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Evaluating Permitted/Protected Versus Protected Left-turn Signals in Louisiana

INTRODUCTION

Provision of left-turn signals at signalized intersections is necessary to prevent delays and crashes for left-turning traffic; nonetheless, depending on its type, a left-turn signal may adversely affect operations. As part of measures to manage left-turning vehicles at signalized intersections, three types of signal configurations are dominant in Louisiana: permitted (P), protected only (PO), and protected/permitted left-turn phase (PPLT). There has recently been the flashing yellow arrow signal (FYA), which does not have a different signal phase from the PPLT, but a different display.

The DOTD's traffic signal manual sets guidelines for PO or PPLT left-turn movements. For instance, the manual's guidance for PO phasing is based on inadequate left-turn sight distances, excessive street widths and speeds of opposing traffic, inadequate geometry, number of left-turn crashes, and the presence of two or more left-turn lanes. When none of the conditions for PO are met, PPLT phasing may be considered, but the safety benefits of PO are higher, while the delays at PPLT are greater. Consequently, to select a left-turn signal type to install, there is a need to balance the safety benefits of an intersection signal configuration with its operational benefits.

a. Charging cameras *b. Mounting camera on a pole*

c. Camera in the field *d. Snapshot from the camera*

Figure 1. Installation of cameras for video data

OBJECTIVE

The primary objective of this project was to study the safety and operation performance of different left-turn phases at intersections along with their geometric features, as described in the DOTD Traffic Signal Manual, to develop guidance on when it is appropriate to install each left-turn signal type. PO, PPLT, and FYA left-turn phases were considered for evaluation.

SCOPE

The study was limited to only signalized intersections with uniform PO and PPLT left-turn phases at all approaches in Louisiana. Left-turn crash data were collected at 166 sampled intersections for safety analysis. However, for the operational analysis, only 28 sample intersections from the 166 (13 with PO, 6 with PPLT, and 9 with FYA left-turn phases) were used due to limited time, available equipment, and human resources. Since intersection approaches with at least one separate left-turn lane were selected, signals with only a P left-turn phase were not considered because of the small sample size. Additionally, since FYA left-turn phase intersections are only operational in District 3 in Louisiana since 2017, the data for FYA intersections were collected from only that district.

METHODOLOGY

Insights were drawn from a nationwide qualitative survey and an analysis of safety and operational data from sampled left-turn signals. The nationwide survey solicited information on the current practices of left-turn operation in the jurisdiction of other state departments of transportation (DOTs) and suggestions on left-turn signal design and operation.

The crash data from January 1, 2015, to December 31, 2019, were extracted from the DOTD crash-1 database and were used for the safety analysis. A total of 14,115 crashes, excluding pedestrian crashes, were extracted, which included 13,278 at PO and PPLT intersections and 837 at FYA intersections. From these, 1,325 crashes were filtered and used for general analysis. In the general crash analysis, a decision tree, for instance, was used to explore the possible association of left-turn crashes with crash attributes

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in addition to with and without evaluations. Further, all left-turn crashes at intersections were used to develop a crash modification factor (CMF) for different left-turn phases using the 13,278 crashes at PO and PPLT intersections. For the operational analysis, two-day video data was collected from the 72 approaches of 28 intersections to estimate delays, using the queue-count technique discussed in HCM 6. The video collection took more than three months and involved charging the cameras for days, installing them at the required intersections as shown in Figure 1, extracting the video data from the camera to provide enough memory space, and recharging the camera for the next data collection schedule. This task was labor-intensive and challenging, especially when the traffic volume was very high and the weather was unfavorable, thus only 28 intersections were selected for the data collection.

CONCLUSIONS

The nationwide survey revealed that more than 60% of the respondent DOTs use three-section vertical left-turn signal arrangements for the P and PO left-turn phase, respectively, while for the PPLT, the majority use a four-section arrangement. From the survey, 65% of the responding DOTs indicated FYA as the preferred left-turn phase in operation, followed by PPLT with 16%. Additionally, 81% of the responding DOTs preferred PO signalized intersections over PPLT and FYA in terms of safety performance.

From the decision tree, PO intersection signals are preferred over PPLT at intersections with a left-turn crash rate of 8 or more crashes every five years. In addition, factors such as the presence of a negative turning lane offset, a raised median, two or more left-turning lanes, speed limits of 45 mph or greater, and higher AADT required the selection of PO over a PPLT left-turn phase.

The safety analysis further revealed that the number of left-turn crashes at PO signaled intersections in Louisiana was about 50% less than that at PPLT signaled intersections. From the estimation, the crashes per year at the PO signalized intersection are 1.2, compared to 2.29 at the PPLT intersection. Further, the estimation showed the crash rate at FYA intersections is lower than that at PO signalized intersections; nonetheless, the limited number of sampled FYA intersections and lower AADT at the FYA intersections make this comparison less robust. Also, while no injury crashes (O) dominate the type of crashes at all signal intersection types, only 2% of the crashes at FYA intersections were fatal compared to 0.26% at PPLT intersections. Further, no fatal crashes were recorded at PO signaled intersections. The before-and-after crash analysis for FYA signalized intersections also showed around a 17% reduction in left-turn crashes, in three years, after converting from PPLT.

The CMF for PO over the PPLT phase revealed a decrease in all severity levels of crashes for both total and left-turn crashes, as shown in Table 1. For instance, the CMF revealed that PO signaled intersections could reduce left-turn fatal and severe crashes by 25.5% compared to PPLT intersections; though, for PDO crashes, there was no significant difference between the performance of the two intersections. The analysis also shows that PO could reduce all severity levels of crashes by more than 50% in the case of only left-turn crashes.

Model	Total crashes	CMF	Standard Error	Change in Crashes	95% Confidence Interval	
Model I	All Severity Levels	0.906	0.103	9.40% reduction	0.704	1.108
Model II	Injury + Fatal Crashes	0.745	0.106	25.5% reduction	0.537	0.953
Model III	PDO Crashes	0.981	0.107	1.90% reduction	0.771	1.191
Model	**Left-turn crashes**	**CMF**	**Standard Error**	**Change in Crashes**	**95% Confidence Interval**	
Model I	All Severity Levels	0.334	0.198	66.6% reduction	-0.054	0.722
Model II	Injury + Fatal Crashes	0.239	0.188	76.1% reduction	-0.129	0.607
Model III	PDO Crashes	0.452	0.184	54.8% reduction	0.091	0.813

Table 1. Crash modification factors (CMF)

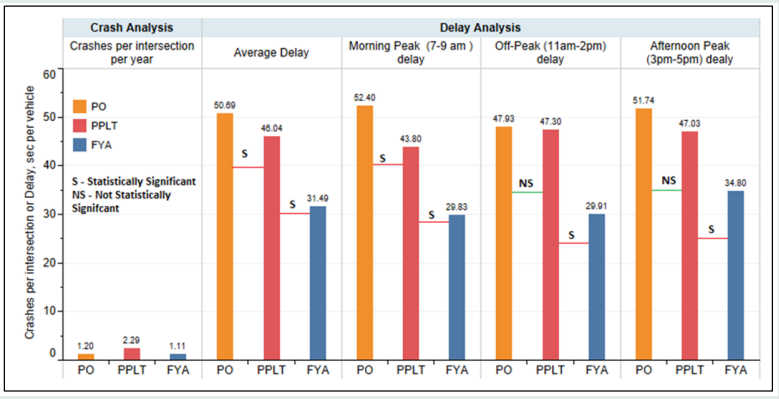

Figure 2. Comparison of delay and left-turn crashes

The analysis of the video data collected at the 28 signalized intersections shows a mean delay of 50.69, 46.04, and 31.49 seconds/vehicle at PO, PPLT, and FYA signalized intersections, respectively. Comparing the delays at the different times of the day, only the delay during the morning peak hour at PO was significantly higher than at PPLT; otherwise, PO and PPLT delays at off-peak and afternoon peak hours were not significantly different, as shown in Figure 2. The delays at FYA were significantly lower compared to PO and PPLT at all times of the day. The lower delay at FYA intersections supports the preference for FYA in terms of operational performance over other signalized intersection types by most DOTs as was revealed from the survey.

In summary, the study's insights indicate that, in Louisiana, PO signalized intersections perform better than PPLT in terms of operation and safety benefits. Also, compared to PO and PPLT, the installed FYA signalized intersections in Louisiana have performed better in terms of safety and operations benefits, though the number and locations of FYA intersections sites in Louisiana and the limited traffic data from these sites compared to other signal types do not support the generalization of this finding.

RECOMMENDATION

It is recommended that a reevaluation of the safety and operational performance of FYA signalized intersection in Louisiana is carried out with adequate data to conclude the findings about FYA intersections in this study.