Developing Design Guidelines for Right-Turn Slip Lanes

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ABSTRACT

Texas crash statistics indicate that intersections present safety challenges for crossing pedestrians and must be designed to account for their needs. One intersection configuration that may be problematic for pedestrians is a right-turn slip lane as it presents a crossing location outside of the physical area of the intersection. As such, the Texas Department of Transportation (TxDOT) sought development of new guidelines for these roadway elements. A three-step work plan was implemented to complete this effort, including a review of available literature on the design and operation of right-turn slip lanes, focus group meetings with TxDOT representatives, and production of design guidelines that accommodate mobility as well as pedestrian and bicyclist safety. The new construction guidance provided for urban and suburban roadways is inspired by the City of Ottawa's "urban smart channel" design that incorporates a sharp angle of entry into the cross street and delineates a narrow turning path for passenger cars. This design promotes slower turn speeds, improves driver comfort, and enhances visibility of the pedestrian crossing location. The design includes a crosswalk located in the middle of the channelized roadway that is perpendicular to the turning roadway. The rural design guidance mainly centers on facilitating mobility through the slip lane, as regular pedestrian activity is not typical at rural intersections. The design guidelines also include information on retrofitting treatments, targeting issues commonly found at right-turn slip lanes.

INTRODUCTION

Right-turn slip lanes are designated pathways that facilitate higher-speed right turns. According to Zeeger et al. (*1*), right-turn slip lanes are characterized by the use of a channelizing island to delineate the right-turn path. Channelization is typically established by depressed, painted, or raised islands. Right-turn slip lanes are recommended at intersections where there are large volumes of right-turning vehicles that incur long delays due to the intersection geometry and traffic control (*2*). Accordingly, right-turn slip lanes are used to increase intersection capacity by separating right-turning traffic from through traffic and consequently reducing vehicular delays.

However, despite the advantages channelized right-turn lanes offer, they can be problematic, especially for pedestrians. As drivers navigate the turning roadway and approach the downstream end, they are often preoccupied with finding gaps in crossing traffic to complete the turn. As a result, their attention is typically focused on the oncoming vehicles and they may not notice a pedestrian intending to cross the right-turn lane. Hence, these lanes must be designed with the safety of pedestrians, including those with vision impairments, in mind.

According to the Crash Records Information System (CRIS) records retrieved from the Texas Department of Transportation (TxDOT) for the years 2007 to 2012, there is a recent upward trend in total number of crashes, including pedestrian-related incidents (*3*). The crash statistics indicate that intersections present safety challenges for crossing pedestrians and must be designed to account for the presence of pedestrians and their needs. One intersection configuration that may be problematic for pedestrians is a right-turn slip lane as it presents a crossing location outside of the physical area of the intersection. This separation facilitates larger curb radii and consequently, higher turning speeds. Typically the crossing location along the turning roadway is essentially uncontrolled; therefore, it is important to produce guidelines for the proper design of right-turn slip lanes that take pedestrian safety into account.

Accordingly, new design guidelines for the application of right-turn slip lanes were developed for the state of Texas to accommodate motorists, pedestrians, and bicyclists. The different elements of right-turn slip lanes were evaluated based on the available literature on slip lane design and operation, as well as the feedback received during focus group meetings held with TxDOT personnel. The guidelines reflect the findings from this process. The following paper presents a summary of the literature review, focus group meetings, and proposed guidance on right-turn slip lane design.

LITERATURE REVIEW

The first task was to review the available guidance on the design of right-turn slip lanes as well as identify key issues with their implementation. The literature review provided the research team with supporting material for developing design guidelines and recommendations for right-turn slip lanes. It helped identify key issues with their implementation and characterize individual design elements.

In many applications, right-turn slip lanes accommodate high turning speeds, result in low visibility of pedestrians, and thus do not provide for safe pedestrian crossings. An improved method for designing right-turn lanes adopts slow turning speeds and a 55–70 degree angle between merging vehicle flows (*4*). This allows for good visibility of pedestrians. A number of design recommendations for right-turn slip lanes have been published, including considerations for pedestrians in the ITE report on designing urban roadways for walkable communities (*5*).

This includes recommendations for limiting turning speeds, providing accessible channelizing islands, and installing proper signing. Generally, the use of right-turn slip lanes can be justified for accommodating larger design vehicles and high turning volumes to improve capacity at intersections and reduce delays associated with traffic control. While these benefits may be clearly demonstrated, there are a number of safety considerations.

Safety

Installation of right-turn slip lanes are expected to reduce rear-end collisions involving right-turning and through vehicles on the same approach, as the speed differential between the two is reduced. However, rear-end and sideswipe crashes on the crossing approach may increase as a result of merging traffic. Furthermore, depending on the turning radius, channelized right-turn lanes may encourage higher speeds, which may increase the potential for crashes involving pedestrians.

In general, channelization has been found to decrease right-turn crashes by 50 percent and all intersection crashes by 25 percent (*6*). As part of NCHRP Project 3-89, a safety analysis was conducted using data from seven years of motor-vehicle and pedestrian crashes at 103 four-leg intersections in Toronto, Ontario, Canada (*7*). The safety of intersection approaches with right-turn slip lanes, conventional right-turn lanes, and shared through/right-turn lanes were compared. The annual crash predictions for channelized right-turn lanes and shared through/right-turn lanes were found to be similar, and 70–80 percent lower than those for conventional right-turn lanes.

In a review of crash statistics for Texas, intersections were found to account for almost a third of all pedestrian-related crashes, with an increase in the number of injuries, fatalities, and overall crashes since the year 2010 (*3*). In particular, the number of pedestrian-related crashes caused by right-turning vehicles has increased from 299 crashes in 2010 to 341 in 2012. Overall, the crash statistics imply that intersections are difficult for pedestrians to cross and must be designed with pedestrian safety in mind. Moreover, the statistics support the need to produce consistent design guidelines for right-turn slip lanes that improve the overall level of safety for pedestrians while curtailing the adverse effects of a ‘free’ right turn.

Geometric Design

A number of geometric elements have been identified pertaining to the design of right-turn slip lanes and their impact on motorists, pedestrians, and bicyclists. These include the following: angle of entry into the cross street, turning radius/angle, pedestrian crossing treatment, channelizing island, traffic control, lighting, bike lanes, lane width, and auxiliary lanes. Many of these elements have been described with design considerations in national guidelines, such as the AASHTO *A Policy on Geometric Design of Highways and Streets (Green Book)* and *Guide for the Planning, Design and Operation of Pedestrian Facilities*, as well as state guidance, including TxDOT’s *Roadway Design Manual*, *Access Management Manual*, and *Texas Manual on Uniform Traffic Control Devices (TMUTCD).*

Right-turn slip lanes allow for high speed turning movements. Therefore, to reduce the threat to pedestrians, the right-turn lane width must be kept to a minimum, though enough to accommodate the design vehicle. Also, the angle of entry into the cross street must be as close as feasible to 90 degrees (*8*). The size of the median/crossing island should be directly related to the expected volume of pedestrians and bicyclists expected to use these roadway facilities. As the activity increases, so should the size of these roadway features (*8*).

To make intersections more accommodating for pedestrians, the TxDOT *Roadway Design Manual* recommends properly placed features such as curb ramps, crosswalks, and pedestrian refuge islands. The manual states that refuge islands should be at least 6 ft wide, with ramps 5 ft wide by 6 ft long and a 5 ft by 5 ft landing area to accommodate pedestrian passage, including those in wheelchairs (*9*). Islands need to be adequate in size to draw the motorist's attention. As such, the AASHTO *Green Book* recommends the minimum size for a curbed corner island to be 50 square ft for urban intersections and 75 square ft for rural intersections (*10*). However, a minimum threshold of 100 square ft is preferable for both settings. Additional requirements for grades, cross slopes, dimensions, and locations of sidewalks, crosswalks, curb ramps, and landing areas relative to intersections and driveways are provided in the manual and applicable standards.

Deceleration lanes are used as a means of safe deceleration of right-turning vehicles outside the through lanes before they reach the crosswalk. Also, deceleration lanes provide storage for right-turning vehicles and subsequently reduce their impact on through traffic (*7*). The TxDOT *Access Management Manual* identifies auxiliary lane thresholds for driveway locations based on right-turn volumes (*11*). According to NCHRP Report 780, and based on NCHRP Project 3-89, acceleration lanes make it more difficult for pedestrians with visual impairments to cross the turning roadway (*7, 12*). Therefore, these features should be used with careful consideration of site characteristics.

The TMUTCD provides guidance on the placement of pavement markings and signs for channelized right-turn lanes at stop-controlled intersections (as shown in Figure 1). The manual provides additional information regarding the delineation of channelizing islands, including the use of retroreflective material for delineating the alignment of the lane separation on the approach, as well as the edge of the island for travel at night or when conditions limit visibility (*13*). Curbed islands may be difficult to spot at night if lighting is insufficient. Therefore, where curbed islands are used, the intersection should have "fixed-source lighting or appropriate delineation such as curb-top reflectors" (*10*).

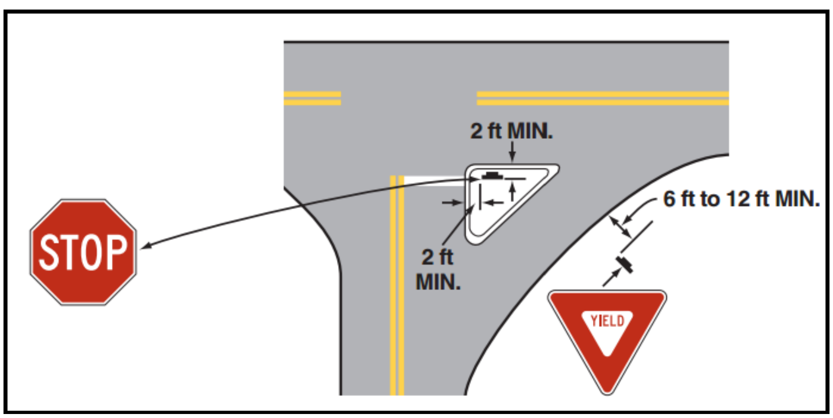

Figure 1. Signage Placement at Right-Turn Slip Lanes (*13*)

Concerning pedestrian crossing facilities, longitudinal crosswalk markings are found to be more visible to drivers from afar. A combination of longitudinal and transverse markings is the most visible to drivers (*4*). A survey of state and local highway agencies for NCHRP Project

3-72 revealed that a majority of the responding highway agencies prefer the placement of crosswalks in the center of a right-turn slip lane and perpendicular to the turning roadway (*14*). This corresponds to recommendations in the NCHRP 3-89 project report (*7*).

There is additional support for supplemental treatments, such as raised crosswalks, additional crosswalk warning signs, pedestrian detection devices, and flashing beacons. A project in Boulder, Colorado was used to investigate intersection treatments that improve pedestrian safety and would encourage active transportation, including rumble strips, in-pavement lights, post-mounted lights, additional signing, and raised pedestrian crossings (*15*). Overall, the treatments were found to increase crosswalk compliance by 34 to 77 percent. In particular, pedestrian-activated, post-mounted lights were found to be the most effective treatment while rumble strips were the least effective.

State-of-the-Practice

Through the literature review, the research team identified a number of right-turn slip lane designs currently implemented in Maryland, North Carolina, Florida, Ottawa, and Texas. Figure 2 illustrates placement of design elements with respect to an intersection with a free right turn and channelizing island (right-turn slip lane) in accordance with TxDOT Design Division Standard PED-12A. It should be noted that the standard identifies placement of the crosswalk at the center of the island with a directional curb ramp from the sidewalk and a combination island ramp.

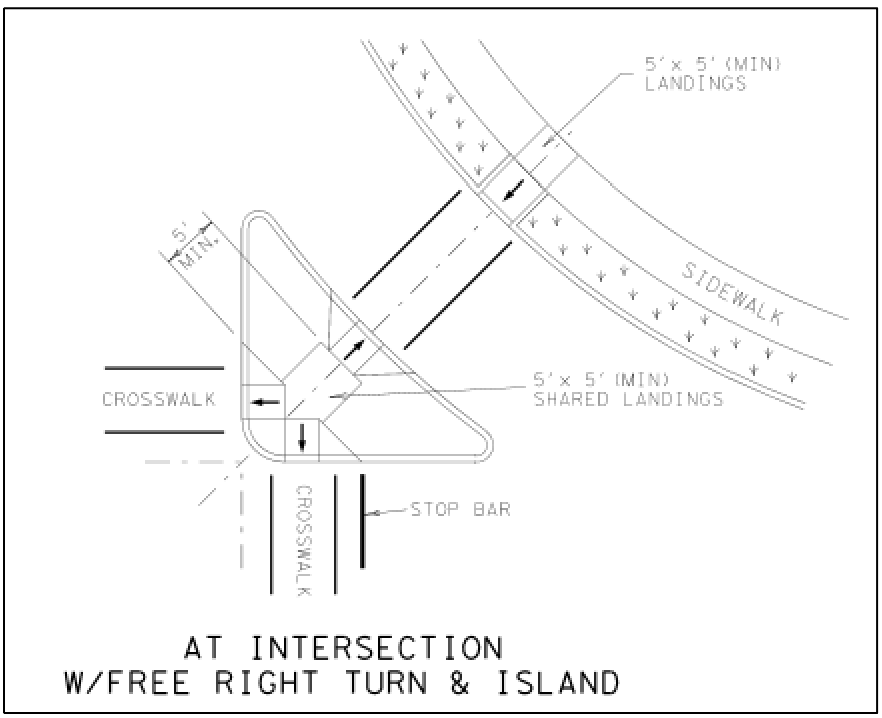

Figure 2. Channelized Right-Turn Lane Configuration [typ.] per TxDOT Standard PED-12A (*16*)

Figure 3 shows the right-turn slip lane design from the Maryland State Highway Administration. This design features a sharp angle of entry into the cross street, a compound curb radius (to accommodate the turning of large vehicles), a crosswalk located at the center of the right-turn slip lane and perpendicular to the direction of travel (with a ladder pattern striping), an elongated island tail along the approach street (facilitating larger radii at the beginning of the turn and improving the visibility of pedestrians to motorists), no auxiliary lanes, a narrower turn lane, and bike lane markings. The North Carolina Pedestrian Master Plan was found to borrow from the Maryland concept and enhances the design by adding the option of a raised crosswalk across the turning roadway.

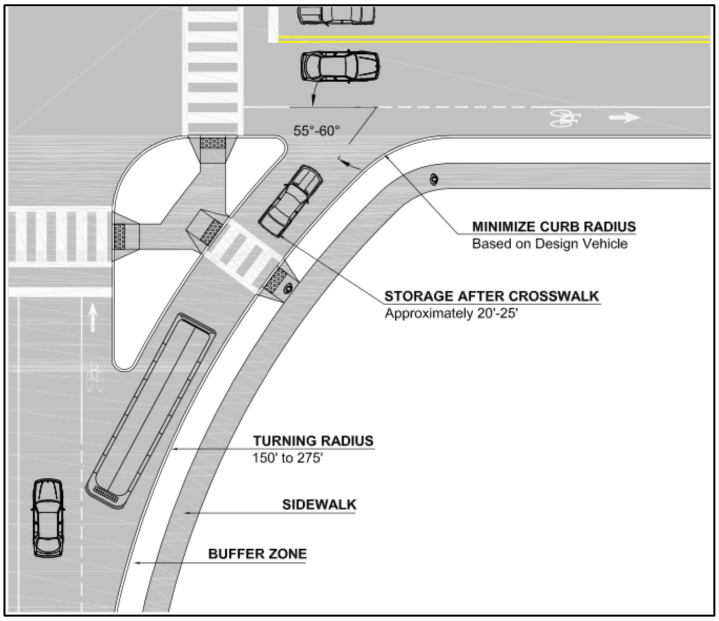

Figure 3. Right-Turn Slip Lane Design (*17*)

Figure 4 shows the right-turn slip lane design adopted by the Florida DOT. This design entails a centrally located crosswalk with a perpendicular orientation and ladder-patterned markings; storage space for one passenger vehicle downstream of the crosswalk; an adequately sized island to accommodate pedestrians; an expanded island using pavement markings (chevron pattern); no bike lane markings; a narrower lane for smaller vehicles that still accommodates the turning movement of larger vehicles (using pavement markings); a lower angle with the cross street; a simple curb radius; an elongated island tail along approach street using only pavement markings; and a deceleration lane.

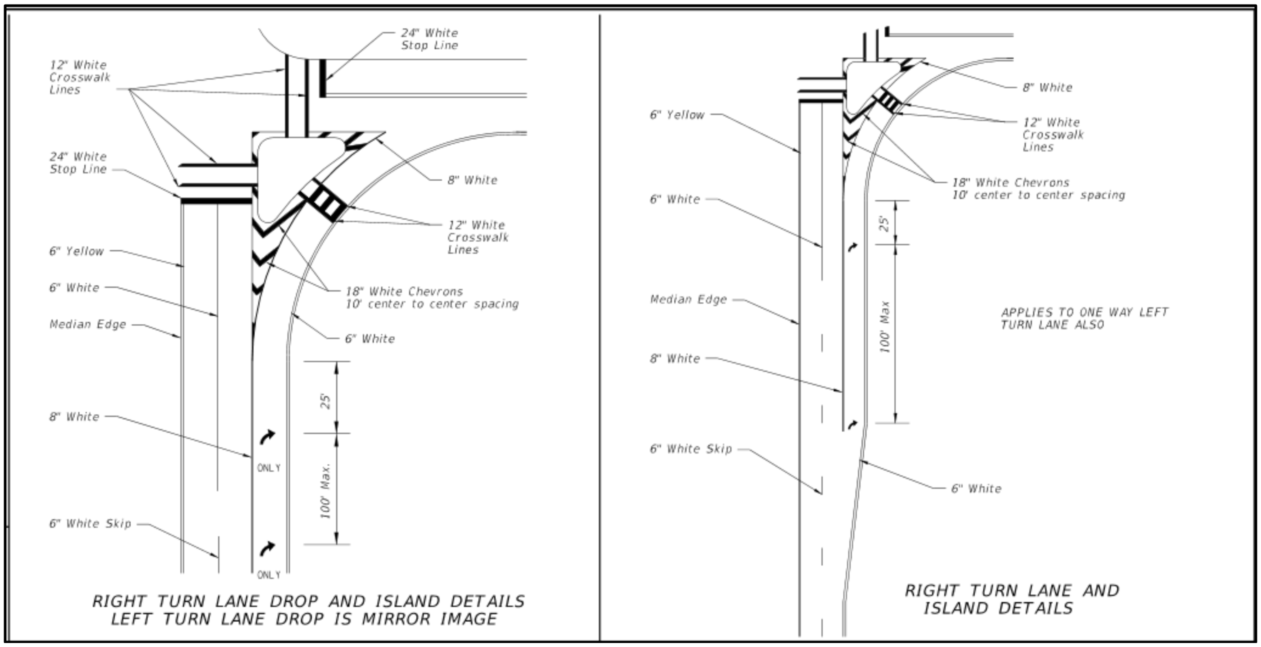

Figure 4. Florida DOT Standard "17346 - Special Marking Areas" (*18*)

Figure 5 shows the right-turn slip lane design as per the urban smart channel design from the City of Ottawa, Canada. This design includes a central crosswalk location that is perpendicular to the turning roadway and marked with transverse striping; a slightly extended corner pork-chop island on the approach street using pavement markings (chevron pattern) facilitating a larger radius at the beginning of the turn that improves pedestrian visibility; bike lane and markings; an expanded curb radius using pavement markings (diagonal crosshatch) creating a higher intersection angle with the cross street (~70^0); a compound curb radius; and an optional deceleration lane (contributing to improved pedestrian visibility).

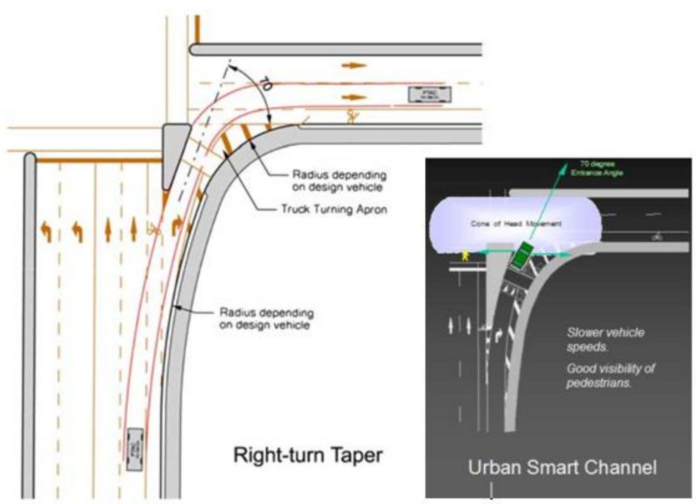

Figure 5. Detailed Pedestrian-Friendly Channelized Right-Turn Lane Using Urban Smart Channel Design (*19*)

The main advantage of this design is that it modifies the channelizing island in such a way as to place the crosswalk in unobstructed view of the driver as they enter the right turn, not during or after (*20*). The City of Ottawa also states that this design does not require motorists to turn their head significantly to spot oncoming traffic and, thus, improves driver comfort. Moreover, this design improves safety by forcing the merge at an angle of approximately 70^0. Studies have shown that this angle of entry forces vehicles to slow down (~ 6 kph) enough to improve safety without interfering with traffic flow. The City notes that contractors are indifferent whether the design is an urban smart channel or a conventional channel as the implementation of the former does not cost more than the latter—the two designs are the same except for the radius markings in the urban smart channel design. The City states that the urban smart channel design may have a smaller footprint than the conventional channel design and, thus, requires less right-of-way acquisition. Accordingly, this design may actually save on implementation costs (*20*).

Upon completion of the literature review, the safety implications, geometric design considerations, and state-of-the-practice strategies were compiled and summarized for dissemination to TxDOT personnel. This was completed through submittal of a technical memo along with a series of focus group meetings hosted by the research team.

FOCUS GROUP MEETINGS

The second phase of the research process entailed conducting two focus group sessions in order to determine the feasibility and effectiveness of the practices identified through the literature review. The research team used the focus group meetings to discuss the identified practices with TxDOT personnel experienced with their design, implementation, and assessment. The first focus group meeting of 13 attendees (9 from TxDOT) involved discussion of the numerous design elements, pedestrian accommodations, and subsequent problems encountered at right-turn slip lane locations, along with potential scenarios that could facilitate the mobility and safety of both vehicles and pedestrians.

The research team discussed a number of elements related to the design of a right-turn slip lane. These elements include radius of turn, angle of entry into the cross street, lane width, auxiliary lanes, crosswalk placement and orientation, type of traffic control, and methods to increase crosswalk compliance. Focus group attendees were then shown examples of right-turn slip lanes in Texas and asked to discuss their strengths and weaknesses. This discussion prompted identification of preliminary guidance for consideration concerning urban, suburban, and rural intersection locations. Other elements not covered in the literature review were identified, including sign and pole placement, drainage, and treatments for existing facilities.

A primary take-away from the first meeting was that a concerted effort should be invested in the examination of potential retrofitting treatments for existing right-turn slip lanes. It was revealed that problems persist at many existing locations and that feasible, cost-effective solutions to problems involving pedestrian safety are needed. Accordingly, the research team reviewed additional literature and design concepts from other agencies to compile information on potential retrofitting treatments. Subsequently, a second focus group meeting was held by the research team to follow up with the TxDOT participants and share the latest findings, including recommendations for installing treatments to improve pedestrian safety at existing intersections.

The participants of the first meeting were invited back for a second focus group discussion concentrated on potential retrofitting solutions for existing intersections. The meeting included presentation of proceedings from a Transportation Research Board (TRB) webinar, potential retrofitting solutions found in the literature as well as proposed by the research team, and the right-turn slip lane designs currently implemented in Maryland, North Carolina, Florida, Ottawa, and Texas.

The research team first shed light on the proceedings of a TRB webinar discussing recent findings from several ongoing research projects. This webinar emphasized the need to account for pedestrians at intersections, especially at roundabouts and channelized right-turn lanes. The webinar highlighted pedestrians with visual impairments and how they go about crossing difficult intersections. The webinar highlighted research investigating use of HAWK signals (with audible devices), rectangular rapid flashing beacons, and raised crosswalks at roundabouts and right-turn slip lanes, with an emphasis on the safety of visually impaired pedestrians.

The focus group participants agreed that transverse crosswalk markings provided needed guidance for the visually and/or cognitively impaired. The attendees stated that, if longitudinal markings are to be used (for better motorist visibility), transverse markings should be used as well to accommodate all pedestrians. They also agreed that hybrid beacons are effective for pedestrian safety.

Subsequent to the overview of pedestrian crossing treatments, the discussion turned to potential retrofitting treatments for right-turn slip lanes. With regards to pedestrians, this turn lane configuration typically provides refuge and, consequently, reduces pedestrian crossing distance by allowing them to cross the intersection in two stages. However, right-turn slip lanes encourage high motorist speeds and create conflict between motorists and pedestrians. Accordingly, it was determined that they can and, in some cases, should be modified to reduce conflict potential and improve pedestrian safety.

In addition, some right-turn slip lanes are found in areas with little or no pedestrian activity and are thus designed to accommodate motor vehicles only. However, as land use changes over time, pedestrian activity may be expected in the future. Accordingly, focus group attendees emphasized that right-turn slip lanes should be designed in such a way to facilitate future retrofits. The goals of retrofitting were defined by the focus group as follows:

1. Slow turning vehicles
2. Shorten crossing distances
3. Improve visibility of pedestrians
4. Improve crosswalk compliance
5. Improve overall safety (crash reduction)

A number of potential treatments were identified and discussed by the focus group. Those treatments included addition/reconstruction of the channelizing island, modification of the pedestrian pathway, enhancement of pedestrian crossing treatments, addition of sound or rumble strips, adjustment to roadside features, addition/removal of auxiliary lanes, and slip lane removal. It was determined that a number of treatments could be considered depending on observed operational conditions and site characteristics, and the research team was instructed to draft guidance on retrofitting treatments in addition to new construction guidelines for right-turn slip lanes.

The research team then presented slip lane designs from different agencies, including those identified in the literature review. The focus group participants discussed pros and cons of the different designs and special considerations for implementation of individual design elements. Some treatments supported by the group included a sharper angle of entry with the cross street, delineation of a narrower turning path for passenger vehicles, and additional crosswalk striping. Ultimately, the Ottawa urban smart channel concept was preferred over all others by the focus group participants. Based on the feedback from TxDOT personnel, the research team developed design guidance for right-turn slip lanes, including retrofitting treatment recommendations, applicable schematics, and design standard drawings.

DESIGN GUIDELINES

The literature review and feedback received during the focus group sessions supported development of design guidelines for both new construction and retrofitting projects and were proposed to provide design solutions that facilitate mobility at intersections, as well as safety for all modes. The guidance for new construction was divided into urban, suburban, and rural designs for consistency with the format of the TxDOT *Roadway Design Manual*.

The proposed urban/suburban design, again based on the City of Ottawa's urban smart channel concept, recommends designing the curb radius of the right-turn slip lane for a large design vehicle to accommodate the turning movements of trucks and buses while delineating a narrower path for passenger cars by striping a smaller inner turn radius. This design is intended to promote pedestrian safety in areas where crossing is anticipated. It introduces a steeper angle of intersection and tighter turn radius to promote slower turns by smaller vehicles, decreases the amount of head turning required by the driver, and places crossing pedestrians in the approaching motorists' line of sight, while providing the paved area required for large design vehicles to make a turn without mounting the outside curb.

The rural design is intended for rural highway intersections in areas where pedestrian activity is not expected and is configured to promote vehicular mobility with a flatter turn radius and a longer, sweeping turning roadway. It is based on the current TxDOT right-turn slip lane design and facilitates inclusion of both deceleration and acceleration lanes. It should be noted that right-turn slip lanes along frontage roads are intended to be designed based on the guidance provided for urban and rural locations, depending on area conditions.

The produced design guidance was a result of an iterative process of refining the design guidelines based on feedback from TxDOT personnel throughout the process. Comments were received and addressed from the design, traffic operations, and maintenance divisions, as well as the statewide bicycle and pedestrian coordinator. The following provides a summary of the recommendations provided:

- Install a raised island of adequate size to provide refuge where pedestrian crossings are expected.
- Place the crosswalk in the center of the turning roadway perpendicular to the direction of travel.
- Set the angle of entry with the cross street to 70 degrees to improve visibility of the crossing location, as well as reduce the head-turning required by motorists to observe cross street traffic.
- Consider using "ladder" markings for the crosswalk along the right-turn slip lane to improve the visibility of the crossing location, as well as help visually impaired pedestrians with wayfinding.
- Design the lane width and curb radius for the appropriate design vehicle to facilitate its turning maneuver while striping a tighter turn radius and sharper entry angle for passenger cars.

- Place drainage inlets upstream of the crosswalk or future crossing location to reduce the spread of water into the crosswalk.
- At intersections with channelization, lighting systems should be installed to illuminate islands, diverge and merge locations, turning roadways, and pedestrian crossings.
- Whenever feasible, signal and other utility poles and signs should be placed outside of paved pedestrian walkways and landing areas. Care should be taken to avoid placing these objects in conflict with future pedestrian facilities.
- Provide a buffer space whenever sidewalks are constructed to add separation between pedestrians and the traveled way.

In addition to formal guidelines, design schematics for pedestrian accommodations at the channelizing island were provided. These were based on recommendations from TxDOT personnel with implementation of a partial cut-through pedestrian pathway, providing the benefit of elevating the pathway to inhibit collection of water or debris, while providing wayfinding benefits for pedestrians and people with disabilities (see Figure 6).

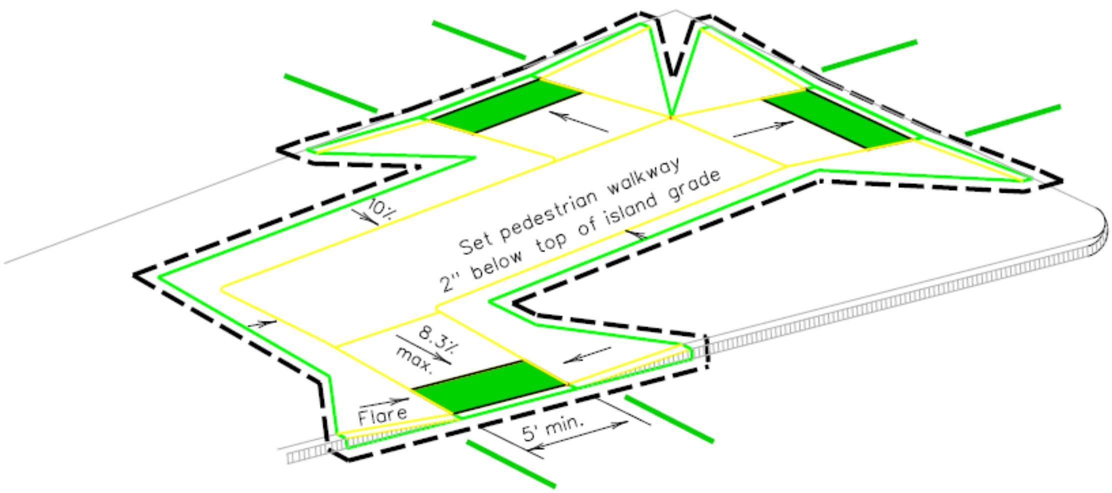

Figure 6. Pedestrian Walkway through Raised Channelizing Island

Design standard drawings were also created for the urban/suburban configuration. Right-turn slip lane drawings with and without a deceleration lane were provided. Highlighted elements include provision of longitudinal crosswalk markings, accommodation of bike lanes, a sharp angle of entry with the cross street, and delineation of a narrow turning path for smaller vehicles with pavement markings along the outside of the turning roadway. A sample design standard drawing is provided in Figure 7.

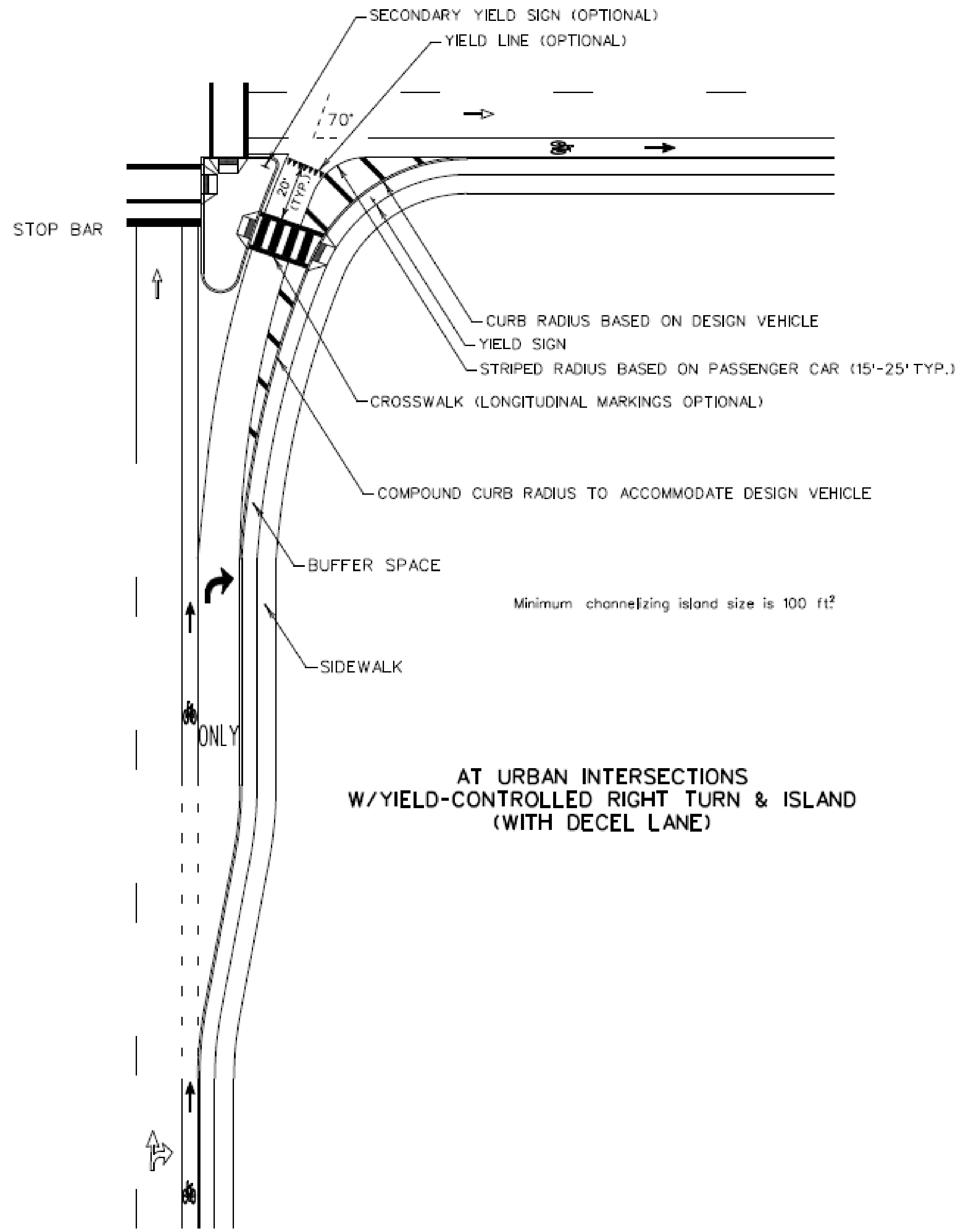

Figure 7. Right-Turn Slip Lane Design for Urban Intersections with Deceleration Lane

To implement guidance on retrofitting treatments, a list of potential treatments corresponding to common issues identified that impede the safe operation of right-turn slip lanes were summarized. Common issues encountered at these locations include the absence of adequate refuge in the channelizing island for crossing pedestrians, failure of motorists to yield to crossing pedestrians, pedestrian noncompliance with the crosswalk location, high-speed turns jeopardizing pedestrian safety, low visibility of crossing pedestrians, and excessive head turning required to observe oncoming traffic. Potential retrofitting treatments designed to mitigate these issues were presented in a user-friendly tabular format along with supporting commentary.

SUMMARY AND CONCLUSIONS

Right-turn slip lanes provide numerous benefits including a reduction in vehicular delay at intersections by separating through from right-turning traffic, and reducing the continuous crossing distance for pedestrians with provision of a channelizing island. However, the literature indicates that conventional right-turn slip lane designs can be problematic for pedestrians, as their geometric design generally prioritizes the needs of motorists over the needs of other, non-motorized modes.

Consequently, the goal of this research effort was to review state-of-the-practice guidance on right-turn slip lanes and produce design guidelines for slip lanes that cater to the needs of different intersection users. The process began with a review of the available literature on right-turn slip lane design and operation. The research team then held focus group meetings with TxDOT representatives to discuss the various design elements that emerged from the literature synthesis. One key take-away from the focus group meetings was the importance of addressing issues at existing facilities in order to improve their safety conditions, particularly for pedestrians. A subsequent focus group meeting was held to solicit feedback on the research team's findings on retrofitting treatments. The information gathered from the literature review and focus group meetings served as the foundation for the proposed design guidance.

The new construction design guidance targets urban, suburban, and rural roadways in accordance with the format of TxDOT's *Roadway Design Manual*. The urban and suburban design is based on the City of Ottawa "urban smart channel" design, as focus group participants agreed that this design succeeds in catering to pedestrian needs without unduly impacting mobility. In fact, the design benefits motorists as well. It provides a large enough curb radius and paved area to facilitate the turning movement of larger vehicles while delineating a narrower path for passenger vehicles to promote lower turn speeds. The channelizing island and striped pathway are aligned in such a way that the turning roadway intersects the cross street at a sharp angle and, as such, does not require excessive head turning on behalf of the motorists to search for gaps in oncoming traffic.

The rural design guidance mainly centers on facilitating mobility through the turning roadway, as regular pedestrian activity is not typical at rural intersections. Accordingly, the design promotes larger sweeping turns, the use of acceleration lanes, unpaved channelizing islands, and a flatter angle of entry into the cross street. In the event that pedestrian activity increases in the future, these intersections can be retrofitted to accommodate area development and travel behavior.

Through the research process, it was determined that the issue of retrofitting existing right-turn slip lanes to improve their safety conditions and make them more accommodating to pedestrians and bicyclists was important. Accordingly, the design guidelines include a section on retrofitting treatments, targeted at issues commonly found at right-turn slip lanes. The subsequent guidance includes a compilation of retrofitting treatments TxDOT representatives agreed could alleviate issues encountered at existing right-turn slip lanes.

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