# IoT Safety Equipped Bicycle

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***Abstract*— When it comes to urban cycling, safety is of utmost importance. Most modern automotive vehicles have smart features such as, lane departure warnings and blind spot vehicle detection that help improve their safety. On the other hand, the bicycle industry hasn't seen considerable advancements in additive safety technologies. According to the US Department of Transportation's National Highway Traffic Security Administration, on an average, about 721 cyclists were killed every year from 2007 to 2016 due to traffic crashes. This paper looks into the opportunities in improving bicycle safety by using existing technologies and the challenges involved in doing so. It serves as an exploratory model for the application of technology to improve safety in bicycles. It adds 3 elements to bicycle safety. Those being, a smart mirror to provide a view of the vehicles behind the bike, a rear lighting module to display turn and stop signals for better visibility and finally, an electric assist module to provide additional power when required.**

***Keywords-Bicycle Safety; Accident prevention; Bicycle lighting; Electric Assist; Smart Mirror; Internet of things.***

## I. INTRODUCTION

In the present-day, cycling is an increasingly popular sport. It is being used, not only as a means of transport but also as a means to stay fit [1]. As a result, the bicycle industry has come up with a variety of bikes for every type of use possible. Today there are 4 major classes of bicycles. Namely, road bikes, mountain bikes, hybrid bikes and electrically assisted bikes. In addition, there are many mobile apps and tracking devices geared toward measuring the cycling activity for fitness analysis. There have been a significant number of innovations in multiple aspects of cycling as a direct result of the increase in demand for them. However, there haven't been considerable advancements in the field of bicycle safety.

According to The US Department of Transportation's National Highway Traffic Safety Administration, from 2001 to 2015, on an average, around 713 cyclists were killed in the US, every year due to traffic crashes. In 2016 the number increased to 840 [2], [3]. This implies that there is a need for an improvement in the safety of bicycles. Due to the advancements in technology in recent years, it is possible to make devices that are small enough to be mounted on a bicycle, that can add safety features [4].

It is evident that the automotive industry has seen huge advancements in safety, since the addition of smart car technologies such as lane keep assist, emergency brake assist and blind spot detection [5]. These systems play a key role in making the current day smart cars safer than their predecessors. On the other hand, bicycles haven't seen major advancements in technologies that improve safety, in spite of their recent increase in adoption [1]. To this day, bicycle safety remains heavily dependent on helmets and other protective gear. While safety gear provides protection in the event of an accident, they offer limited functionality to help prevent them.

Some concepts of the safety systems in cars can be modified and applied to bicycles, to achieve the same effect that they have in cars. Research suggests, that non junction accidents accounted for 58% of fatalities in 2016 in the US [3]. Non-junction accidents, such as rear end collisions and overtaking collisions, are caused due to low visibility at night and the difference in speed between the vehicles and the bike, respectively [6]. The proposed system addresses these issues by implementing a robust lighting system, that makes the bike stand out in low light conditions and by providing an assist module that helps the cyclist get to and maintain appropriate speed for the lane.

## II. PRODUCT RESEARCH

In the US, the bicycle industry is estimated to have a market of 6.2 billion dollars with 17.4 million in unit sales [7]. This large market provides an opportunity for companies to make addons for bicycles. Several commercial products are available in the market, that provide a wide variety of applications and features. Analysis of some of these products can provide insights into building a robust safety system. The products that are currently available in the market can be broadly divided into three categories. (a) Fitness oriented products, (b) Lighting systems and (c) Other safety related products. Each of these categories of products is designed to appeal to a niche crowd.

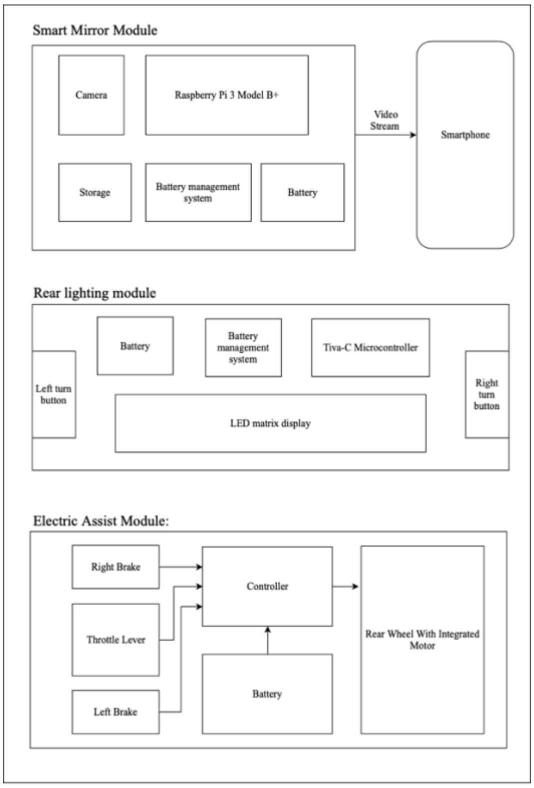
Garmin is a company that makes high-end devices for several sports, including cycling. Garmin has a wide range of products offering multiple functionalities, with a primary focus on performance-oriented / professional cyclists. On the other hand, startups concentrate on a wider customer base. This could be due to a lack of branding capital and dedicated customer base. Garmin makes cycling computers that may cost up to $600, based on the model. In addition to that, they also have add-on devices that can be connected to their cycling computers. One of the add-ons offered by the company is a cycling radar that helps riders spot the vehicles behind them by providing the distance of the vehicle. It also acts as a rear safety light. These are highly useful features for bikers as it helps prevent rear ended collisions. Garmin's products provide their users with a robust fitness tracking experience. Some of their addons are also geared towards safety. However, Garmin's products are on the expensive end of spectrum and are not made with the average commuter in mind. This may be due to their model customer being a rider that is fitness oriented.

Products like Revo Lights, which are front and rear wheel mounted light strips, Zackees Turn signal gloves, which are cycling gloves with integrated turn signaling lights, Visijac Commuter Jacket, which is a jacket that lights up at night and Helios Bar, which is a smart handlebar that implements lighting and GPS tracking, focus primarily on bike lighting so that the bikes can be seen easily on the road. These products provide a safer ride at night by making the bicycle more conspicuous. However, lighting systems alone provide minimal accident prevention especially in the case of overtaking accidents.

Apart from the products mentioned above there are a few other products that offer a different set of features. Cycliq Fly6v and Cycliq Fly12v are products that allow the rider to record their rides using cameras. This is a highly desirable feature especially in an urban environment, where the camera footage can be extremely useful, in the event of an accident. In addition to the video recording hardware, the devices are equipped with LED lights that enable the devices to act as front and rear lights. The Hammerhead bike navigation system is a product that connects to your phone via BLE and displays the turns that need to be taken while on a route. The main use of this product is that it can help save the battery of your phone while implementing a navigation system which is easier to comprehend.

Upon analyzing some of the products available in the market, it is evident that there is a lack of an all in one solution that can provide all the useful safety-oriented features. It is possible to make a device, which implements all the features and still be small enough to fit on a bike conveniently. This paper gives an example architecture of how this can be done.

## III. PROPOSED SYSTEM




The system consists of 3 modules that work together to enable a safer ride by providing a rear view of the road, helping with peddling and providing increased visibility at night.

### A. SMART MIRROR MODULE:

This module is mounted on the back of the bike and is implemented using a Raspberry Pi 3 Model B+ and a pi camera. It creates a Wi-Fi access point using the Wi-Fi chip on the pi. It captures the video using the pi camera and streams it to a pre-determined IP address on the network. The video stream can be accessed by any device connected to the network. Therefore, it can be accessed by any smartphone mounted on the handle of the bike, to display the video and thus act as a smart mirror providing the rear video feed to the rider. In addition to that, it stores the video on the SD card attached to the raspberry pi to facilitate review in case of an accident.
This module is powered by using a battery management system connected to a 3800mAh battery.

### B. REAR LIGHTING MODULE:

THIS MODULE IMPLEMENTS LIGHTING FEATURES SUCH AS STOP/TURN INDICATOR LIGHTS AND ALWAYS FLASHING BIKE LIGHT. IT DOES SO, USING AN LED MATRIX DISPLAY, BUTTONS AND A TIVA-C MICROCONTROLLER. THE BUTTONS ARE USED TO TRIGGER THE TURN SIGNALS AND TIVA-C BOARD IS USED TO DETECT BUTTON PRESSES AND DRIVE THE LED MATRIX DISPLAY. THE MICROCONTROLLER CONTROLS THE MATRIX DISPLAY USING SSI PROTOCOL. WHEN NO TURN SIGNAL IS TRIGGERED, THE ENTIRE MODULE FLASHES TO PROVIDE INCREASED VISIBILITY.

### C. ELECTRIC ASSIST MODULE:

The bike is equipped with a motorized rear wheel, throttle, brakes and required electric components to control the motor. The electric assist can be engaged by using a throttle lever. The brakes are fitted with switches, to detect the application of brakes. While braking, the system cuts the power to the motor even if the throttle is engaged, so that the bike can stop quickly. The electric assist system does not interfere with the normal operation of the pedals and the drive train. Therefore, the rider can modulate the amount of assist provided and when it is provided, by using a combination of peddling cadence, gear selection and electric assist throttle.

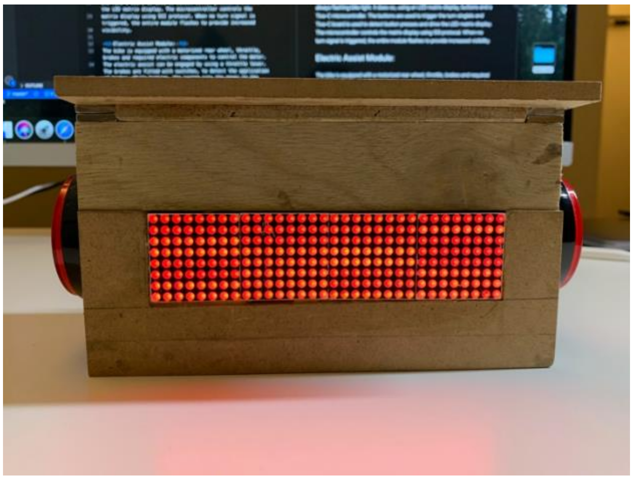


Figure 1 Front view of Rear Lighting Module

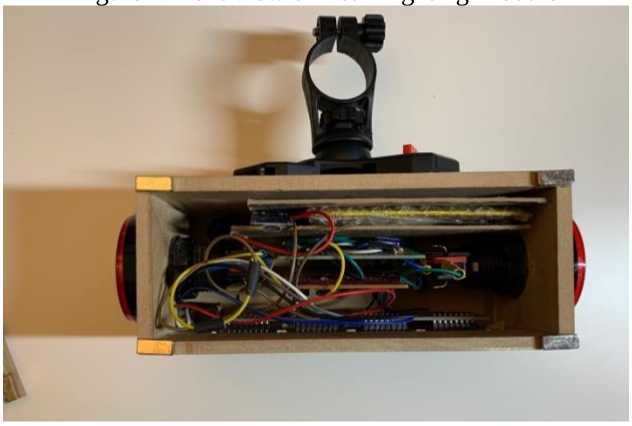


Figure 2: Top View of Rear Lighting Module

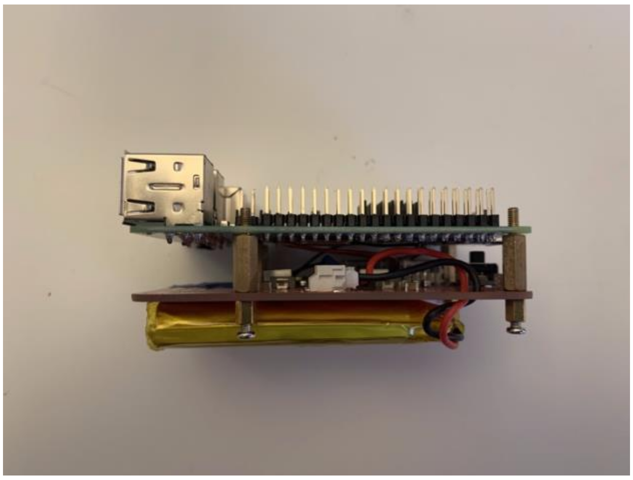


Figure 3: Hardware Components of Smart Mirror Module.

Figure 4: Smart mirror module with case.

## IV. Hardware Components

### A. Smart Mirror module:

#### 1) Raspberry pi 3 Model B+:

The Raspberry Pi 3 Model B+ is a single board computer that has a Broadcom BCM2837B0 , Cortex-A53 (ARMv8) 64-bit system on chip running at 1.4GHz and 1 GB of LPDDR2 SDRAM. It is running a linux operating system specially designed for the pi called Raspbian Stretch Lite. The pi is used to capture the M-JPEG video and stream it to a webpage that it hosts. The website is hosted on a network that is created by the Pi itself using a package called as hostapd. The network is IEEE 802.11a standard which operates at 5GHz and is protected by WPA-2 encryption. Any device that wants to establish a connection with the network requires a password.

#### 2) Battery management system:

The battery management system has a 3800mAh battery and a battery management board that handles the charging of the battery and ensures uninterrupted power supply to the pi.

#### 3) Camera:

The camera used for capturing the video, is a raspberry pi camera revision 1.3 which can capture 1080p HD video at 30fps.By utilizing its video-capture capabilities, it can capture a sequence of images rapidly using the JPEG encoder.

#### 4) Storage:

The Raspberry pi 3 Model B+ uses a 64 Gb Micro-SD card as its primary storage device. Therefore we use it to store the video.

### B. Rear Lighting Module

#### 1) Tiva-C series launchpad:

The Tiva-C board is a development platform for 32-bit ARM cortex M-4 processor. It uses a TM4C123GH6PM chip from Texas instruments and has 256 KB of flash, 32 KB of SRAM and 2KB EEPROM. It is used to implement the rear lighting unit as it can communicate with the LED matrix display using the SSI protocol. The buttons used to trigger the turn light are connected to the microcontroller. The microcontroller uses interrupts to initiate turn signal display sequences.

#### 2) LED matrix display:

This display is an 8x8x4 red LED matrix module that uses a MAX7219 IC to control the LEDs using the SSI protocol. The LEDs provide 8 levels of brightness which can be controlled by using the microcontroller.

3) Battery management system:

The 3800 mAh lithium polymer battery is controlled by a battery management system that has a TP4056 lithium battery charging circuit.

### C. Electric Assist Module:

1) Rear hub motor:

The rear hub motor is integrated into the rear wheel. This allows it to bypass the drive train and not interfere with the rider's pedaling. When powered by 48V, DC the motor outputs 1000W at 470 RPM.

2) Electric Assist Battery:

The electric assist battery is mounted at the center of the bike and can be detached from the bike using a key, for charging elsewhere. It is enclosed within a waterproof and shockproof enclosure to prevent damage to the battery that can be caused due to the atmospheric elements and ride vibrations. It powers the electric assist hub motor through a controller circuit that is connected to the throttle lever and the brake sensors. The range and runtime achieved by using the battery are heavily dependent on conditions such as hill grade of the road, speed, pedaling power provided by the rider, weight of the rider and riding style.

TABLE I. Battery Specifications

| ***Parameter*** | ***Value*** |
|---|---|
| Nominal Voltage | 48V |
| Rated Capacity | 10Ah |
| Maximum Constant Discharge Current | 30A |
| Peak Current | 80A |
| Weight | 5.5 Kg |
| Dimensions | 36 x 11 x 9 cm |

## V. Software Architecture

### A. Wi-Fi Access point:

The raspberry pi has a Wi-Fi chip that is capable of creating an access point. Therefore, we use an application called Hostapd (Host Access Point Demon) to implement an access point using the 5Ghz spectrum. The access point is capable of assigning IP addresses to devices that connect to it. This is achieved by using an application called DNSmasq which implements a DHCP server. The access point is configured in such a way that the IP address of the pi on the network is static.

### B. Webserver:

The webserver is implemented using a python script that uses python's in-built 'http.server' module to implement a video streaming server. The server is hosted on the pi at port 8000 and can be accessed by any device on the network.

### C. Streaming:

The M-JPEG stream captured from the camera is sent to the webpage. The stream has a resolution of 640X360 and has a framerate of 40 fps. The script uses python's 'pi camera' module to capture the video.

### D. Software for the lighting unit:

The lighting unit software is implemented using C/C++ with the help of libraries from Texas instruments. The Interrupt driven software design uses a custom driver for the LED matrix display to display desired patterns efficiently.

## VI. Results and Analysis

### A. Smart Mirror Module:

The Smart Mirror module captures the rear video and streams it to the private network and can be accessed by a smartphone with a delay that is virtually un-noticeable. This module provides a clear view of the rear road without the need to take the eyes off of the road ahead. In urban traffic this capability is an extremely useful feature.

### B. Rear Lighting module:

The rear lighting unit implements turn and stop lights in a clearly visible fashion. It has a battery that is capable of delivering 12 hours of normal, continuous use of the module.

### C. Electric Assist module:

The electric assist module is capable of providing pedal assist and if needed, is capable of propelling the bike without any effort from the rider. The bike has a top speed of around 25mph (40kmph) and a range of 15 to 20 miles.

## VII. Conclusion

This paper examines the need for bicycle safety based on accident statistics and the factors that cause bicycle accidents. It then tries to provide a solution to some of the issues that are identified by research as the causes of accidents. It implements 3 modules, each addressing a different domain of safety concerns. It implements a smart mirror system, to give the rider a better view of his surroundings. It also implements a rear lighting system to help other motorists spot the bike on the road, especially at night. It provides electric assist to the rider using the electric assist module. The combination of all the three modules helps prevent rear end collisions and overtaking accidents, thus providing a safer ride experience. In addition, the paper provides a good example of how to go about building safety systems in bicycles for building safer and smarter bikes of the future.

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