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Safety effects of exclusive and concurrent signal phasing for pedestrian crossing

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ABSTRACT

This paper describes the estimation of pedestrian crash count and vehicle interaction severity prediction models for a sample of signalized intersections in Connecticut with either concurrent or exclusive pedestrian phasing. With concurrent phasing, pedestrians cross at the same time as motor vehicle traffic in the same direction receives a green phase, while with exclusive phasing, pedestrians cross during their own phase when all motor vehicle traffic on all approaches is stopped. Pedestrians crossing at each intersection were observed and classified according to the severity of interactions with motor vehicles. Observation intersections were selected to represent both types of signal phasing while controlling for other physical characteristics. In the nonlinear mixed models for interaction severity, pedestrians crossing on the walk signal at an exclusive signal experienced lower interaction severity compared to those crossing on the green light with concurrent phasing; however, pedestrians crossing on a green light where an exclusive phase was available experienced higher interaction severity. Intersections with concurrent phasing have fewer total pedestrian crashes than those with exclusive phasing but more crashes at higher severity levels. It is recommended that exclusive pedestrian phasing only be used at locations where pedestrians are more likely to comply.

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1. Introduction

Pedestrian safety is a serious concern worldwide. In 2012, 4743 pedestrians were killed and an estimated 76,000 pedestrians were injured in traffic crashes in the United States (NHTSA, 2014) as shown in Table 1. This translates, on average, to one pedestrian fatality every two hours and an injury every seven minutes. Table 1 also shows that while total motor vehicle fatalities have decreased between 2006 and 2012, the number of pedestrian fatalities has not. In fact, pedestrian fatalities as a percentage of total roadway fatalities have increased from 11 to 15%. Overall gains in road safety over the past few years have apparently not translated into safety improvements for pedestrians, indicating the importance of focusing on improving pedestrian safety.

One important issue in pedestrian safety is safe accommodation for pedestrians crossing the road at traffic signals. There are two common types of pedestrian phasing used at signalized intersections, which for the purposes of this paper we call concurrent and exclusive phasing. A concurrent pedestrian phase allows the pedestrian to cross at the same time that the motor vehicle traffic on approaches parallel to the crosswalk receives a green indication. Pedestrians and vehicles share the same phase of the traffic signal, permitting longer uninterrupted phasing for vehicles and pedestrians. There are interactions between pedestrians and motor vehicles turning left or right across the crosswalk, but not between pedestrians and motor vehicles departing from approaches perpendicular to the crosswalk (other than right turns on red). Alternatively, an exclusive pedestrian phase stops vehicular traffic on all approaches to allow pedestrians to cross any leg of the intersection with no interaction with any vehicles (with the exception of vehicles turning right on red when permitted). Following are pertinent sections of the Connecticut Department of Transportation policies and procedures regarding pedestrians (CTDOT, 2009):

- Pedestrians must adhere to pedestrian control signals where they exist at intersections (Sec. 14-300).
- Special pedestrian street or sidewalk markings should be provided in areas with high proportions of elderly persons (Sec. 14-300a).

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Table 1
Total fatalities and pedestrian fatalities in traffic crashes.

Year	Total fatalities	Pedestrian fatalities	Percentage of total
2006	42,708	4795	11%
2007	41,259	4699	11%
2008	37,423	4414	12%
2009	33,883	4109	12%
2010	32,999	4302	13%
2011	32,479	4457	14%
2012	30,800	4743	15%

- Motorists must yield to pedestrians at the entrance to, or in, marked and unmarked crosswalks (Sec. 14-300b and Sec. 14-300c).

With concurrent pedestrian phasing, pedestrians must exercise more caution and judgment when crossing, obviously watching for possible conflicts with motor vehicles that are turning across the crosswalk. Exclusive pedestrian phasing is thus becoming popular for attempting to improve pedestrian safety, especially with senior and disabled advocacy groups (Al-Ghamdi, 2002; Zegeer et al., 1993). However, since traffic is stopped on all directions, exclusive pedestrian phasing results in longer delays for motor vehicles and pedestrians. Pedestrians often do not wait for the pedestrian phase, potentially resulting in unexpected interactions between pedestrians and motor vehicles. The requested pedestrian phase may then go unused, frustrating drivers who must then wait for the phase to run its course. This leads us to ask a basic question regarding the safety of pedestrians, “Is exclusive pedestrian phasing really safer for pedestrians?”

The primary objective of this study was to compare pedestrian crash counts and observed conflicts between pedestrians and motor vehicles between these two signal phasing types. To do this, interactions between motor vehicles and pedestrians and various physical characteristics of intersections were observed. Interactions between motor vehicles and pedestrians were classified by severity for 152 crossings at 42 signalized intersections in four cities in central Connecticut. Crash data were collected for each pedestrian crossing at these intersections over a six-year time span from January 2008 through December 2013. Finally, crash and conflict prediction models were estimated to determine the safety of pedestrians at intersections that have an exclusive pedestrian phase relative to those with concurrent pedestrian phasing. A secondary objective of this study was to investigate if pedestrian–vehicle conflicts can be a useful exposure measure for predicting pedestrian crashes, or a surrogate in place of observing pedestrian crashes.

2. Background

Considerable studies have been conducted on estimating pedestrian crash prediction models (Lee and Abdel-Aty, 2005; Al-Ghamdi, 2002; Garder, 2004; Zajac and Ivan, 2003; Lyon and Persaud, 2002; Hosseinpour et al., 2013). Some have focused on understanding pedestrian safety problems at signalized intersections with different types of pedestrian crossing behavior. Garder (1989) studied pedestrian conflicts at signalized intersections and found that exclusive pedestrian signal phasing is highly safety-beneficial at intersections with a low percentage of pedestrians walking against the red light. Bechtel et al. (2004) described implementation of a scramble signal for pedestrians in place of concurrent phasing at an intersection in California to determine whether it would improve pedestrian safety. A scramble signal includes a pedestrian phase that stops all vehicular traffic and allows pedestrians to cross an intersection in any direction, including diagonally, at the same time. The modification to scramble signal phasing at the intersection resulted in a statistically significant decrease in conflicts between pedestrians and vehicles and a statistically significant increase in pedestrian violations. Yang et al. (2005) found that exclusive pedestrian phases are effective measures to reduce conflicts between pedestrians and motor vehicles at signalized intersections. They studied the capacity of crosswalks for turning vehicles when pedestrians are passing and the pedestrian average delay under the influence of turning motor vehicles.

On another note, several researchers have investigated the importance of exposure for predicting crashes. Lyon and Persaud (2002) showed how pedestrian collision prediction models can be used for identifying intersections for safety improvement and for evaluating the effects of treatment. These models, which relate safety to pedestrian and vehicle traffic volumes, can be used to identify locations that might be targeted for treatment and to help evaluate treatment effects. Models were developed using either pedestrian or vehicular volumes or with vehicle volumes only and they found models with pedestrian volume information provide good estimation of pedestrian safety. Kim et al. (2006) developed models for pedestrian crashes as well as other collision types based on data collected from 837 motor vehicle crashes at two-lane rural road intersections in the State of Georgia, USA. For the pedestrian crash type, they found that three variables (annual average daily traffic on minor roads, shoulder width on major roads, and lighting on major roads) were statistically associated with pedestrian crashes. Shankar et al. (2003) also found that average daily traffic and intersection design variables have a statistically significant effect on pedestrian crash probabilities.

Lee and Abdel-Aty (2005) used log-linear models and found that pedestrian and driver demographic factors and road geometric, traffic and environment conditions are closely related to the frequency and injury severity of pedestrian crashes. They found that middle-age male drivers and pedestrians were correlated to more crashes than the other age and gender groups. Higher average traffic volume at intersections increases the number of pedestrian crashes; however, the rate of increase is steeper at lower values of average traffic volume. They also estimated the likelihood of pedestrian injury severity when pedestrians are involved in crashes (*i.e.*, likelihood of crash occurrence relative to a reference value) using an ordered probit model.

Agbelie and Roshandeh (2014) investigated the impacts of signal-related, traffic, and highway geometric characteristics on crash frequency at urban signalized intersections. They showed that a unit increase in the number of signal phases would increase crash frequency by 0.4. Additionally, the ratio of traffic volume on the major road to the traffic volume on the minor road was shown to unambiguously increase crash frequency. Prato et al. (2014) analyzed the risk factors associated with crash severity on low-volume rural roads, including crash characteristics, driver attributes and behavior, vehicle type, road features, environmental conditions, distance from the nearest hospital, and degree of “ruralness”. They modeled injury severity by estimating a generalized ordered logit model. The estimates and pseudoelasticities show that aggravated crash injury severity is significantly associated with involvement of vulnerable road users (*i.e.*, pedestrians, cyclists and motorcyclists).

A number of studies identified that the fatality rate of the senior pedestrian group (age 60 and over) was the highest due to their increased level of exposure to vehicle traffic (Al-Ghamdi 2002; Zegeer et al., 1993; Oxley et al., 1997). Some other studies examined the effect of population density on pedestrian crash risk. Garber and Lienau (1996) found that the fatality rate of pedestrian crashes in rural areas with lower population density was higher than in urban areas. Similarly, Zajac and Ivan (2003) found that pedestrian