TECHBRIEF

Pedestrian and Bicycle Safety

Safety Evaluation of Leading Pedestrian Intervals on Pedestrian Safety

FHWA Publication No.: FHWA-HRT-18-060

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This document is a technical summary of the Federal Highway Administration report *Safety Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety* (FHWA-HRT-18-044).

Introduction and Objective

Pedestrian safety is an important issue for the United States, with pedestrian fatalities representing approximately 16 percent of all traffic-related fatalities in 2016.[1] In recognition of the magnitude of this problem, the Federal Highway Administration (FHWA) funded a study to evaluate promising infrastructure improvements to increase pedestrian safety. Following a literature review that summarized the existing knowledge on 18 countermeasures, FHWA and a Technical Advisory Panel selected 2 as the highest priorities for detailed evaluation in this study—the provision of protected and protected/permissive left-turn phasing and the provision of leading pedestrian intervals (LPIs). The objective of the study was to develop statistically rigorous crash modification factors (CMFs) for these countermeasures using state-of-the-art analytical methods.

This TechBrief summarizes the LPI evaluation. FHWA wrote a separate TechBrief for the evaluation of protected left-turn phasing.[2] The safety effectiveness of the countermeasure was measured by crash frequency for total crashes (all severities combined), total injury crashes (K, A, B, and C injuries on the KABCO scale, where K is fatal injury, A is incapacitating injury, B is nonincapacitating injury, C is possible injury, and O is property damage only), and vehicle–pedestrian crashes (all severities combined). The analysis was conducted using an empirical Bayesian (EB) before–after study design and data from urban inter sections in three cities that had installed one

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or both of the countermeasures of interest (Chicago, IL; New York City (NYC), NY; and Charlotte, NC).

At signalized intersections equipped with pedestrian-signal indications, it is common practice for the pedestrian "walk" interval to coincide with the adjacent circular green vehicle phase, creating a potential conflict between turning vehicles and pedestrians. LPI timing typically gives pedestrians the opportunity to enter an intersection 3 to 7 s before drivers are given a green signal. This "headstart" for pedestrians allows them to establish their presence in the crosswalk and places them in a location that is more visible to drivers. The use of an LPI is expected to result in the following benefits:

- Increased visibility of crossing pedestrians.
- Reduced conflicts between pedestrians and vehicles.
- Increased likelihood of motorists yielding to pedestrians.

Figure 1 shows a pedestrian crossing an intersection with an LPI.

Literature Review

There have been several studies on the safety effects of LPIs, but only a few used crashes as the basis for safety measurement. King analyzed intersections with and without LPIs in NYC. The results indicated that LPIs had a positive effect on pedestrian safety, especially where there was a heavy concentration of turning vehicles. The treated sites experienced a 28-percent decrease in vehicle–pedestrian crash rates relative to control sites.[3] Fayish and Gross published a crash-based analysis of 10 intersections in Pennsylvania where LPIs were implemented. Results suggested a 58.7-percent reduction in vehicle–pedestrian crashes.[4]

Methodology

The research evaluated the impacts of the following two pedestrian safety improvements on crash frequency: adding either protected/permissive or protected-only phasing to one or more legs of signalized intersections and implementing LPI timing on some or all pedestrian crossings at signalized intersections. The LPI evaluation used data from 56 treated sites in Chicago, 42 treated sites in NYC, and 7 treated sites in Charlotte. The project team considered the following target crash types for the LPI evaluation:

- Total crashes (all severities combined).
- Total injury crashes (K, A, B, and C injuries).
- Vehicle–pedestrian crashes (all severities combined).

Another objective was to investigate ways in which safety effects might vary by site characteristics and strategy implementation details. An economic analysis was conducted to estimate a benefit–cost (B/C) ratio.

The project team used the EB methodology for observational before–after studies for this evaluation.[5] This methodology is considered rigorous in that it accounts for regression to the mean using a reference group of similar but untreated sites. In the process, the project team used safety performance functions (SPFs). SPFs are equations that serve to estimate the expected crash frequency of a site based on characteristics that influence crashes (e.g., traffic volumes). The use of SPFs in the EB methodology rationally normalizes traffic-volume differences between the before and after periods, accounts for time trends, and reduces the level of uncertainty in the estimates of safety effects. The methodology also provides a foundation for developing guidelines for estimating

Figure 1. Photo. Intersection with an LPI.

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the likely safety consequences of a contemplated strategy.

The project team estimated the SPFs used in the EB methodology through generalized linear modeling assuming a negative binomial error distribution, which is consistent with the state of research in developing these models. In specifying a negative binomial error structure, the project team iteratively estimated an overdispersion parameter, which is used in the EB calculations, from the model and the data.

The full report provides a detailed explanation of the methodology, including a description of how the project team calculated the estimate of safety effects for target crashes.[6]

Results

The effect of the LPI treatment on total crashes was consistent across all cities individually, with CMFs ranging from 0.84 to 0.90. The CMF for total crashes for all cities combined was 0.87, which was significant at a 95-percent confidence level.

The effect of the LPI treatment on total injury crashes was also consistent across all cities, with CMFs ranging from 0.83 to 0.86 (omitting the result from Charlotte, which was not significant). The CMF for total injury crashes for all cities combined was 0.86, which was significant at a 95-percent confidence level.

The effect on pedestrian crashes was generally beneficial, showing decreases in pedestrian crashes across all cities. The results in Chicago showed a CMF of 0.81, which was significant at a 95-percent confidence level. NYC sites showed a beneficial but lesser effect on pedestrian crashes, with a CMF of 0.91, but this result was not significant at a 95-percent confidence level. The result from Charlotte showed a decrease in pedestrian crashes, but this result was based on very few crashes and was highly insignificant. For the combined group of all cities, the CMF for pedestrian crashes was 0.87, which was significant at a 95-percent confidence level. Table 1 shows the CMFs of the LPI evaluation for all treated sites combined.

The team conducted a disaggregate analysis on Chicago data according to how the LPI timing was implemented at the treatment sites. The treatment sites were classified into two categories, one with 42 sites where an LPI was implemented at all crossings (across major and minor roads) and the other with 9 sites where an LPI was implemented only for crossings across the minor road (parallel to the major road). For total crashes and total injury crashes, the CMFs were lower for the second category, but a statistical test for homogeneity showed that the differences in the CMFs were not statistically significant.

The project team also explored the potential for developing crash modification functions that would relate the effect of major site characteristics on the effectiveness of an LPI. However, the low magnitude of the sample size available led to convergence issues, and the team was unable to develop any meaningful functions for any of the studied crash types.

Economic Analysis

The project team conducted an economic analysis to determine the potential B/C ratio for an LPI. Since the main objective of the study was the safety evaluation of vehicle–pedestrian crashes, the economic analysis focused on those crashes. The project team used the statistically significant reduction in vehicle–pedestrian crashes for the three cities combined as the benefit for this treatment strategy. On the cost side, the analysis was based on cost information obtained from the cities involved in this project. The analysis conservatively assumed a useful service life for safety benefits of 20 yr and a real discount rate of 7 percent.[7] With this information, the capital recovery factor was determined to be 0.094 for all intersections, giving annual costs of $112.80 if only the basic LPI adjustment was made.

The project team calculated that the aggregate 2016 unit cost for vehicle–pedestrian crashes at urban intersections was $414,993. The total crash reduction was 10.549 for all intersections. Considering the number of treated intersections (105), this resulted in an average savings of 0.1005 crash per

Table 1. CMFs for LPI evaluation—all cities combined (105 treatment sites).

Crash Type	Estimate of CMF*	Standard Error
Total crashes (all severities combined)	0.87	0.02
Total injury crashes (KABC)	0.86	0.03
Vehicle–pedestrian crashes (all severities)	0.87	0.05

*CMFs in this table are statistically significant at a 95-percent confidence level.

intersection per yr. By multiplying the crash reduction per site-year by the cost of a crash, the project team determined the annual dollar benefit from reduced crashes to be $41,707 per intersection.

The U.S. Department of Transportation has recommended conducting a sensitivity analysis by assuming values of a statistical life of 0.56 and 1.40 times the recommended 2016 value.[8] The resulting B/C ratio ranged from 1:207 to 1:517 if only the basic LPI adjustment was made. These results suggest that the strategy, even with conservative assumptions on cost, service life, and the value of a statistical life, can be cost effective for reducing pedestrian crashes at signalized intersections.

Summary and Conclusions

This study examined, with a particular focus on pedestrian safety, the effect of protected and protected/permissive left-turn phasing and LPIs on the safety of signalized intersections. The LPI evaluation used data from Chicago, NYC, and Charlotte. The effect of LPIs on total crashes for all cities combined was a CMF of 0.87, which was significant at a 95-percent confidence level. The effect on total injury crashes for all cities combined was a CMF of 0.86, which was significant at a 95-percent confidence level. The effect on pedestrian crashes was generally beneficial, showing decreases in pedestrian crashes across all cities. The results in Chicago showed a CMF of 0.81, which was significant at a 95-percent confidence level. NYC sites showed a beneficial but lesser effect on pedestrian crashes, with a CMF of 0.91, but this result was not significant at a 95-percent confidence level. The result from Charlotte showed a decrease in pedestrian crashes, but this result was highly unreliable given the large standard error and very small sample of crashes. For the combined group of all cities, the CMF for pedestrian crashes was 0.87, which was significant at a 95-percent confidence level. This was shown to lead to a potential B/C ratio ranging from 1:207 to 1:517.

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Key Words—Leading pedestrian interval, pedestrian, safety improvements, empirical Bayesian

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SEPTEMBER 2018

FHWA-HRT-18-060

HRDS-30/09-18(WEB)E