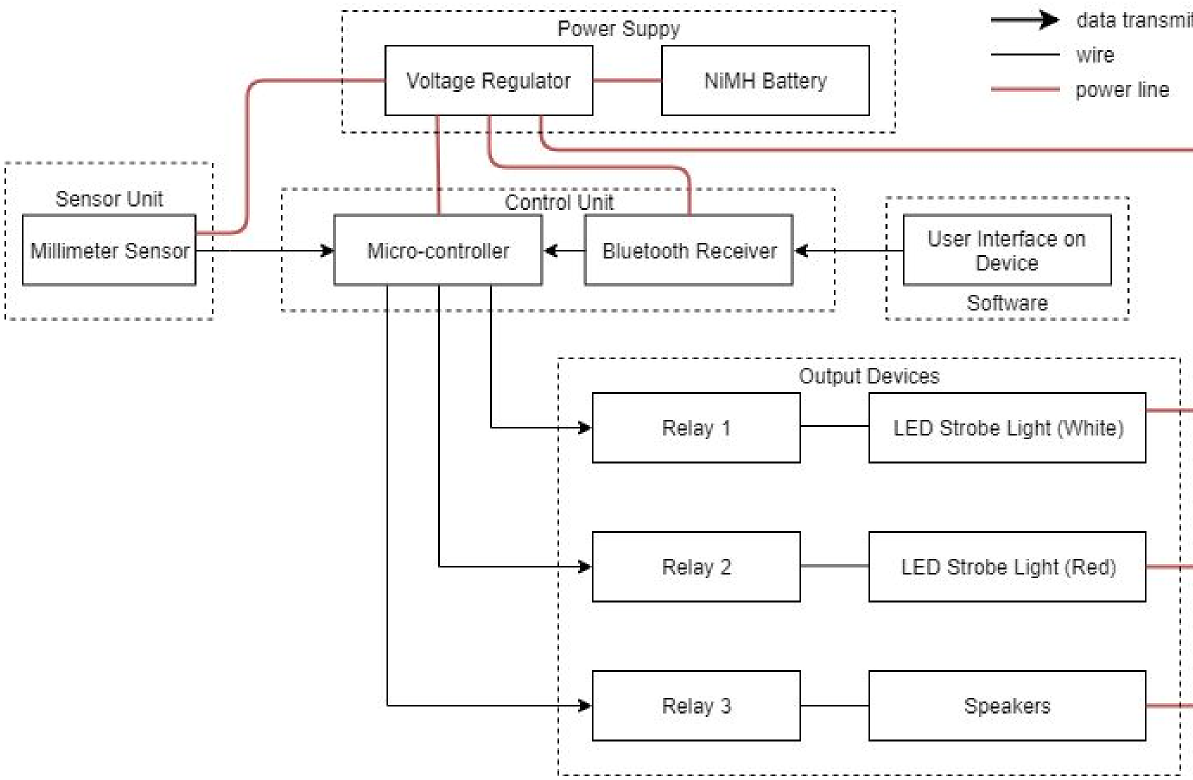


Figure 1. Block Diagram

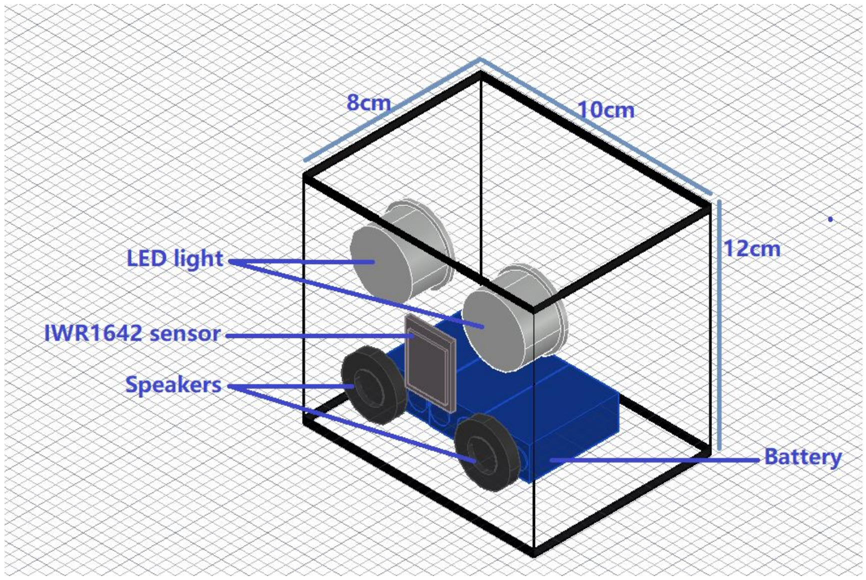


Figure 2. Physical Design

2.1 Sensor Module

The sensor module is the input of the device. The sensor module contains a single chip IWR1642 which contains a on-chip microcontroller unit ARM Cortex-R4F and a integrated digital signal processing unit TI C674X. The module will operate at 40MHz clock cycle, which will be part of the one complete clock cycle of the Atmega328P. The external RX and TX antenna, which has 14dB gain, will be installed on the board for sensing vehicle approached from behind. And the detecting angle will be set to 120 degrees and the detecting range as 40 m max. And the effective width that take the data account will be the width of the cyclist, which would be 1 m. And the sensor will only take the vertical distance between the cyclist and the vehicle as data to compare with trigger threshold; and only the vertical relative velocity towards the cyclist would be taken to compare with the trigger threshold input from Atmega128P.

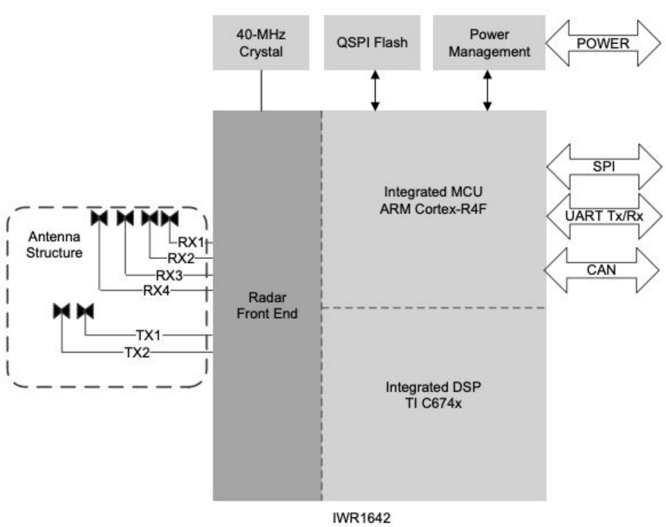


Figure 3 : Block diagram for the IWR1642

Requirements	Verifications
1. The Garmin Lidar sensor (SEN-14032) can correctly collect velocity and distance data 2. The Radar Sensor (SEN0192) can detect the distance that is perpendicular to the parallel surface of the antenna. 3. The close distance laser sensor can detect close distance object	1. A. Connect the sensor to the Control Module and use a testing program that contains the distance threshold of 3m and approaching velocity of 0.5m/s. And connect the output to a simple LED B. Run the program to check if data from the input exceeds thresholds. If both input data is higher than thresholds, the LED turns on 2. 3. A. Connect the sensor to the Control Module and use a testing program that contains the distance threshold of 1.5m. And connect the output to a simple LED B. Run the program to check if data from the input exceeds thresholds. If the distance between the testing object and the sensor is smaller than 1.5m the LED is on.

2.2 Control

A control unit that is able to take the data from the sensors as input and determine which output device should be triggered according to the data collected. This unit is made up of two chips, one is the microcontroller from the IWR1642, Cortex-R4F, which is integrated in the chip for working on the logic of which mode should be activated, the other is our own microcontroller, which is Atmega128p for handling output devices and input parameters.

2.2.1 Microcontroller

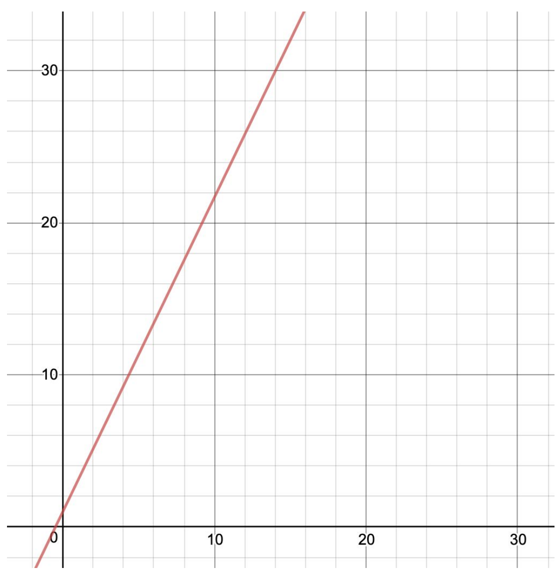
Microcontroller, Atmega328P with 32 KB flash memory, is chosen to handle input data management received via the HC-05 bluetooth transceiver and determine whether the input data can pass on to the next microcontroller Cortex-R4F in the IWR1642. And the way to check the input data is using the following equation:

$$D = 1 + t \cdot v + \frac{v}{2gf}$$

Eq. 1: stopping distance equation from Geometric Design of University of Idaho (7)

D: total distance between the car and the bike.
t: response time/delay time.
g: gravitational constant
v: velocity of the vehicle relative to the bicycle.
f : frictional constant on the ground.
1 : safety distance between vehicle and the biker

It is also capable to receive user input via UART by Bluetooth for the triggering parameters. The user will be able to select the which frictional constant they want from the device. Frictional constant will be default at 0.75, which is the constant for dry road. And the default response time will be 2 seconds. Then we will have the following figure when the f and t is at default values:



Graph 1. The total distance between the vehicle and the back of the bicycle vs. velocity of the vehicle relative to the bicycle.

Users will be able to modify f, t and D. Frictional constant will be depended on that day's weather. The user can pick the road condition to set f. The f is 0.75, if user pick "dry" as road condition; the f is 0.45 if user pick "wet" as the road condition. Then depends on if the user wants the device to be more sensitive or less sensitive on the velocity of the vehicle behind the cyclist. If the delay is smaller, the device is less sensitive. If the delay is longer, the device will be more sensitive on the relative velocity.

Table 1: An example of a trimmable parameter and the range calculated according to the equation below with the default values.

Distance of 33m [25m,40m]	Velocity of 15.5 m/s [11.6m/s, 19m/s]	Potential Rear Crash detected, activating flashing white strobe light
Distance of 20m (10m,25m)	Velocity of 9.3 m/s (4.4m/s, 11.6m/s)	Potential Rear Crash detected, activating flashing red strobe light
Distance of 8m [2m, 10m]	Velocity of 3.4 m/s [0.5m/s,4.4m/s]	Potential Rear Crash detected, Triggering horn for final warning

The microcontroller is programmed through a JTAG interface. In order to use a mobile device to input the parameters the user want, addition Bluetooth transceiver HC-05, which has a detecting range of 10m, is needed to handle the wireless data transmission. And Atmega328p will operate at 16MHz clock cycle, which is fast enough to respond for this device.

IWR1642 single chip milliwave sensor will be responsible for collecting the velocity and distance data. And the system clock cycle will be the same as Atmega128p. And the data transmission for input parameters from the Atmega328p is input in the IWR1642. And the output from the chip will be put back into the Atmega328p to determine which output device should be activate. And the functionality of the IWR1642 would be verified on the sensor module.

Requirements	Verifications
1. Can both receive and transmit over UART at a speed at least 120kbps 2. Can give out signals to activate output devices 3. Cortex R4F can receive the output signal from the Atmega328p and passback the testing signals to Atmega328p	1. A. Use a test program that contains time.h output the variable that stores the input received from the UART to the console B. Type in a set of data of parameters from the device and send it to the microcontroller C. Check the output on the console see if it matches to what was input from the mobile device 2. A. Use a test program that sends a active low signal to the pins where the output

	devices such as the strobe LED and speaker are connected. B. Check if the corresponding activated device is on 3. A. Carry out a constant high signal to the CortexR4F where it has a program to negate the signal and pass to volatile address for output. B. Atmega128p then pass the input to one of the output pin, which connects to an relay and a LED that turns on when active low signal receives.

2.3 Output

There would be three relays used between the two output LED strobe lights and speakers and the control unit. The light and speakers would be turned on only when the relay receives the signal from the control unit to close the circuit. The operating rated voltage of the LED strobe lights ranges from 12 V to 16 V for 450 Lumens to 700 Lumens. The maximum current of the LED strobe lights is 850 mA. The operating voltage of the speakers ranges from 2.83 V to 3.46 V for various amplitude. The maximum current of the speaker is 350 mA. They are added up to 2400 mA maximum possible current.

2.3.1 LED Strobe Lights

Requirement	Verification
1. Can blinks when relay is active 2. Provide bright enough light that the driver is able to see	1. Connect the LED lights in series with the relays 2. Operate the relay in a desire way, check if the LED blinks as it is set up 3. Turn on the LED light and place it near the road in day and at night 4. Check if the LED light is able to be seen

2.3.2 Speakers

Requirement	Verification
1. Can play sound when relay is active 2. Provide loud enough that the driver is able to hear	1. Connect the speakers in series with the relays 2. Operate the relay in a desire way, check if the speakers operate as setup 3. Play the sound and place it around a car 4. Check if the drive is able to hear the sound

2.4 Software

The control unit will be accessed by android devices via Bluetooth. We will use the HC-05 Bluetooth Module with our microcontroller, which connects the devices using the serial communication. And we will start with using the serial communication at default baud rate of Bluetooth, 38400 baud rate. The Bluetooth device transmit data to the transceiver at a 2.4 GHz frequency, which would not interfere our sensor unit that works at 76 to 81 GHz. We will also make an user interface using the MIT App Inventor, which will provide an user interface to change parameters for range and relative speed for different modes of operation. [5]

Requirement	Verification
1. Can use bluetooth connected devices to modify the parameters in microcontroller and also read the current parameters of the device once connected	1. Use a test program that reflects the status to the Bluetooth Device and takes input to turn on the LED connected from the Atemega328p 2. Connect the bluetooth device to the microcontroller and Check if it could change the status of the LED and reads the current status of the LED

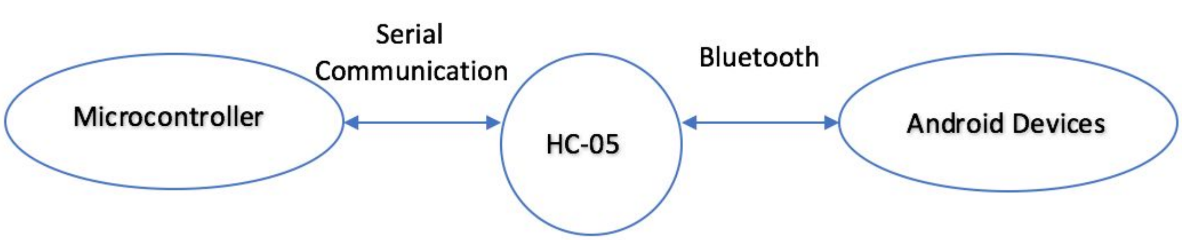


Figure 4: Bluetooth connection Diagram

2.5 Power Supply

The power supply provides the circuit with maximum 27 volts by three 9 volts 2200 mAh NiMH batteries. It supplies the control unit, the sensor unit, and the output devices, with approximately 2500 mA in total. The speakers, and LED lights take majority of the current.

2.5.1 Voltage Regulator

A 12 volts, a 5 volts, and a 3.3 volts voltage regulators would be used to maintain constant voltage output from the batteries source. The BA50DD0T-ND would be used for the 5 volts voltage regulator. The 576-2223-ND would be used for the 12 volts voltage regulator.

Requirement	Verification
1. Maintain a constant 3.3 volt voltage level 2. Maintain a constant 5 volt voltage level 3. Maintain a constant 12 volt voltage level 4. Can operate a currents within 0-2000mA	1. Connect the voltage regulator in a test circuit 2. Measure the output voltage using an oscilloscope 3. Choose proper load connected to the circuit 4. Measure the output current using an oscilloscope

2.6 Schematic

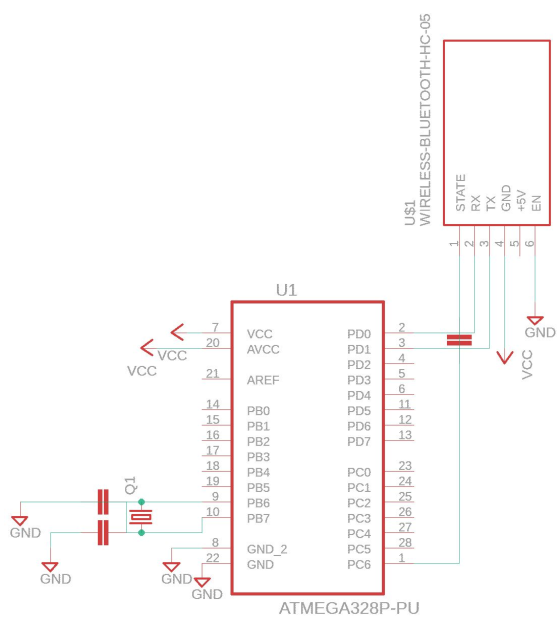


Figure 5: Control unit schematic

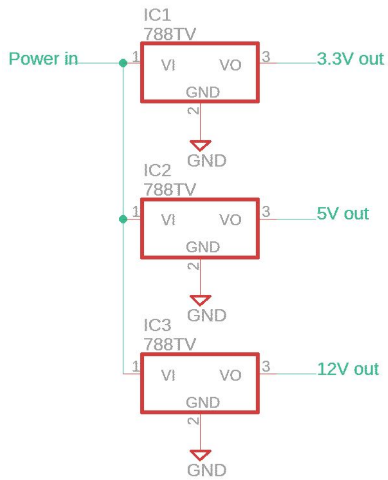


Figure 6: Power unit schematic

2.7 Tolerance Analysis

The IWR 1642 detects objects up to 84 meters with range resolution of 37 cm.

$$percentage\ error = \frac{|eperimental\ value - accepted\ value|}{accepted\ value} \tag{2}$$

The percentage error for this range resolution will be 0.37/84 = 0.44%.

The antenna field of view has +/- 60 degrees with angular resolution of approximately 15 degrees, which makes a percentage error of 15/60 = 25%. When it is rainy and people who are detected have walk on their bodies, it can result a range accuracy from 0.01 mm to 0.1 mm with range of 20 m to 140m, which has a percentage error of (0.1-0.01) / (140-20) = 8.25%.

Moreover, when we are detecting people, the IWR 1642's tracking accuracy is bigger than 93%, counting density of 3 people people m^2. [6]

For the power supply for the IWR1642 single chip, 1.2 V, 1.8 V, 1.3 V are required for digital power supply, CMOS IO, analog and RF supply. And their maximum voltage rating are 1.4 V, 2 V and 1.35 V respectively. The tolerance for voltage regulator of the chip, in order to power the correlated parts, are $\frac{|1.4-1.2|}{1.2} = 16.7\%$, $\frac{|1.8-2.0|}{1.8} = 11.1\%$ and $\frac{|1.3-1.35|}{1.3} = 3.85\%$ respectively. If the voltage regulator failed to achieve the tolerance above, it could possibly damage the integrated IWR1642 chip.

3 Cost

The fixed development costs are estimated to be \$20/hour, 12 hours/weeks for three people. It approximately takes 11 weeks to be done.

$$3 \cdot \frac{\$20}{hr} \cdot \frac{12hr}{wk} \cdot 12wk = \$8640$$

Part	Cost (prototype)	Cost (bulk)
9 volt 2000mAh NiMH rechargeable battery *3 (Amazon; Energizer)	$26.55	$14.99
3.3 volt voltage regulator (Digikey; LM1117T-3.3/NOPB)	$1.54	$0.622
5 volt voltage regulator (Digikey; BA50DD0T)	$3.01	$1.36
12 volt voltage regulator (Digikey; MIC29301-12WT)	$4.26	$3.23
Microcontroller (Digikey; ATmega328P)	$2.25	$1.78
16MHz crystal (Sparkfun; COM-00536)	$0.95	$0.33
Bluetooth receiver (Amazon; HC-05)	$11.11	$2.95
Millimeter wave sensor (Digikey; IWR1642AQAGABLR)	$42.53	$28.03
Relay *3 (Amazon; ky-019)	$8.99	$3.56
LED strobe light *2 (Amazon; Hontiey)	$6.49	$3.34
Speakers *2 (Digikey; 102-3841-ND)	$7.40	$4.16
Total	$115.08	$64.35

4 Schedule

Week	Anchu Zhu	Jimmy Gan	Jiawen Chen
02/25/2019	Begin protocol design and programming	Begin sensor unit schematics	Begin PCB design
03/04/2019	Continue programming, research data transmission protocols	Complete sensor schematics	PCB design version 1
03/11/2019	Begin data transmission protocols	Begin sensor unit test	Begin Power supply test
03/18/2019	Continue data transmission	Continue sensor unit test	Begin output device test
03/25/2019	Complete programming	Continue sensor unit test	Continue output device test
04/01/2019	Start finalize units	Start finalize units	Start finalize units
04/08/2019	Prepare mock demo	Prepare mock demo	Prepare mock demo
04/15/2019	Mock demo; Prepare demonstration	Mock demo; Prepare demonstration	Mock demo; Prepare demonstration
04/22/2019	Prepare presentation; Start final report	Prepare presentation; Start final report	Prepare presentation; Start final report
04/29/2019	Complete final report	Complete final report	Complete final report

5 Ethics and Safety

There are several safety concerns for the project. Since the device will be connected to a standard flashing red light, high-intensity white strobe light, and a horn, the first concern is about the power safety. Approximately 27 volts would be needed for the project, which would be relatively safe to human. However, for the NiMH battery, overcharge may occur, which can potentially cause damage to other modules. Another concern would be that if the high-intensity white strobe light is too bright, it would potentially cause drivers behind dazzling or even unable to see. Therefore, further testing on the strobe lights will be conducted to determine the frequency of the flashing pattern.

Since the device is attached to a bicycle which would be at the outside for most of time and face raining or sunny weather. For these reason, it could possibly cause a short circuit or other potential safety problems. In that case, a waterproof case with heat-sink would be used for the device.

This project aligns with the IEEE Code of Ethics because the device itself is safe and will not do any damage to others. Moreover, it is supposed to alarm both bicyclists and car drivers and prevent potential dangers, which results in decreasing the bicycle accident involved with cars. Therefore, the project will " hold paramount the safety, health, and welfare of the public" and "disclose promptly factors that might endanger the public or the environment"[2].

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