Prospectus

Design of *The Sentinel*: A Solar Powered Radar Vehicle Detection System for Bicycles
(Technical Topic)

Analysis of Toyota's 2009-2011 Vehicle Recalls
(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

This is a proposal to address the question of how to ensure safety for vehicle customers. As more and more people are becoming bicyclists, bicycle safety has also become a greater safety issue. Since 2003, bicycles have outsold cars (Walljasper, 2018). There are many advantages of riding bicycles: cycling improves physical health, increases time outdoors, and is a cheaper and more environmentally friendly transportation alternative (*Cycling—Health benefits*, 2021). However, biking also presents risks: severe weather, hard terrain, and the potential for an accident that could cause bodily harm. In a survey of over 1000 bicyclists, health benefits ranked as the top motivation for riding a bicycle, whereas the crash risk ranked the greatest discouragement (Useche et al., 2019). In 2019 alone, 843 people died in fatal bicycle-car collisions (*Fatality facts 2019: Bicyclists*, 2021). Unlike automotive collision detection systems, which have grown in prevalence and popularity in recent years, the market for bicycle collision systems is limited (*Latest car safety features*, 2021). To increase biker safety, our capstone group will create a solar-powered radar system with intuitive LED warnings to help alert bicyclists of vehicles approaching from behind: *The Sentinel*. The development of this technology will enable bicyclists to enjoy the benefits of cycling while increasing overall bicycle safety.

While the creation of *The Sentinel* may address the technical problem, it is insufficient to advance the overarching goal of safety. Technical advancement of bicycle vehicle detection systems and providing greater variety in product availability for customers may be the main drivers for the creation of *The Sentinel*, but there are also other important economic factors, regulatory factors, and user-interface factors that will influence the safety for users. Some of these non-human factors include budget constraints, user perception of safety, and regulatory guidance for traffic safety. To explore these potential factors, I will analyze the case of Toyota's mass vehicle recalls in 2009-2011 associated with unintended acceleration of many of its models, and Toyota's failure to ensure consumer safety. A limited understanding of the relationship of non-human and human factors on the overall safety for vehicle consumers will stymie the success and implementation of *The Sentinel* and thereby thwart efforts to reduce injuries and fatalities of bicyclists.

Both the social and technical factors affecting the overall network of vehicle safety must be understood in order to create an operational product that increases bicycle safety. I will discuss the technical procedure for developing a solar-powered radar-object detection system for bicyclists. To address the complexity of creating a network of safety, I will utilize Actor-network theory to understand the human and non-human actors that lead to a series of Toyota Vehicle Recalls from 2009-2011: the overall failure of that socio-technical network to ensure customer safety.

Technical Project

Vehicle Crash Collisions systems have evolved greatly over the last 20 years and have become more and more prevalent among the automotive industry (*Latest car safety features*, 2021). However, these collision detections systems have not been comprehensively adapted to the bicycle. Bicycle vehicle collisions can prove extremely dangerous, it is estimated that ninety -six percent of the 783 people killed in 2015 in pedacylist crashes were involved in single-vehicle crashes. Eighty-four percent of the cyclists were impacted with the front of a vehicle in these types of collisions (National Center for Statistics and Analysis, 2017). Crash collisions systems should similarly be created for the bicycle format to increase safety for riders. These new systems could help to mitigate the risk of riding and make it more attractive for people to use their bikes as an alternative to car transportation.

Several products on the market attempt to address the safety concerns of bicycle users. Bike mirrors are a technical solution that alerts riders of oncoming cars and trucks. Bike mirrors have a long range of view but they require a rider to constantly be scanning his or her field of view, and it can be hard to see objects in dark conditions with the glare of car lights. The other major product on the market is the Varia ™ by Garmin. This product is a bike seat-mounted radar with a 220° FoV (field of view), has a battery life of 6-16 hours, and a sensing range of 140 m for vehicle speeds of 10-160km/hr (Garmin, n.d.). The radar communicates via Bluetooth to the Garmin Edge device, a GPS computer with an LCD screen mounted on the front of the bike. Although this radar has sensing abilities, a customer would need to also purchase an onboard computer LCD display mount to use the radar. Additionally, both the LCD and the radar need to be charged when they run out of battery. Furthermore, when the batteries within the radar no longer work, there is no easily accessible way for consumers to replace these batteries. Most of the time the customer has to buy a completely new unit, which is both wasteful to the environment and expensive. Thus, the Varia ™, although achieving similar detection, may be unused by consumers because of its environmental impacts, battery charging constraints, and its reliance on multiple products.

Our project, named *The Sentinel*, is a solar-powered bike radar system that alerts cyclists of oncoming cars. The system utilizes an OPS243-C-FC-RP radar sensor with an MSP430 microcontroller to activate a display board mounted on the handlebars when metallic objects approach the user from the rear. Using a small 10-watt solar panel and just two Li-Ion 18650 cells, the system can remain powered indefinitely under nearly all use conditions. Below in Figure 1, is a depiction of the physical design of the system. The LED display will be connected via wire to the back mount which includes both the solar array and the sensor.

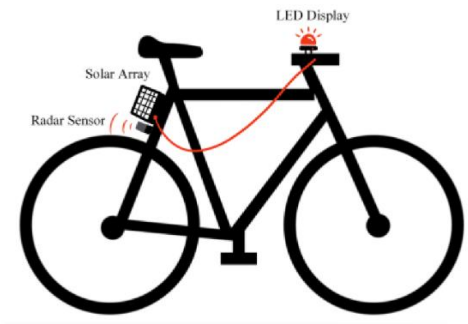

Figure 1: Basic Physical Design of The Sentinel System

In Figure 2, the connections between the various components are described in a block diagram.

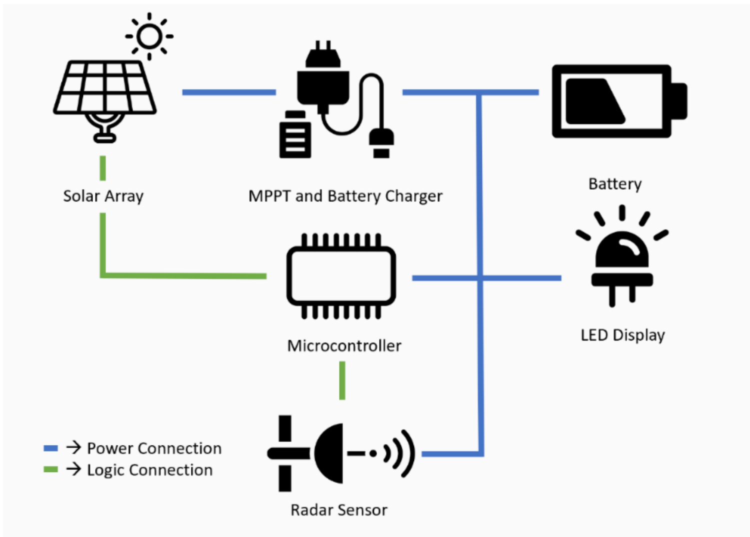

Figure 2: Block Diagram of The Sentinel system

The goal of the technical project is to design a radar-vehicle detection system that is solar-powered and provides intuitive LED warnings to the bicycle rider. This project must also meet certain design restraints and goals. The total cost of the components of the project, including prototypes not included in the final iteration, must amount to less than five hundred dollars and meet specific metrics for success. There are five metrics of success that will be tested and verified: distance sensing of an object, relative speed sensing, intuitive notifications, backup power storage, native power generation, weatherproofing, and sensing in all weather conditions.

In each of these metrics, the goal is to have the sensor provide accurate and meaningful alerts as well as withstand various weather conditions.

STS Project

As the vehicle industry grows and matures there is a growing number of features that are becoming essential for use and safety standards (*Latest car safety features*, 2021). The market for vehicles includes both automobiles and bicycles. In the automotive industry, consumer reports show that safety ranks number one in influencing car choice once the vehicle fits within a customer's desired functionality and cost bracket (Naranjo, n.d.). In early 2009, Toyota Automobile Company was considered a trusted car brand and had not had a major recall in the United States since its inception in 1933. In 2009, Toyota increased its forecasted growth by three percent, had an overall projected growth of eight percent, and was expected to sell a total of 6.45 million units in the upcoming year (Shunk, 2009). After a series of highly publicized vehicle crashes which alleged unintended acceleration of the vehicle, Toyota released its first recall of floor mats in 4.2 million vehicles on November 2nd, 2009 (Evans & Mackenzie, 2010). Later Toyota released two more recalls related to these accelerator issues, alleging other technical issues (Evans & Mackenzie, 2010).

While the failure of the network to ensure safety is largely attributed to the technical failures of various automobile designs— floor mat incursion, mechanical sticking of the accelerator pedal, and issues with the anti-lock brake in hybrids— and company’s internal coverup of the issues, this understanding fails to account for the role of the government’s oversight, human misuse, and the role of the media in the failure (*Justice department announces*, 2014). A study of the totality of the network and its associated non-human and human actors will provide a full understanding of the failure to ensure safety.

I argue that the poor design of the Toyota vehicles, internal pressures for growth, driver error, regulators succumbing to political pressure, and a frenzied media led to the large-scale recalls of Toyota vehicles and destabilized the network of Toyota's customer safety. I will use Actor Network theory to understand the interaction of human and non-human actors in the creation of the network of safety for consumers. Actor Network Theory attempts to understand the creation of networks as a coalition of human and non-human actors. In the process of creating a network, a network builder will bring these human and non-human actors together to achieve a goal (Cressman, 2009). By applying this theory, I will attempt to understand the process in which human and non-human actors worked countercurrent to the network of safety of Toyota. I will utilize primary source evidence from Toyota's press releases, lawsuits brought against Toyota, media releases about the recalls and related car crashes, and extensive documentation from various investigations, including congressional hearings involving the Secretary of Transportation.

Conclusion

A functioning solar-powered, radar-object detection system with LED alerts will be the final deliverable for the technical project discussed in this paper. Detailed testing and documentation will accompany this working demo to verify its efficacy. I will additionally explain the factors that contributed to the large-scale recall of Toyota vehicles in 2009-2011. I will use Actor Network Theory to understand the complex network of actors and how their varying interests and actions ultimately lead to the large-scale failure of Toyota to provide safe vehicles to its customers. Both the technical and STS papers will help to understand the complex actors that compete in a technological network and ultimately determine the success and safety of a project in the real social world.

Word Count: 1742

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