1. PROBLEM

1.1 Historical Introduction

The crosswalk is one of the most commonplace structures on city streets and has been for centuries. Paved roadways have been in existence since 4000 B.C.E, and crosswalks followed in 79 C.E. [1, 2, 3]. In 1868, the first illuminated crosswalk symbol was designed, but it required constant manual operation of a gas-lamp [4]. Even though crosswalk lighting technology has progressed since then, the first pedestrian fatality due to an automobile accident occurred in 1896 as a woman crossed a London street, and the number of crosswalk-related fatalities has increased every year [5, 6, 7]. More than 4000 pedestrians were killed in traffic accidents every year between 2003 and 2012, most of whom were hit at night [6].

Furthermore, most current traffic laws do not have a firm stance when it comes to the right of way of pedestrians and motorists in crosswalks [8]. Laws that regulate crosswalks without traffic control devices, called "uncontrolled crosswalks," are few, especially considering how many people use them daily. Shockingly, only "[n]ine states and the District of Columbia require motorists to stop when approaching a pedestrian in an uncontrolled crosswalk" [8]. Other states require motorists to stop only when the pedestrian is in the motorist's same lane, while some states only require the motorist to yield [8]. Even though the Federal Highway Administration is in the process of implementing more programs to bring awareness to pedestrian friendly walking environments, uncontrolled crosswalks still present a danger of accidents to many people [9].

The need for dynamic safety systems in crosswalks is clear. Motorists need to be aware of pedestrians, and research has shown that pedestrians and motorists are more alert and observant while using a dynamically flashing crosswalk than while using a traditional crosswalk [10]. This increased alertness due to adding dynamic lighting is likely to reduce the number of pedestrian-related injuries and fatalities that occur in crosswalks.

1.2 Market and Competitive Product Analysis

The Smart Crosswalk Dynamic Lighting System (SCDLS) is the only smart crosswalk system available that requires no direct pedestrian interaction and combines both a smart crosswalk and a traffic monitoring system into one unit. Most commercially available crosswalk illumination systems are either always on, push button activated, or require the installation of obtrusive posts around the crosswalk to sense pedestrians and activate the lighting system. Furthermore, the vast majority of these other systems require significant alterations to the road during installation, such as running wires under the road from an external distribution box to the system. These alterations, though effective, can be very costly and cause substantial disruption to the normal use of the road.

In addition to the high cost of the installation, most of these systems cost significant amounts of money to even obtain. For example, a company named LightGuard Systems offers a smart crosswalk unit costing $19,885 for a two-lane pedestrian system that blinks for a pre-set amount of time. Their system requires the pedestrian to push a button to activate the system, which is a step that can be easily forgotten, making the device no more useful than an uncontrolled crosswalk [11]. Finally, few systems offer smart capabilities, such as data gathering. This capability is instead often seen as a separate product altogether. One such popular traffic monitoring system often used by municipalities is the MetroCount 5600, which costs $1307. SCDLS has all of the functionality of the MetroCount system, but wirelessly transmits traffic information without the need for personnel onsite [12, 13]. Finally, the MetroCount system and other competition products require unsightly external hardware that must be locked to nearby trees and presents a tripping hazard.

The primary consumer of lighted crosswalks and traffic monitoring systems are municipalities and road maintenance companies. As such, SCDLS will be marketed towards the same clientele. Given the reduced cost and ease of installation of SCDLS compared to systems already available on the market, municipalities may be interested in implementing SCDLS in a small number of crosswalks as a case study to determine if they would be interested in wide scale adoption.

1.3 Concise Problem Statement

SCDLS seeks to prevent collisions between vehicles and pedestrians in crosswalks by lighting crosswalks in a way that alerts both motorists and pedestrians automatically. This system is an improvement over the competitors' solutions mentioned above because of its lower cost, relative ease of installation, and traffic statistics collection capabilities. The system's various sensors enable it to detect pedestrians in the crosswalk and alert pedestrians and vehicles of potential collisions. The units themselves are easy to install, requiring no destructive modifications to the road.

SCDLS is a wirelessly networked system of modules that are mounted across the road on the outer sides of the crosswalk. The modules are solar powered, eliminating the need to cut into the road to route power to them. The modules function as a single system that can detect pedestrians and alert drivers. They can also effectively measure and record both pedestrian and vehicle traffic usage for analysis by administrators.

A typical SCDLS module consists of the following: a solar panel for power harvesting, a lithium ion battery to store the power produced by the solar panel, a 2.4 GHz wireless radio for mesh networking between modules, sensors to determine if pedestrians are actively using the crosswalk, and LEDs to alert pedestrians and drivers of hazards using varying blink patterns. These components allow the devices to effectively detect pedestrians and vehicles and provide the information to other units on the crosswalk as well as to transportation authorities. In short, SCDLS is a dynamic road information mesh network that will help prevent crosswalk collisions and, ultimately, save lives.

1.4 Implications of Success

The intended result of implementing SCDLS in crosswalks is to reduce the number of pedestrian fatalities and injuries resulting from motor vehicle crashes. The benefits include the prevention of death or injury due to reduced collisions, as well as gathering data for use by municipalities. Reductions in pedestrian fatalities and injuries will cut back on the annual $99 billion spent on automotive crashes, as indicated in a 2010 CDC study [14]. Along with economic advantages, the use of the SCDLS will improve driver engagement with the road, which could in turn reduce the number of crashes resulting from distracted driving.

Municipalities could also use the data gathering capabilities of SCDLS to improve their road infrastructure. The aggregate data from all intersections in a city could help analyze pedestrian and vehicle traffic, reducing congestion and optimizing traffic routing. According to the traffic analysis company INRIX, traffic congestion has an annual economic cost of upward of $120 billion, which is "expected to increase … to $186 billion by 2030" [15]. SCDLS could help cities reduce these costs.

Large scale adoption of SCDLS could also have effects on the market for crosswalk and pedestrian safety devices. Competing crosswalk lighting devices may begin to include some of the smart features used by SCDLS, such as pedestrian sensors and traffic data gathering capabilities. Additionally, the design of SCDLS modules allows for the possibility for these to be adapted for other applications to warn drivers of road hazards. However, the primary result of large scale adoption of SCDLS will still be the protection of human life.

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