Channelized Right-Turn Lanes at Signalized Intersections: A Review of Practice

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ABSTRACT

This paper presents an investigation into the current practice regarding the use of channelized right-turn lanes at signalized intersections, the type of traffic control used, and the safety experience of highway agencies. The study involved literature review and a practice survey, which was distributed to state and local agencies in the United States. The literature review revealed the overall lack of knowledge about the operational and safety aspects of channelized right-turn lanes explaining, to a large extent, the lack of guidance in practice. Survey results suggest the heavy reliance on engineering judgment by highway agencies in the use of channelized right-turn lanes and the selection of traffic control. Further, results confirmed a general perception in practice about of the safety benefits of signal control at channelized right-turn lanes, despite the fact that such benefits were not supported by studies or statistics. The study emphasized the dire need for further research on the operational and safety aspects of this right-turn treatment at intersections.

Keywords: right-turn, signalized intersections, channelization, survey

INTRODUCTION

Turning movements have a determining effect on the safety and operations at signalized intersections. Therefore, various treatments of turning movements have been the focus of attention of those involved in the design and operations of intersection signal control.

Right-turn movement at signalized intersections is subject to multiple treatments. Lower volume intersections typically involve a shared lane for the through and right-turning traffic. As traffic level increases including the right-turning traffic, the need for providing an exclusive right-turn lane also increases. Providing exclusive turning lanes at signalized intersections has become common practice at new intersections as well as in many improvement and upgrade projects at existing older intersections. For right-turn movement, exclusive turning lanes are mostly added parallel to through lanes and continue to the stop bar at the main intersection approach. In fewer instances, the right-turn movement is channelized from the rest of traffic on the main intersection approach using painted or curbed islands. In this treatment, right-turn traffic is channelized through a curved alignment to access the crossing street without the need to proceed to the approach stop bar or use the intersection area. Channelized right-turn lanes (CRTL) using raised (curbed) islands is the focus of this investigation. An illustration of a CRTL without deceleration or acceleration lanes is provided in Figure 1.

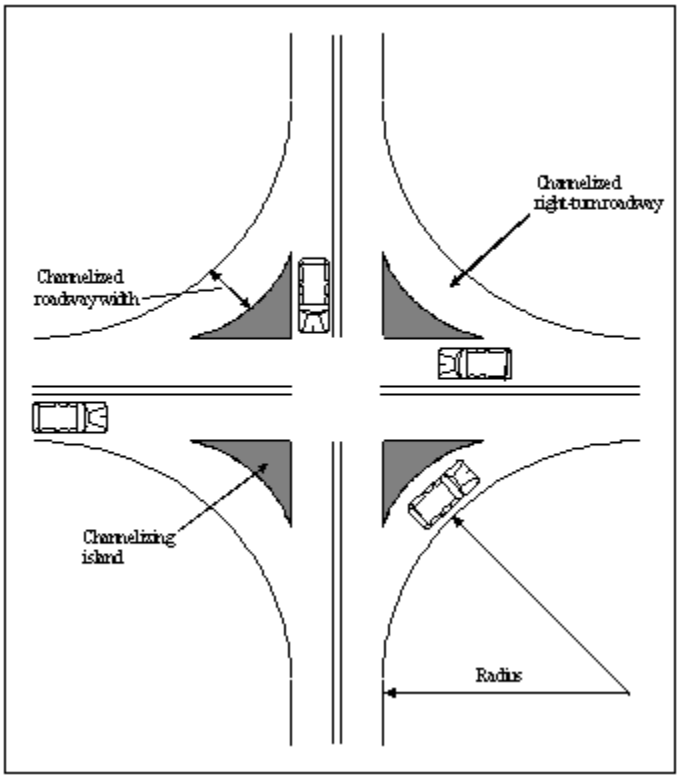

FIGURE 1 Channelized right-turn lane. ***(1)***

Among the benefits of channelizing right-turning movements are increased capacity, reduced delay and number of stops, improved safety particularly at skewed intersections, and a better accommodation of heavy vehicles by using larger turning radii without unnecessarily increasing the pavement area *(2*). Other benefits may include reducing right turn queues and lowering emissions *(3).*In the case of channelization using curbed islands, it also provides an area of refuge for pedestrians and a location for traffic control devices (2). For CRTL using curbed islands, access control for right turning vehicles is typically treated in practice using yield control, stop sign control, traffic signals, or

no traffic control device (4). Further, channelized right turn lanes may be used with either deceleration lanes, acceleration lanes or both, depending on vehicle speeds, traffic volumes, percentage of trucks or the type of service provided (5). The design principles presented in the AASHTO Policy on Geometric Design for Highways and Streets (5) indicate that the type of traffic control used at the cross street influences the desirable angle of intersection between the right-turn roadway and the cross street.

The main disadvantage of this right-turn treatment is the motorists' higher speeds, which could be a concern for pedestrian safety (3). In many ways, it may not be the design of the channelized roadway, but the type of traffic control at an intersection with a channelized right turn, that most directly affects the safe navigation of the intersection by pedestrians and bicyclists (1).

BACKGROUND

The subject of right turn movements has not been as much a focus as left-turn lanes, as the right-turn movements involve fewer conflicts (6). This lack of attention was evident in the initial literature review conducted in the course of this study. While the limitation in the guidance applies to all aspects of CRTL at intersections, it is particularly true for the selection of the most appropriate type of traffic control. Drivers expect and, to a degree, anticipate certain geometric and operational situations at intersections. The channelization and traffic control used at an intersection should, as a minimum, avoid violating driver expectations, and should desirably reinforce these expectations (1).

The Manual on Uniform Traffic Control Devices **(**MUTCD**)** defines the standards used by road managers nationwide to install and maintain traffic control devices on all streets and highways (2). The MUTCD addresses traffic signal needs studies and the general application of yield and stop control but guidelines specific to channelized right turning lanes are not provided. It is worthy to mention the MUTCD has been adopted by all states; 23 states with complete conformance, 21 with state supplements and 6 with substantial conformance (7).

The AASHTO Policy on Geometric Design of Highways and Streets provides guidance on the design of channelized right turns under the topic of turning roadways (5). The policy describes the geometric design elements and criteria for turning roadways but does not give guidance as to when this type of treatment should be used.

The Intersection Channelization Design Guide (NCHRP 279) recommends using CRTL for the purposes of safe pedestrian refuge, safe merging for right turn movements operating under yield control or no control, and to separate right-turn merge conflicts (8). It provides the most extensive discussion of considerations found for right-turn lanes but offers no quantifiable guidelines (6). The Traffic Engineering Handbook (9) refers the user to the Intersection Channelization Design Guide for a detailed description of the techniques that have proven effective and lists nine principles of intersection channelization. It also provides warrants for turning lanes based on peak hour volumes.

Channelized right-turn lanes are often designed for unimpeded vehicular movements, leaving pedestrians vulnerable to high speeds. Channelized right-turn lane intersections designed to accommodate safe pedestrian crossings using tight curb radii and shorter crossing distances can be less problematic to pedestrians (10). The AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities recommends turning lanes to be kept as narrow as the turning path of the design vehicle will allow and be kept as close to 90 degrees as the effective turning radius will allow (11).

The main reasons for providing channelized right turns are to increase vehicular capacity at an intersection and to reduce delay incurred by motorists. However, no existing data and no established methodology are available to directly compare the operational performance of urban intersections with and without channelized right turn lanes (1). Several other studies in the literature have addressed other topics such as the effect of skewness of CRTL intersections on drivers performance (12), free right-turn movement risk probabilities (13), traffic volumes to justify a right-turn lane at an intersection approach (14), and the effects of right turn movements on traffic operations (15, 16).

RESEARCH MOTIVATION

The limited guidance in practice concerning the use of CRTL and the selection of traffic control controlling access to the crossing roadway was the main impetus for the current study. The main objective of the study is to review the current state of practice as related to the use of channelized right-turning lanes at signalized intersections, procedures and guidelines in place, and agencies experience with this treatment from safety and operational perspectives. The aim is to gain a better understanding of the way this right-turn treatment is used in practice with particular emphasis on the selection of traffic control devices intended for vehicles entering the channelized lanes. The study presented in this paper is part of an ongoing project to evaluate the effectiveness of various traffic controls at channelized right-turn lanes.

SURVEY OF HIGHWAY AGENCIES

The state of practice was examined regarding various aspects of the use of the CRTL at signalized intersections. An online questionnaire survey was sent to two groups of highway agencies requesting their participation in the study. The first group involved all the 50 state departments of transportations (DOTs) while the second group involved 109 cities and municipalities across the United States. Prospective participants at those agencies were identified using the AASHTO subcommittee on traffic engineering and the ITE traffic engineering council. A total of 37 state DOTs answered the questionnaire representing a 74-percent response rate. On the other hand, 38 local agencies answered the questionnaire in the second group representing approximately a 34-percent response rate. It is assumed that the lack of the respective expertise at small local agencies may partly explain the much lower response rate for the second group. The survey addressed the following aspects of the current practice in using CRTL at signalized intersections:

1. The use of in intersection design;
2. The selection of traffic control devices for access control at the location where the channelized right-turn lane meets the crossing roadway; and
3. Agency experience with safety and operations for this type of treatment.

It should be noted one state agency and seven local agencies provided contact information without answering the questionnaire, and therefore were excluded from the analysis. Survey responses were analyzed and results are provided in the following sections.

The Use of Channelized Right-Turn Lanes at Signalized Intersections

Although the national design documents and tools provide some high-level guidelines for the design of channelized right-turn lanes, guidance for the use of CRTL remains limited in general. Specifically, no detailed procedures for making this determination are available to the practitioners involved in the planning and design of at-grade intersections. Given the implications of this treatment on safety and operations, such a determination should be based on well-established design procedures or a reliable analysis of those safety and operational impacts.

Survey participants were asked whether the CRTL are used by their agencies as part of intersection design. The majority of agencies reported the use of this treatment with around 95-percent of state DOTs and 90-percent of local agencies. Reasons for not using this treatment as reported by some agencies include snow plowing and the right-of-way required by channelized right-turn lanes.

One agency noted that CRTL are used heavily in roundabout designs but there has not been a benefit to implementing this treatment at signalized intersections.

When asked about the guidelines for the use of channelized right turning lanes in intersection design, 62-percent of the state agencies that use channelized right turning lanes reported using national guidelines versus 50-percent state guidelines. Moreover, 74-percent reported the use of engineering judgment while only 9-prercent reported the use of other guidelines. The corresponding percentages for local agencies were 50-percent national guidelines, 33-percent state guidelines, 73-percent engineering judgment and 16-percent other guidelines. The higher percentage of agencies that use engineering judgment besides other guidelines may be partly due to the lack of detailed procedures and guidelines for this type of intersection treatment. Figure 2 shows the questionnaire results regarding the guidelines followed by state and local agencies.

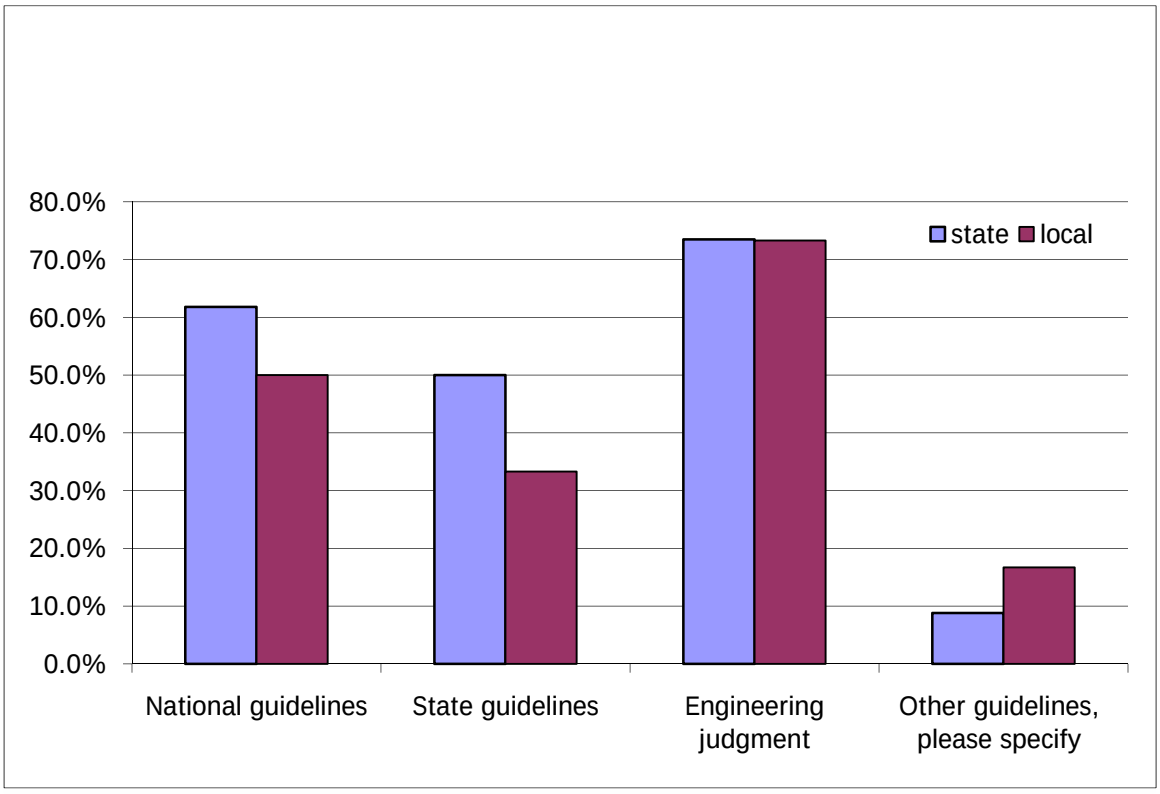

FIGURE 2 Guidelines used by state and local agencies for the use of CRTL.

One state agency specified NCHRP 457 (17) as a source of guidelines for the use of CRTL in intersection design while another state agency reported the use of "basic intersection design tools" for the same purpose without providing specifics about the design document.

One local agency has implemented their own master thoroughfare plan and design standard based on AASHTO and National guidelines while another local agency has adopted its own guidelines as part of its access management plan which follows typical design standards. Further, another agency reported the use of context sensitive solution (CSS) guidelines as a source of guidance in making the determination on the use of CRTL at signalized intersections.

As for the major considerations for use of CRTL at signalized intersections, high right-turn volume was the most frequent consideration reported by both state and local agencies (88 and 96 percent respectively). For state agencies, oblique angles between intersecting roadways was reported as the second most frequent consideration followed by vehicular crashes and pedestrian crashes respectively. For local agencies, vehicular crashes was reported as the second most frequent

considerations followed by the oblique angle between intersecting roadways and pedestrian crashes respectively. The summary of responses for state and local agencies is shown in Figure 3.

Among other major considerations stated by state and local agencies are presence of bicycle facilities, corridor coordination improvement, pedestrian traffic, vehicle mix, and location for installation of signal heads and other street hardware.

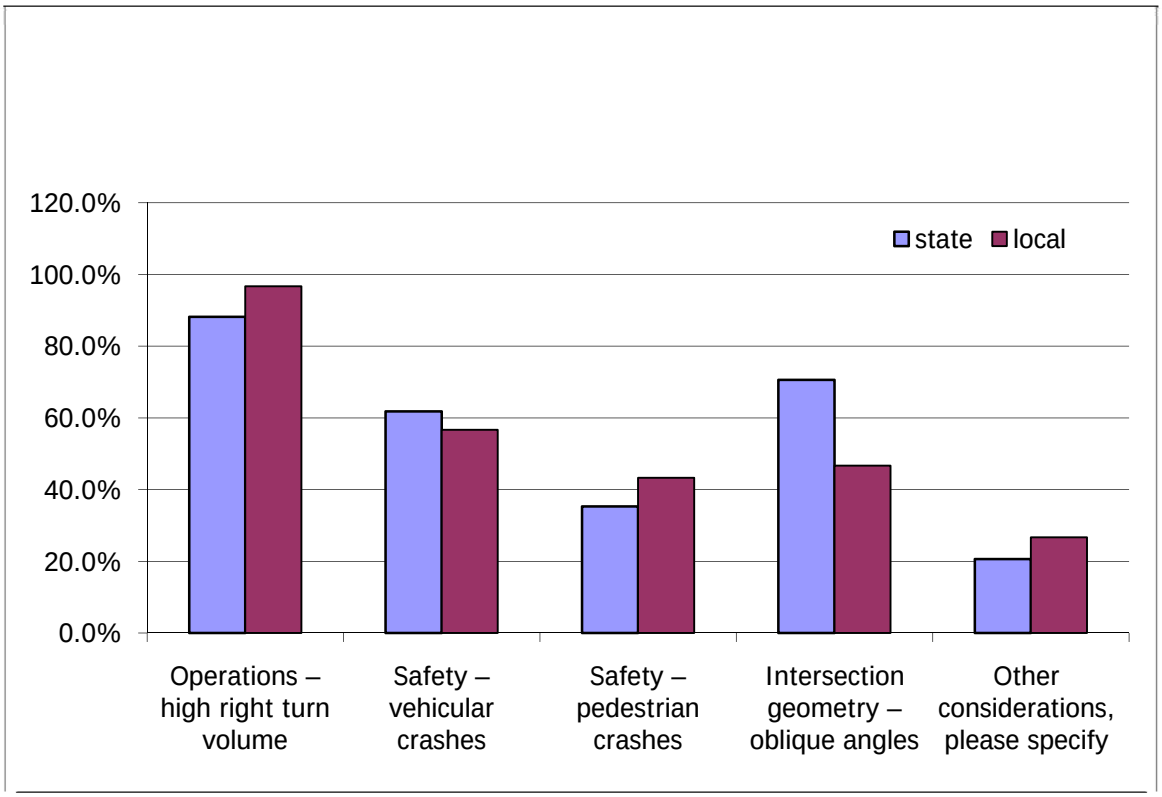

FIGURE 3 Considerations for the use of CRTL.

Access Control at Channelized Right-Turn Lanes

Various types of traffic control devices may be used to control access at CRTL including yield control, stop control, traffic signals, and no control. The selection of the most appropriate type of traffic control is of utmost importance for the safety and operations of this right-turn treatment.

Highway agencies were asked about the guidelines they use in selecting the traffic control devices which control access to the intersecting roadway. Around two thirds of state DOTs reported the use of national guidelines versus 56-percent among local agencies. The use of state guidelines was reported by around 44-percent of state agencies and 33-percent of local agencies. Engineering judgment was the most frequently reported source of guidance by state and local agencies (67-percent and 83-percent respectively). Figure 4 shows the questionnaire results for the guidelines used by state and local agencies in the selection of traffic control at CRTL.

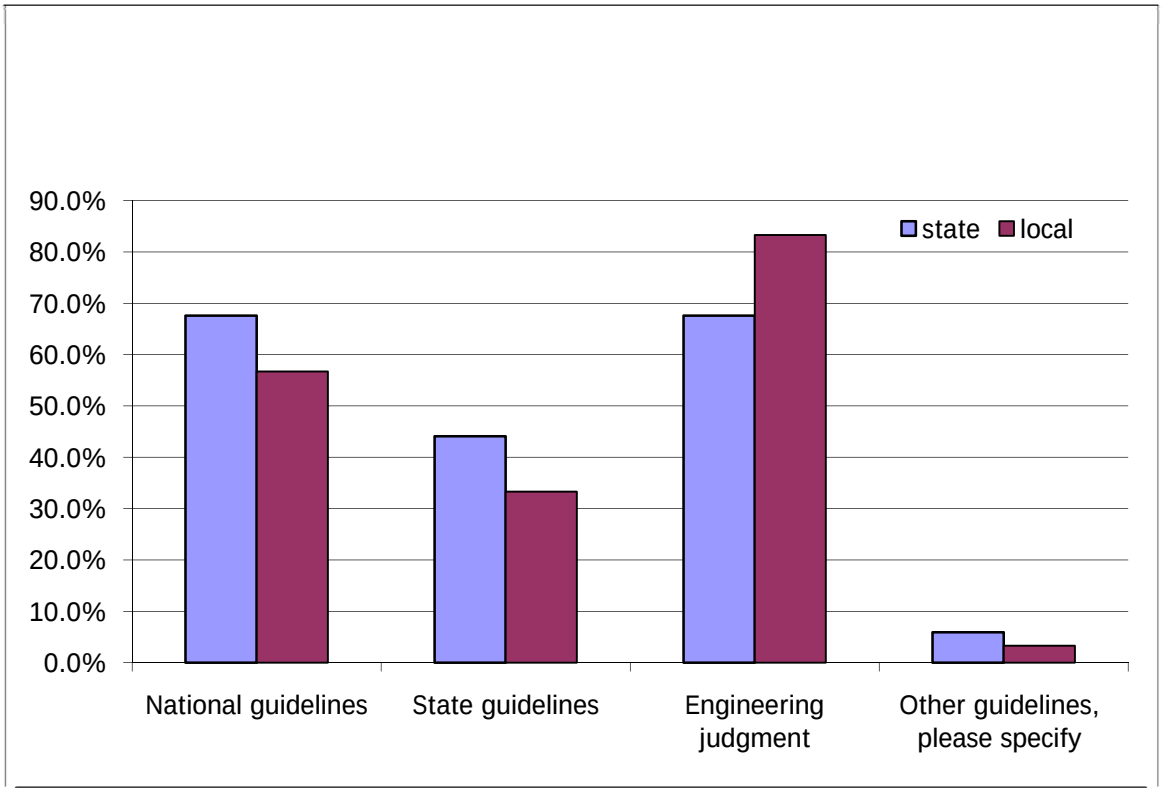

FIGURE 4 Guidelines used by state and local agencies for traffic control at CRTL.

The fact that 50-percent of the state DOTs use the MUTCD in complete conformance, and that the selection of traffic control for CRTL is not addressed in this document leaves no surprise that engineering judgment is used extensively for traffic control selection by most highway agencies.

The comments made by survey participants generally confirm the common practice, i.e. the yield control being the most appropriate traffic control at this particular intersection treatment. However, it was interesting to get a comment from one state agency stating, "Typically if we get to a point where the channelized right turn is problematic, it would most likely be studied for being placed under signal control…"

The survey also included a question about the major considerations used by highway agencies in the selection of traffic control at CRTL at signalized intersections. Vehicular traffic was the most frequently reported consideration by both state and local agencies (88- and 97-percent respectively). Vehicular crashes was the second most reported consideration by state agencies followed by pedestrian traffic and pedestrian crashes respectively. On the other hand, pedestrian traffic was the second most frequently reported consideration by local agencies followed by vehicular crashes and pedestrian crashes respectively. The summary of responses for state and local agencies is shown in Figure 5.

Other considerations provided by survey participants included bicycle activity, vehicular traffic character and composition, available sight distance, speed, and geometric layout considerations.

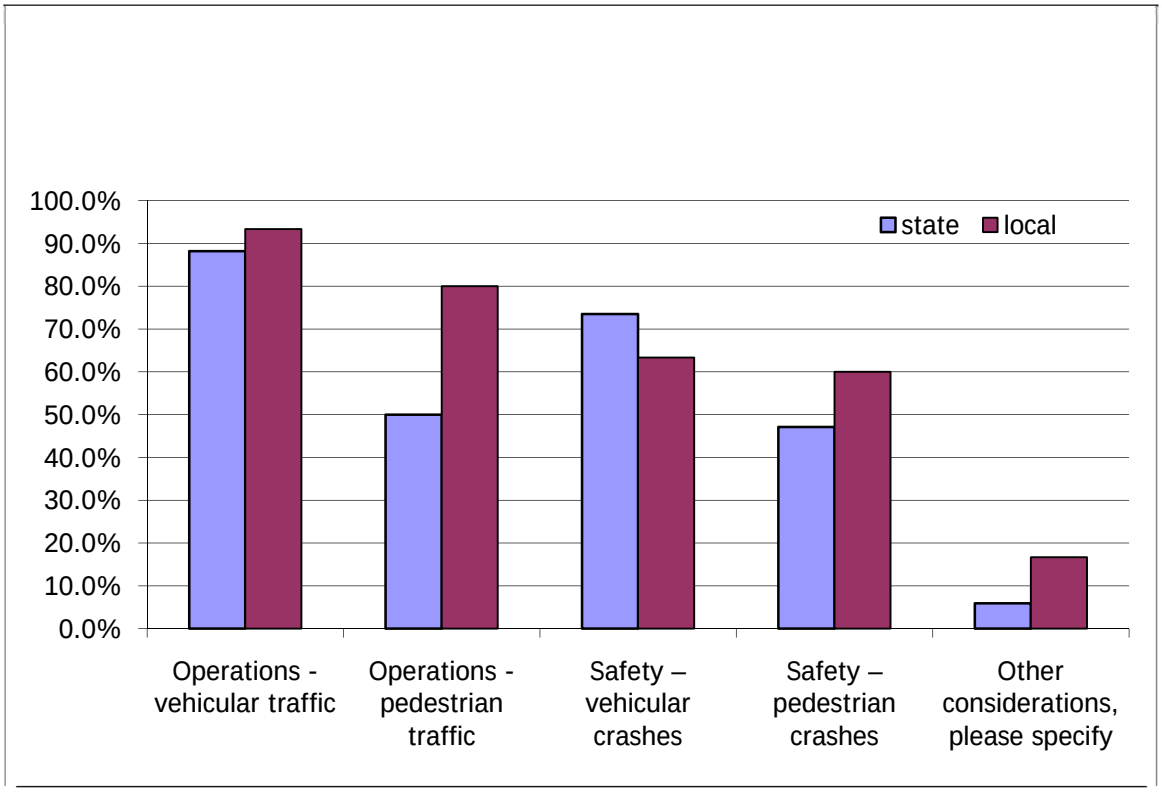

FIGURE 5 Considerations for traffic control device selection at CRTL.

One question in the survey was more specific in asking highway agencies whether they use formal warrants for the installation of exclusive signal control at channelized right-turn lanes. Around 12-percent of state and 27-percent of local highway agencies reported the use of such warrants in installing signal control at channelized right-turn lanes. These percentages are very low given the fact that similar warrants are always required when traffic signals are installed at unsignalized intersections. This attests to the fact that exclusive warrants for signal installation at CRTL do not exist at the national level.

Among other considerations reported by highway agencies for using signal control at this intersection treatment are high crash rates, simulation operational studies, and engineering judgement.

Safety Experience

Safety is a critical aspect when it comes to the use of CRTL at signalized intersections. Channelization separate traffic movements and minimize conflict between different movements at an intersection approach. On the other hand, in most instances, adding a channelized right-turn lane to an intersection layout creates a merge area where right turning vehicles have to merge with the mainline traffic of the crossing roadway. Drivers, especially older drivers, may not be comfortable with the higher speed of the turn when trying to turn their head to look upstream while making the merging decision. Some drivers may prefer to slow or stop at the end of the lane. This behavior could result in rear-end

collisions, as more familiar drivers who are more comfortable with the higher speed may not anticipate the stopped vehicles (18). Furthermore, pedestrian safety could be an issue given the free-flow right-turn movement using the channelized lane and the extra pedestrian crossing created by this lane.

It was therefore important to examine the practice for the safety experience of this intersection treatment. It is worthy to mention here that responses to this part of the survey were based in most instances on personal observations, opinions, and perceptions. The lack of relevant data or studies was mentioned explicitly several times in the comments provided by survey respondents. This partly explains the high percentage of survey participants who chose not to answer the survey questions related to the agency safety experience.

When asked about their safety experience with CRTL at signalized intersections, around 49-percent of state agencies and 67-percent of local agencies believed that this treatment improves vehicular safety. On the other hand, much lower percentages were reported for state and local agencies who believe that this treatment decreases vehicular safety (15-percent and 3-percent respectively). It is obvious that the majority of highway agencies perceive CRTL at signalized intersections to improve vehicular safety. Relative to vehicular safety, there is less agreement among agencies in regards to pedestrians safety, as fewer agencies thought of this treatment to improve pedestrians safety (30-percent of state and 37-percent of local agencies) and more agencies thought of this treatment to decrease pedestrian safety (9-percent of state and 27-percent of local agencies). The summary of responses for state and local agencies is shown in Figure 6.

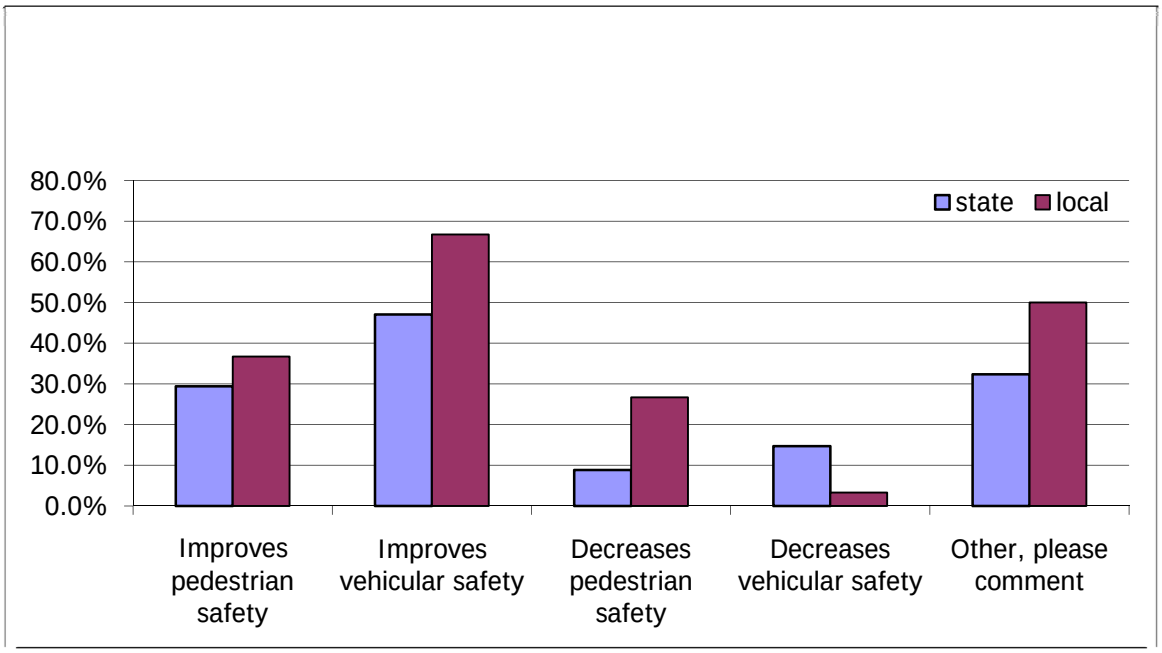

FIGURE 6 Agency saftey expereince with the use of CRTL.

Many comments were made in response to this question which provided additional insights into the agency experience or perception of the safety and operational benefits of this intersection treatment. One agency stated that they occasionally receive complaints from pedestrians about right-turning vehicles not yielding to pedestrians. Another agency stated that the use of CRTL increases vehicle speeds, and in an effort to maintain pedestrians' safety, a speed hump was installed at one of their intersections. While there was overwhelming agreement among participants about the operational

benefits of channelized right-turn lanes, numerous comments were made that safety data and studies simply does not exist to answer this question. This shows the need for future research into the safety aspects of CRTL at signalized intersections.

Another important issue concerned with the safety at CRTL is the type of traffic control devices used to control access to the crossing roadway. Survey participants were asked to evaluate their agency's safety experience with the two most-common traffic controls used; yield control and signal control.

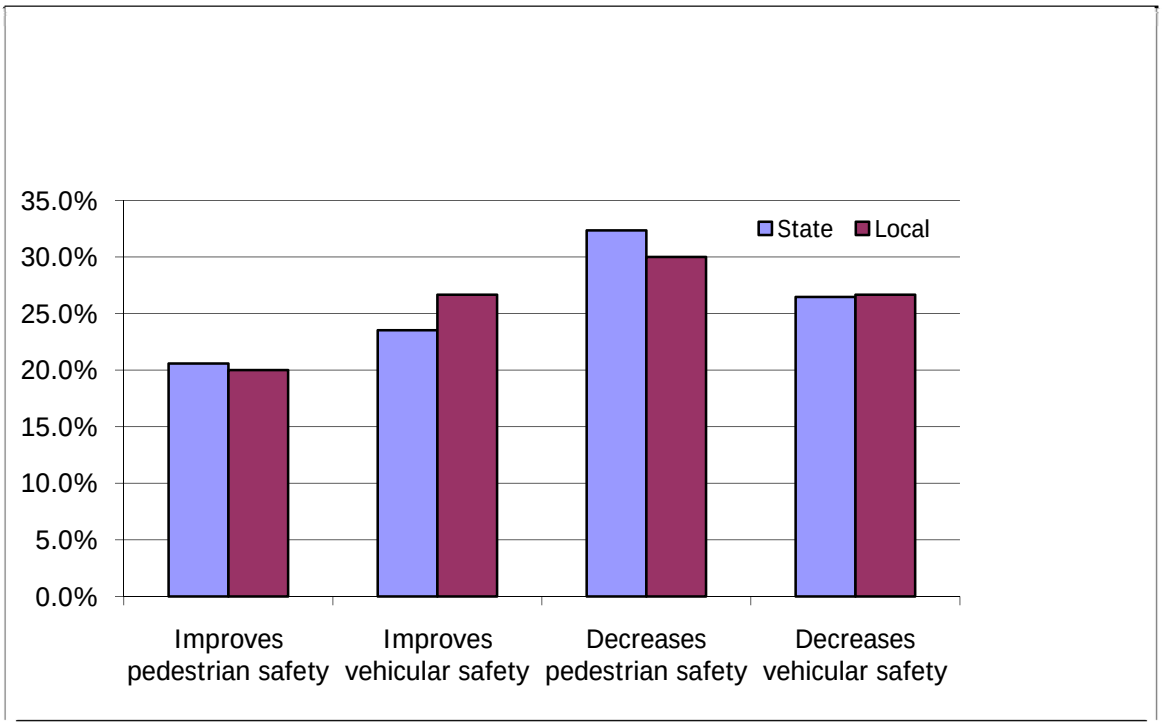

FIGURE 7 Agency saftey expereince with the use of yield signs at CRTL.

In regards to yield control, there is a relatively high agreement among state and local agencies concerning its safety effect at CRTL as shown in Figure 7. In general, more agencies (32-percent of state and 30-percent of local agencies) perceive yield control to decrease pedestrian safety than those who percieve it otherwise (around 20-percent of both state and local agencies). As for vehicular safety, the numbers are more evenly split. Specifically, around 27-perecnt of state and local agencies percieve yield control to decrease vehicular safety versus 27-percent of local and 24-percent of state agencies that perceive it otherwise.

Figure 8 shows the agency safety experience with signal control at channelized right-turn lanes. Again, there is a high level of agreement among state and local agencies about the safety aspects of using signalization to control access at channelized right-turn lanes. It is interesting to note that most of the respondents in the two groups targeted in this study thought of signal control as contributing to pedestrian and vehicular safety. Specifically, around 55-percent of state and 53-percent of local agencies thought that signal control improves pedestrian safety versus 44-percent of state and 40-percent of local agency respondents who thought of signal control as improving vehicular safety. A few respondents (4 total) in the two groups thought of signal control to have negative safety impacts on pedestrian and vehicular traffic.

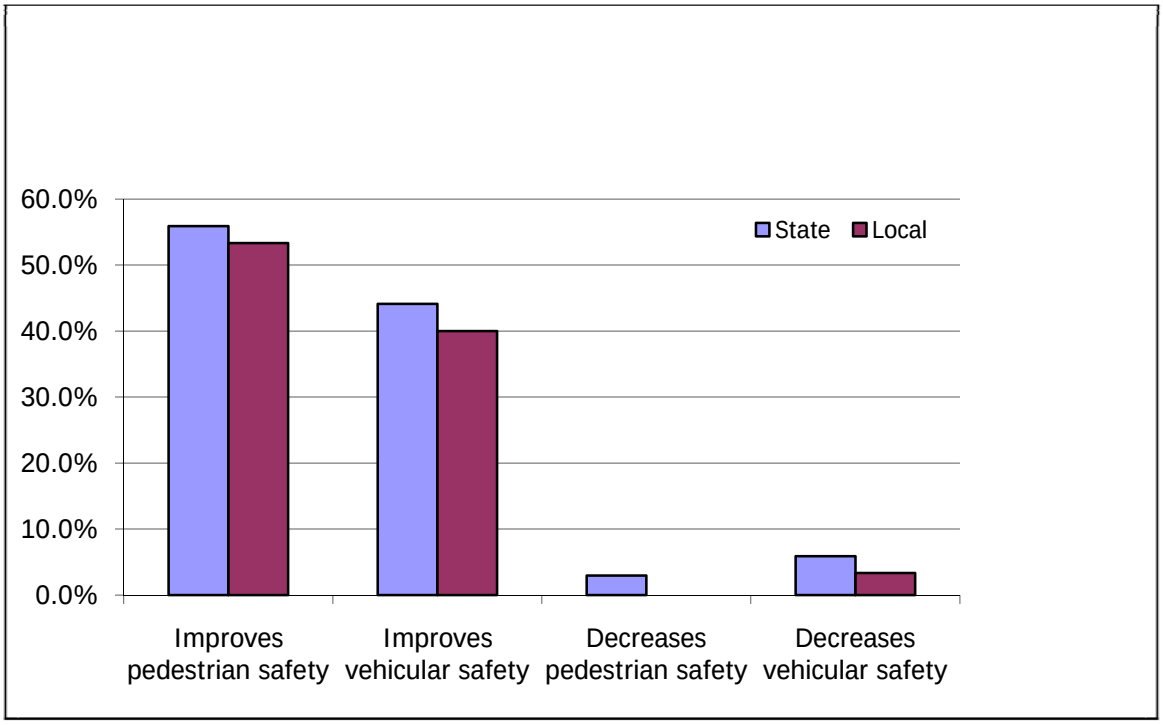

FIGURE 8 Agency saftey expereince with the use of signals at CRTL.

SUMMARY OF FINDINGS

A questionnaire survey was conducted to review the current practice concerning channelized right turning lanes at signalized intersections. The survey was sent out to the 50 state DOTs and more than a hundred cities and municipalities across the United States. The three major focus areas in the survey were the use of CRTL for intersection design; the selection of traffic control devices for access control at the crossing roadway; and agency experience with safety and operations for this type of treatment. The most important findings of the practice survey are summarized below:

- The decision on using CRTL and the type of traffic control heavily relies on engineering judgment by most state and local agencies. This is somewhat expected given the limited guidance available in the national design documents and standards used by most agencies.
- The lack of guidance is particularly true for the selection of traffic control, as only 12-percent of state and 27-percent of local agencies reported the use of warrant studies in installing signal control at channelized right-turn lanes.
- There is an overwhelming perception by most state and local agencies about the safety benefits of signal control at channelized right-turn lanes. This notion is not supported by studies or statistics showing these benefits.
- Vehicular traffic operation was the most prevalent consideration for using the CRTL and for the selection of traffic control.

The literature review revealed lack of guidance in general, and a focus on the volume warrants, and delay benefits of right-turning lanes. This was confirmed with most agencies selecting operations

as the most common consideration for the use of CRTL. However, capacity and delay benefits may well be affected when signals are used in controlling access to the crossing roadway. The survey also revealed the lack of safety data concerning the CRTL and the type of control used. This data is essential in developing guidelines for the use of this treatment as well as for the selection of the most appropriate control type at channelized right-turn lanes. As such, further research is needed on the operational and safety aspects of using this treatment and the type of traffic control used.

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