TTI: 0-6997

Guidelines for Implementing Super 2 Corridors in Texas

Technical Report 0-6997-P1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE

COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
http://tti.tamu.edu/documents/0-6997-P1.pdf

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-21/0-6997-P1		

4. Title and Subtitle	5. Report Date
GUIDELINES FOR IMPLEMENTING SUPER 2 CORRIDORS IN TEXAS	Published: August 2021
	6. Performing Organization Code
7. Author(s) Marcus A. Brewer	8. Performing Organization Report No. Report 0-6997-P1
9. Performing Organization Name and Address Texas A&M Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. Project 0-6997
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office 125 E. 11th Street Austin, Texas 78701-2483	13. Type of Report and Period Covered Technical Report: September 2018–August 2020 14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Project Title: Develop Capacity and Cost Benefits of Super 2 Corridors

URL: http://tti.tamu.edu/documents/0-6997-P1.pdf

16. Abstract

Multiple research projects on Super 2 passing lanes for rural two-lane highways have produced guidance for practitioners on the design and implementation of those passing lanes. In addition, guidance documents such as the Texas Department of Transportation *Roadway Design Manual* and the *Texas Manual on Uniform Traffic Control Devices* provide recommendations for practitioners. This guidebook combines information on key topics from those documents into a single location, providing a primary source for practitioners seeking information on the implementation of Super 2 corridors in Texas. References to research and guidance documents are provided for the practitioner to obtain more detailed information.

17. Key Words	18. Distribution Statement
Super 2 corridor, passing lane, rural two-lane highway, design, operations, safety, benefit-cost, traffic control devices, taper length	No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia http://www.ntis.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	40	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

GUIDELINES FOR IMPLEMENTING SUPER 2 CORRIDORS IN TEXAS

by

Marcus A. Brewer, P.E., PMP
Research Engineer
Texas A&M Transportation Institute

Report 0-6997-P1
Project 0-6997
Project Title: Develop Capacity and Cost Benefits of Super 2 Corridors

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: August 2021

TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of FHWA or TxDOT.

This report does not constitute a standard, specification, or regulation. This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Marcus A. Brewer, P.E. (TX #92997).

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. Wade Odell of TxDOT served as the 0-6997 project manager. The author gratefully acknowledges the assistance and direction that the TxDOT 0-6997 project advisors (Matt Evans, Andrew Holick, Cathy Kratz, Ana Minjares, Rebecca Wells, and Mark Wooldridge) provided over the course of the project. The author also acknowledges the project advisors from previous TxDOT-sponsored research projects (specifically, 0-4064 and 0-6135) that contributed to these guidelines. The author would further like to acknowledge the contributions of current and former Texas A&M Transportation Institute staff members Tim Barrette, Gary Barricklow, Kunhee Choi, Liang Ding, Kay Fitzpatrick, David Florence, Brianne Glover, Barry Heard, Sangsoo Lee, Carroll Messer, Angelia Parham, Byung-Jung Park, Selvam Raghupathy, and Steven Venglar for their contributions to this project and previous projects.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER 1: INTRODUCTION

BACKGROUND

Many of Texas' highways are two-lane rural roadways and will remain so for the foreseeable future. As volumes increase, motorist satisfaction and operational performance on those roadways typically decrease. The traditional answer to these problems, expansion to a four-lane cross-section, is often not feasible for many of these facilities due to budgetary constraints.

An alternative approach is to provide lower-cost improvements on existing two-lane rural roads, thereby upgrading a larger number of roadways. Both domestic and international research and experience spanning more than three decades have shown that the provision of passing lanes, turning lanes, localized alignment improvements, and other relatively low-cost measures can be highly cost-effective in improving both traffic operations and safety on existing two-lane rural roads. These options are also most appropriate for roads with lower traffic volumes that may not warrant major improvement projects and on recreational or other routes with high seasonal demand (*1*). Passing lanes are one of the most effective methods of improving the level of service on a two-lane roadway because they increase passing opportunities and provide smoother traffic operations with fewer vehicle-vehicle conflicts (*2*). Passing lanes allow motorists the opportunity to safely and easily pass slower vehicles, improving traffic flow at a much lower cost than a traditional expansion to four lanes. Additionally, safety evaluations have shown that passing lanes and short four-lane sections reduce crash rates below the levels found on conventional two-lane highways (*3*).

The use of passing lanes on rural two-lane highway corridors is known in Texas as a "Super 2" design. They are a common treatment on two-lane roadways to improve overall traffic operations by breaking up traffic platoons and reducing delays caused by inadequate passing opportunities over substantial lengths of roadway. Passing lanes on a two-lane roadway are often much more cost-effective in providing passing opportunities than continuous four-lane sections because locations with high construction costs (e.g., major earthwork, expensive structures) can be avoided (*1*). Judicious use of Super 2 corridors on rural two-lane highways can increase capacity, reduce delay, increase average speeds of through vehicles, and reduce crashes (*4*, *5*, *6*).

WHAT IS A SUPER 2?

The Texas Department of Transportation (TxDOT) *Roadway Design Manual* (RDM) (*7*) defines a Super 2 highway as one in which a periodic passing lane is added to a two-lane rural highway to allow passing of slower vehicles and the dispersal of traffic platoons. The passing lane alternates from one direction of travel to the other within a section of roadway, allowing passing opportunities in both directions. A Super 2 project can be introduced on an existing two-lane roadway where there is substantial slow-moving traffic, where there is limited sight distance for passing, and/or where the existing traffic volume has exceeded the two-lane highway capacity, thus creating the need for vehicles to pass on a more frequent basis.

One of the benefits of the Super 2 design is that it is flexible in where and how the roadway is widened to provide the passing lanes. Figure 1 shows nine different configurations of passing lanes (*8*). Widening of the existing pavement can be symmetric about the centerline or on one side of the roadway depending on right-of-way (ROW) availability and ease of construction. The isolated passing lane shown in Figure 1a is typically used to reduce delays occurring at a specific isolated bottleneck and is not truly a Super 2 corridor treatment. The other configurations allow some interaction between consecutive passing lanes in opposite directions, and they are used when traffic improvements are needed in both directions of travel over a corridor. The existence of multiple passing lanes along a corridor triggers the Super 2 designation.

Similarly, the distinction should be made between Super 2 passing lanes and climbing lanes. Although the purpose of each is to reduce platooning of traffic behind slower moving vehicles, the objectives are inherently different from one another. The design objectives used in the construction of a climbing lane are based on a desire to eliminate platooning due to a significant change in grade at a single location; that is, the size and length of the grade change direct the design. The design objectives for passing lanes are to disperse platoons and improve traffic operations through the provision of enhanced passing opportunities along a roadway corridor.

The alternating passing lanes shown in Figure 1f and Figure 1g can be used when sufficient width is available; Figure 1g is the typical cross-section for what is commonly described as a 2+1 road in many parts of the country and around the world. Overlapping passing lanes, shown in Figure 1h and Figure 1i, can be used when a passing lane is located on a crest or sag vertical curve, respectively. Side-by-side passing lanes, shown in Figure 1j, can be used where the location of a passing lane is constrained by nonflexible factors. Those factors include (but are not limited to) obtaining ROW, when heavy traffic is the cause of platooning rather than no-passing zones, and where the need for passing lanes exists in both directions (*8*).

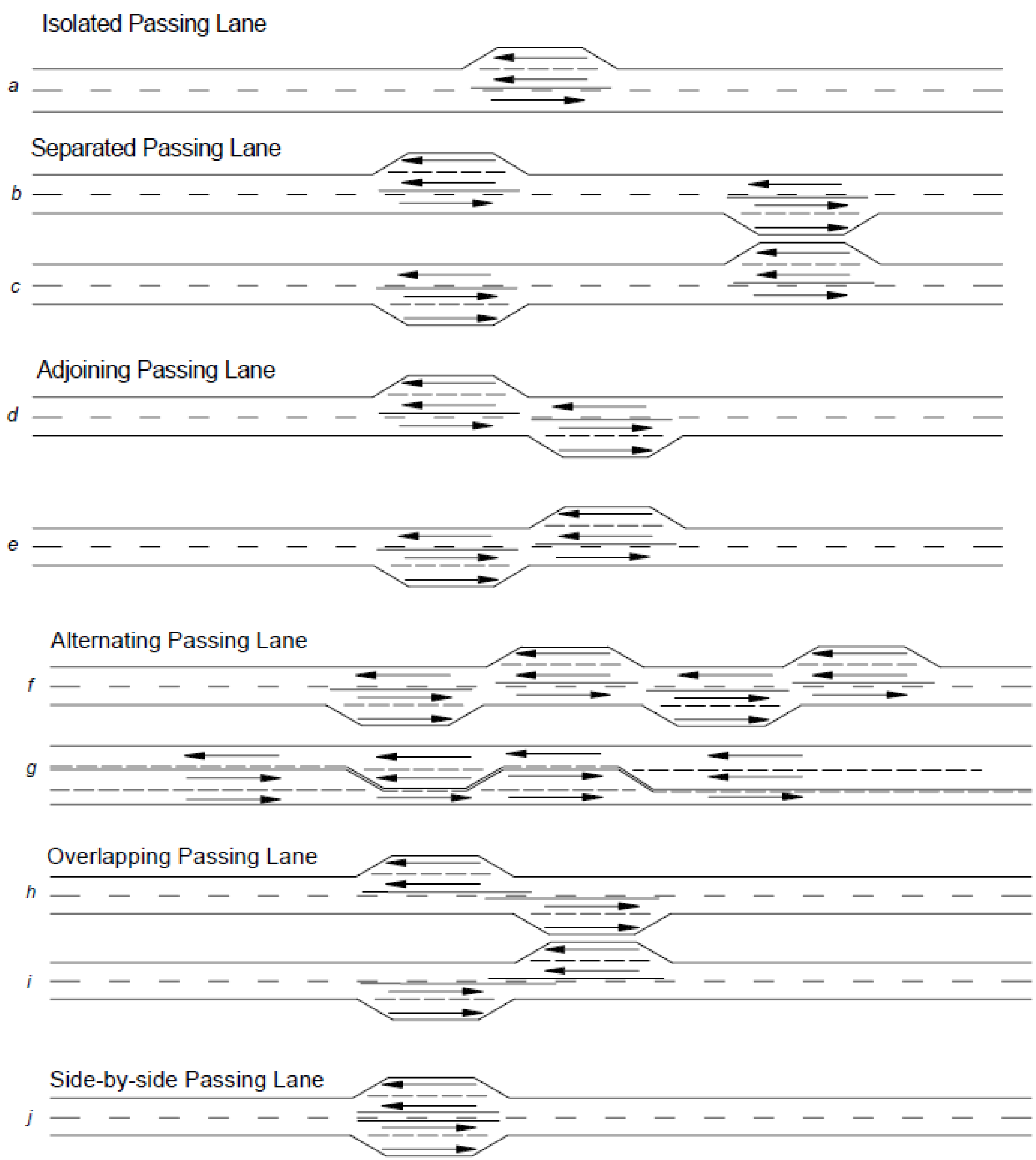

Figure 1. Passing Lane Configurations (*8*).

Because the Super 2 design allows such a high degree of flexibility, the practitioner has a great deal of latitude in the details of the design and implementation of a Super 2 corridor. This flexibility also means that the practitioner has a responsibility to exercise good engineering judgment in determining which details to include when designing and constructing the passing lanes and any other elements associated with a project that contains a Super 2 component. Many of the design details are consistent with the principles used for any rural highway, but the context of the passing maneuver on an otherwise two-lane highway needs to be considered. The information provided in the following chapters of this document provide guidance for the practitioner to use in selecting an appropriate cross-section for a particular corridor, determining the optimal design elements for passing lanes within a Super 2 corridor, and preparing the required and recommended traffic control devices that correspond to the completed design.

CHAPTER 2: SELECTION OF ALTERNATIVES

A practitioner considering whether to install a Super 2 corridor on a rural two-lane highway should first consider the available alternatives to determine which of those alternatives is best to select for that location. This chapter provides information on how to consider operational, safety, and economic measures in the decision to select a particular alternative.

OPERATIONAL MEASURES

The Super 2 design is primarily an operational treatment, so it is important to consider the operational characteristics of the highway in question to determine how it might benefit from the addition of passing lanes.

Volume

Traditionally, rural two-lane highways have been widened to four lanes when traffic volumes become high enough to have a sufficiently negative effect on operations, whether that be in terms of low speeds, long platoons, lack of passing opportunities, high delay, or other metrics. However, as more rural highways approach conditions that meet these criteria, budgetary constraints make it increasingly difficult to widen all of those highways, creating more opportunities where Super 2 highways may be effective.

Previous research in Texas (*4*) demonstrated that periodic passing lanes can improve operations on two-lane highway corridors with low to moderate volumes (e.g., average daily traffic [ADT] at or below 5,000 vehicles per day [vpd]), but more recent research (*5*, *6*) indicates that Super 2 corridors can provide operational benefits for volumes as high as 19,000 vpd. The results shown in Figure 2 indicate that a roadway with nearly 15,000 ADT sees a decline in both delay and the percent time spent following as the number and length of passing lanes increase, in both rolling and level terrain, even as the truck percentage increases.

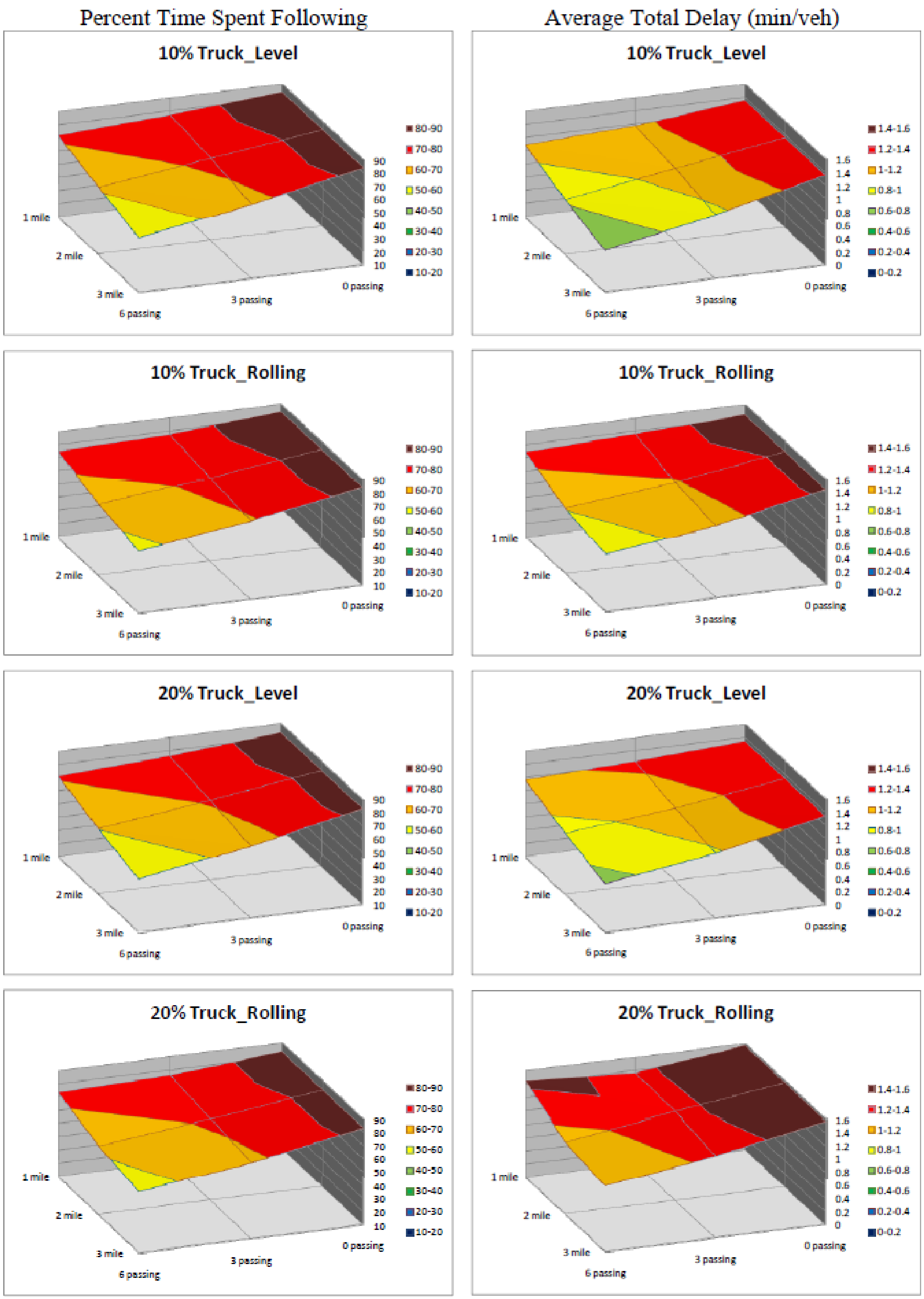

Figure 2. Performance Measures for Different Passing Lane Configurations— 14,667 ADT Scenarios (*5*).

Research also indicates that providing passing lanes on two-lane rural highways provides a benefit in reduced delay and time spent following, which improves operations and reduces the need for drivers to pass on two-lane sections. A single passing lane has a carryover benefit into the downstream two-lane section because previous platoons are partially or completely dispersed, and traffic flow is improved. This carryover benefit of a single passing lane exists for high-volume locations, but it is even greater for low-volume sites where a single slower vehicle can delay a higher proportion of trailing vehicles.

A similar look at average speeds across a variety of cross-sections in Figure 3 shows that Super 2 (2S) corridors perform better than two-lane undivided roadways (2U) at every volume level. The Super 2 cross-sections also perform as well as or better than most other options across the ADT spectrum. Table 1 shows a description of the abbreviations for each cross-section in the legend in Figure 3.

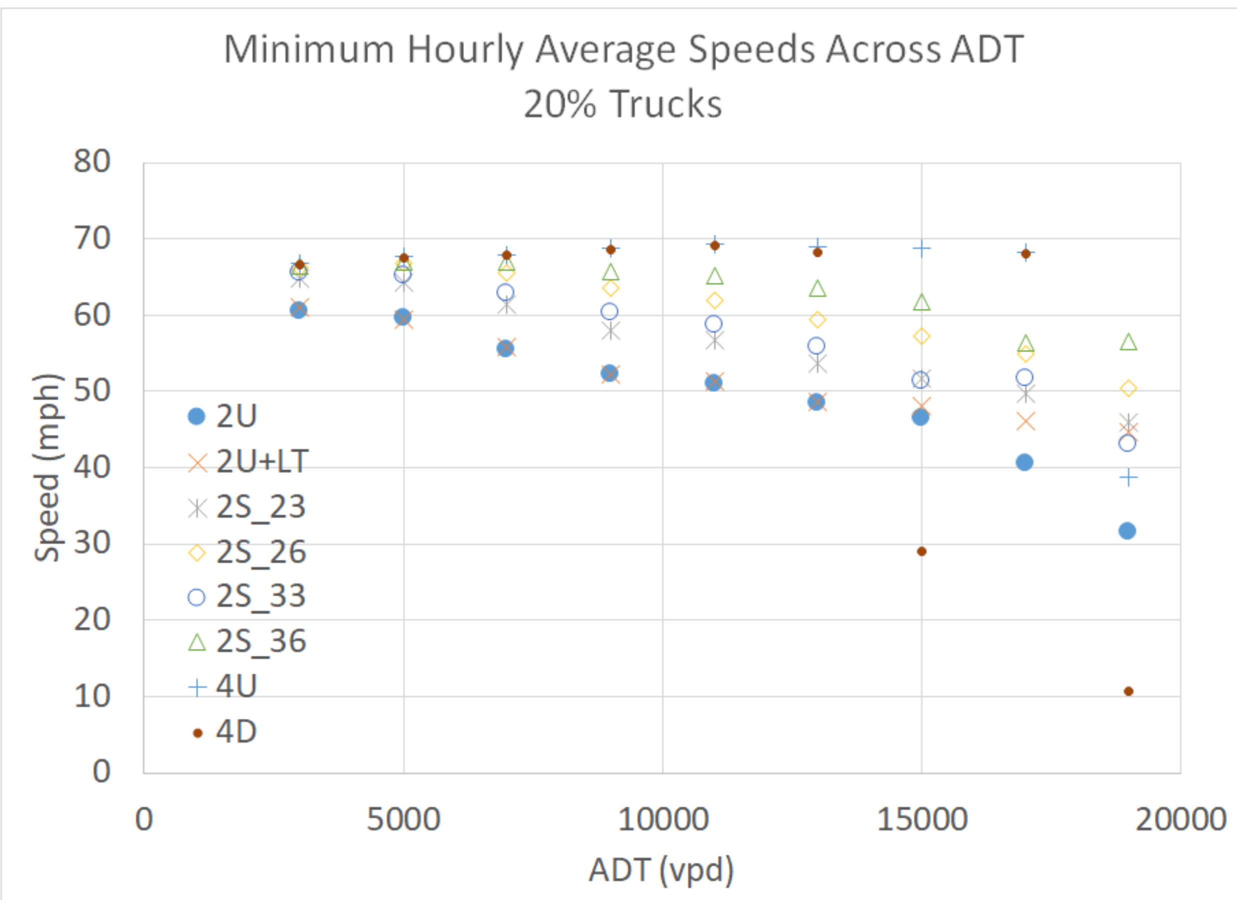

Figure 3. Minimum Hourly Average Speeds Across ADT—20 Percent Trucks (*6*).

Table 1. Description of Cross-Section Abbreviations (*6*).

Abbreviation	Cross-Section	Passing Lane Length	Number of Passing Lanes in Each Direction
2U	2-lane undivided	None	None
2U+LT	2-lane undivided with left-turn lanes at highway intersections	None	None
4U	4-lane undivided	None	None
4D	4-lane divided	None	None
2S-23	Super 2	2 miles	3 passing lanes
2S-33	Super 2	3 miles	3 passing lanes
2S-26	Super 2	2 miles	6 passing lanes
2S-36	Super 2	3 miles	6 passing lanes

As a result, there is not an upper limit of ADT for the installation of passing lanes. There is a theoretical capacity of a two-lane highway above which a four-lane cross-section will perform better, but adding passing lanes can substantially extend this theoretical capacity.

While ADT need not be a limiting factor in installation, it can be used to prioritize candidate sites for passing lanes, particularly when considering truck volumes. A traffic analysis of candidate sites will help the designer determine which locations may receive greater benefit from lengthening existing passing lanes or installing new passing lane sections.

As budget, terrain, and other factors allow, passing lanes may be added or lengthened to provide additional passing opportunities regardless of volume. There is, of course, the proviso that as passing lanes are added and lengthened, the highway more closely resembles a four-lane undivided alignment, and the incremental cost and operational benefits of each added lane can diminish. (See the Economic Measures section of this chapter for more details on those relative benefits.)

Truck Percentage

As discussed in the previous section, Super 2 corridors can accommodate heavy vehicles as well. Relative to ADT, truck percentage tends to have very limited impact on many performance measures, particularly the influence by truck percentage on percent time spent following. That said, an increase in trucks does have an effect on the operational performance of a highway, and in comparison to a traditional two-lane highway, the addition of passing lanes can provide benefits in average delay and the number of passing maneuvers completed.

Terrain/Vertical Alignment

Similar to truck percentage, terrain does not generally have a large effect on the performance of a Super 2 corridor, although a Super 2 does see more improvement over a two-lane highway in rolling terrain than in level terrain, simply because the rolling terrain limits the natural opportunities for passing zones. The addition of passing lanes helps to overcome those limitations.

Through Vehicles versus Turning Vehicles

An important consideration in evaluating the expected performance of an improved two-lane highway corridor is the amount of traffic that travels the entire length of the corridor compared to vehicles that turn into and/or out of access points within the corridor. A Super 2 corridor is most effective for through traffic because it provides passing opportunities for vehicles that are traveling long distances. A corridor that has frequent driveways or intersections (particularly locations that are substantial traffic generators) may see greater benefit from turning treatments (e.g., left-turn lanes, wider shoulders, acceleration/deceleration lanes for right turns, etc.) than from additional opportunities for high-speed passing. Turning and passing treatments are not exclusive—both can be installed on the same corridor—but on corridors where a high level of turning traffic creates interrupted flow, passing lanes may not be as effective as on corridors that primarily or exclusively serve through traffic.

SAFETY MEASURES

While the fundamental benefits of a Super 2 emphasize operational measures of effectiveness, safety benefits exist as well, because drivers are less likely to execute a passing maneuver in a two-lane section of the corridor. Depending on the traffic characteristics of the site in question, a Super 2 can also provide safety benefits that should be considered when determining what specific design alternative to select in an improvement project.

Previous research in Texas (*5*) showed that that the installation of passing lanes on the corridors that were studied led to a statistically significant crash reduction of 35 percent for KABC segment-only crashes and 42 percent for KABC segment and intersection crashes. This finding is consistent with findings of previous safety-related studies of Super 2 corridors, which show improvements in safety from the installation of passing lanes, even at traffic volumes higher than those considered under previous guidance in Texas.

A combination of data from studies in other states (*9*, *10*) produced a crash modification factor (CMF) for a conventional passing or climbing lane added in one direction of travel on a two-lane highway of 0.75 (i.e., a 25 percent reduction) for total crashes in both directions of travel over the length of the passing lane from the upstream end of the lane addition taper to the downstream end of the lane drop taper. This CMF assumed that the passing lane is operationally warranted and that the length of the passing lane is appropriate for the operational conditions on the roadway.

In addition to the crash reductions documented in the Texas research (*5*), the CMF Clearinghouse (http://www.cmfclearinghouse.org) provides results from other studies with similar reductions in crashes. A search on "passing lane" in the CMF Clearinghouse produces results ranging from 7 to 42 percent reductions in crashes, depending on the type of crash (e.g., roadway departure, head-on, etc.) or location (e.g., at intersection, not at intersection, etc.) being studied. Crash reduction benefits on a specific corridor will vary, but a practitioner installing new Super 2 passing lanes on a rural two-lane highway should expect some crash reduction along the improved corridor. Thus, while a Super 2 is primarily an operational treatment, the treatment typically comes with safety benefits as well.

ECONOMIC MEASURES

The cost of a construction project in comparison to its expected economic benefit should not be ignored when considering the installation of a Super 2 corridor. A practitioner can consider a wide variety of inputs when conducting a benefit-cost analysis (BCA), but the broad categories typically can be summarized as follows:

- Vehicle operating cost savings.
- Business and personal time cost savings.
- Safety benefits.
- Environmental benefits.
- Capital costs.

Vehicle operating costs include but are not limited to fuel, purchase payments, insurance premiums, tires, maintenance, and repairs. Business time cost savings are the business costs of labor for professional drivers and paid crew. Personal time cost savings are the valuation of the average passenger's time. Safety benefits are the monetized value associated with the reduction of crashes that result in a fatality or injury, and environmental factors include the cost savings of air pollution and greenhouse gasses per vehicle hour of travel.

An economic analysis model was developed to calculate the benefits and costs for Super 2 projects in Texas (*6*). That BCA model also has the ability to consider four-lane divided and four-lane undivided cross-sections, all compared to a baseline scenario of a traditional two-lane highway. The model exists in a spreadsheet tool (distributed with this guidelines document) that enables practitioners to calculate the benefits and costs of their own construction projects in order to decide which cross-section may be best suited for a particular location.

The spreadsheet tool provides prompts for a selected number of inputs from the user to the model and then provides results based on those user inputs. Table 2 depicts the model inputs for a sample 2S-26 project (i.e., Super 2 with 2-mile passing lanes and six passing lanes in each direction of travel), as entered into the BCA spreadsheet model. The top three factors highlighted in yellow allow the user to select from a pull-down menu, while the Project Cost Override factor, located at the bottom, allows the user to override the default project cost calculated by the model if more accurate project cost information is available. The remaining default factors highlighted in gray depict the values used for this analysis that can be altered if other data are available.

Table 2. BCA Model Inputs (*6*).

Inputs	
Please Select from Pull-Down Menu	
Project Type	2S-26
ADT	11,000
Percent Trucks	40%
Traffic Growth Rate	2%
Construction Start Year	2021
Operation Start Year	2023
Constant Dollar Year	2020
Project Length (Miles)	40.0
Estimated Project Cost	$40,545,609
Known Project Cost Override	

Table 3 shows the outputs of the BCA model for the sample project. The total benefits over the 20-year period of operation are presented at the top (discounted at 3 percent), followed by the discounted project cost. The model also presents the benefit-cost ratio (BCR) and the net present value (NPV) of the sample project. The BCA calculations include consideration of previously discussed operational benefits, which are components of the operational cost benefits, time cost benefits, and environmental benefits that result from reduced delay and increased capacity.

Table 3. BCA Model Outputs (*6*).

Outputs	
Benefits and Costs	**Present Value (M 2018$)**
Vehicle Operating Cost Savings	$149.5
Business and Personal Time Cost Savings	$176.4
Safety Benefits	$230.0
Environmental Benefits	$1.3
Total Benefits	**$557**
Capital Costs	$38.8
Total Costs	**$39**
Benefit-Cost Ratio	**14.4**
Net Present Value (NPV)	**$518**
3% Discount Rate	

The results shown in Table 3 indicate that this sample 2S-26 corridor has a robust BCR of 14.4:1 and an NPV of $518 million (in 2018 dollars) when compared to a traditional two-lane highway. Table 4 and Table 5 summarize the results of other sample scenarios that were considered in the development of the model (*6*). Values shown in red represent BCRs less than 1.0 and negative NPVs. Values in Table 5 are in millions of 2018 dollars. Abbreviations for the project type in Table 4 and Table 5 are shown in Table 1.

Table 4. Benefit-Cost Ratios (Discounted at 3 Percent) (*6*).

Project Type	3,000 ADT		19,000 ADT	
	20% Trucks	40% Trucks	20% Trucks	40% Trucks
2S-23	2.1	2.2	26.2	70.6
2S-33	2.2	2.3	28.6	73.8
2S-26	2.3	2.5	33.9	80.6
2S-36	2.4	2.5	40.1	87.7
4U	0.2	0.2	6.2	13.4
4D	1.0	1.0	5.9	26.2

Table 5. Net Present Values (M 2018$, Discounted at 3 Percent) (*6*).

Project Type	3,000 ADT		19,000 ADT	
	20% Trucks	40% Trucks	20% Trucks	40% Trucks
2S-23	$42	$46	$977	$2,700
2S-33	$45	$49	$1,072	$2,825
2S-26	$52	$56	$1,277	$3,090
2S-36	$55	$59	$1,517	$2,264
4U	($191)	($185)	$1,271	$3,062
4D	($7)	($1)	$829	$4,236

Practitioners should use the BCA tool with the specific details of their projects to determine the applicable benefit-cost values for those projects. Results will vary with each project; however, the results in Table 4 and Table 5 show that Super 2 corridors consistently outperform the baseline two-lane scenario, and they also generally outperform the 4U and 4D at lower volumes and can do so at higher volumes as well. The four-lane cross-sections in Table 4 and Table 5 have negative NPVs and marginal BCRs at the lower ADT because the project costs are higher, and the lower volumes produce smaller operational and safety benefits than those benefits attributed to the Super 2 scenarios. These comparative results are intuitive based on the normal assumption that a four-lane widening project typically is not necessary for volumes that low.

Results in Table 4 and Table 5 also show that the 2S-26 scenario showed better results than the 2S-33; this discovery is consistent with findings from previous research (*5*, *6*) indicating that adding shorter passing lanes to a Super 2 corridor is often more beneficial than providing fewer but longer passing lanes.

The BCA tool provides calculations for both BCR and NPV. When comparing two specific scenarios, one scenario may have a better BCR, while the other may have a better NPV. In general, this possibility underscores that, when evaluating BCA results, BCR and NPV should be mutually considered in decisions regarding benefits or ranking of one project type over another. It also underscores the fact that the BCA tool is a single component in the decision-making process and should not be used as the only source of information when evaluating alternatives; although the BCA tool does contain considerations for operational and safety benefits, those benefits should also be considered in detail in conjunction with the BCA tool to produce a more comprehensive evaluation of alternatives when making a final decision.

CHAPTER 3: DESIGN CONSIDERATIONS

Some basic design principles govern the typical construction of a Super 2 corridor. While the full details of those design principles and supporting material can be found in other documents, such as the TxDOT RDM (*7*) and reports from the research that produced that guidance (*4, 5, 6*), this chapter summarizes key topics that a practitioner should consider in the design of a Super 2 corridor. The designer should consult the external documents listed above for more information.

BASIC PRINCIPLES FROM ROADWAY DESIGN MANUAL

Super 2 highways are described in the TxDOT RDM in Chapter 4, Section 6. The RDM describes a Super 2 highway as one in which

> a periodic passing lane is added to a two-lane rural highway to allow passing of slower vehicles and the dispersal of traffic platoons. The passing lane will alternate from one direction of travel to the other within a section of roadway allowing passing opportunities in both directions. A Super 2 project can be introduced on an existing two-lane roadway where there is a significant amount of slow moving traffic, limited sight distance for passing, and/or the existing traffic volume has exceeded the two-lane highway capacity, creating the need for vehicles to pass on a more frequent basis. Widening of the existing pavement can be symmetric about the centerline or on one side of the roadway depending on ROW availability and ease of construction. (*7*)

The RDM provides some basic principles for the designer to consider when designing a Super 2 project (*7*):

- Analyze existing ROW width considerations to determine feasibility of upgrading to a Super 2.
- Consider providing a left turn lane if a significant traffic generator falls within the limits of a Super 2.
- Consider providing full shoulders (8 to 10 feet) in areas with high driveway density.
- Evaluate the location of large drainage structures and bridges when considering the placement of passing lanes.
- Evaluate traffic operations, including truck volumes, if consideration is given to terminating passing lanes on significant uphill grades. Coordinate passing lanes with climbing lane needs to improve operating characteristics.

- Avoid closing a passing lane over a hill or around a horizontal curve where the pavement surface at the end of the taper is not visible from the beginning of the taper.
- When evaluating the termination of a passing lane at an intersection, consider traffic operations, turning and weaving movements, and intersection geometrics. If closure of the passing lane at the intersection would result in significant operational lane weaving, then consider extending the passing lane beyond the intersection.
- Allow adequate distance (recommend stopping site distance) between the end of a lane closure taper and a constraint, such as metal beam guard fence, a narrow structure, or major traffic generator.
- Consider providing a passing lane in the direction leaving an incorporated area for potential platoons generated in the urban area.

The RDM also provides a description of basic design criteria, the key elements of which are summarized in Table 6. Note that some elements, namely design speed and clear zone (i.e., horizontal clearance) are the same as rural two-lane highways.

Table 6. TxDOT Super 2 Design Criteria (Table 4-6 in the RDM [*7*]).

Design Element	Minimum	Desirable
Design Speed	See Table 4-2	
Clear Zone	See Table 4-2	
Lane Width	11 ft	12 ft
Shoulder Width	3 ft[a]	8–10 ft
Passing Lane Length	1 mi	1.5–2 mi[b]

[a] Where ROW is limited.
[b] Longer passing lanes are acceptable, but not recommended for more than 4 miles. Consider switching the direction if more than 4 miles.

The discussion of basic design criteria also describes the taper length for beginning and ending a passing lane as L = WS/2 and L = WS, respectively (see Figure 4), where:

- L = Length of taper (feet).
- W = Lane width (feet).
- S = Posted speed (miles per hour).

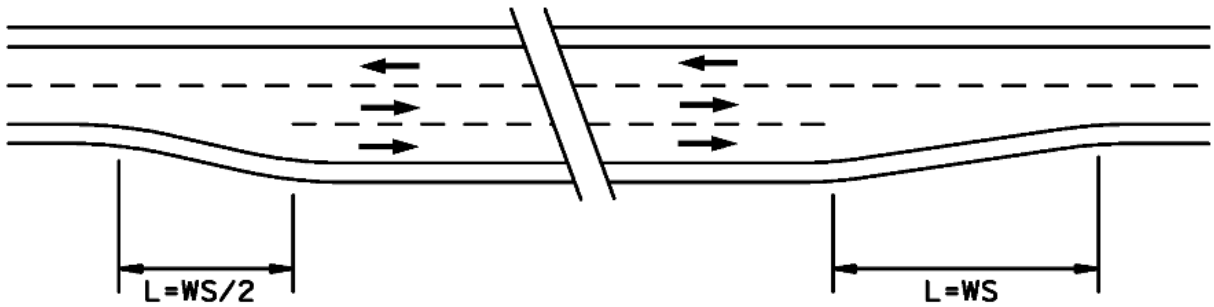

Figure 4. Opening and Closing a Passing Lane (Figure 4-1 in the RDM [*7*]).

When switching the passing lane from one direction to another (closing the passing lane in each direction), provide a taper length from each direction based on L = WS, with a minimum 50-foot buffer (stopping sight distance [SSD] desirable) between them, as shown in Figure 5. When opening a passing lane in each direction (see Figure 6), provide a taper length based on L = WS/2.

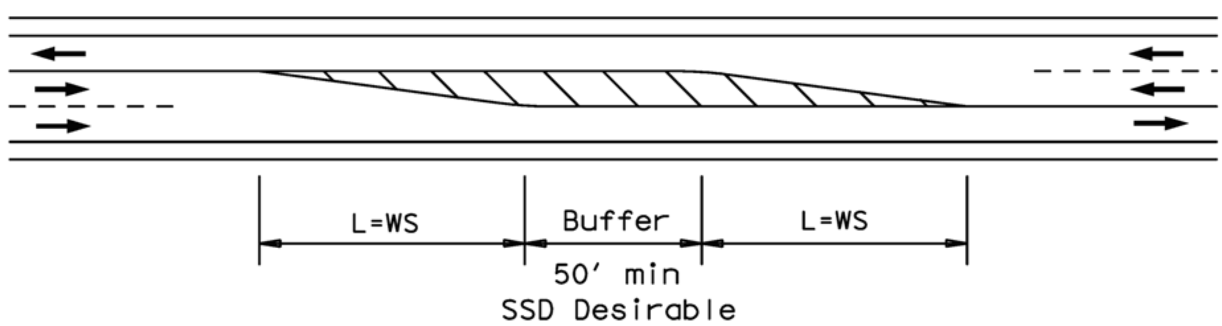

Figure 5. Closing the Passing Lane from One Direction to Another (Figure 4-2 in the RDM [*7*]).

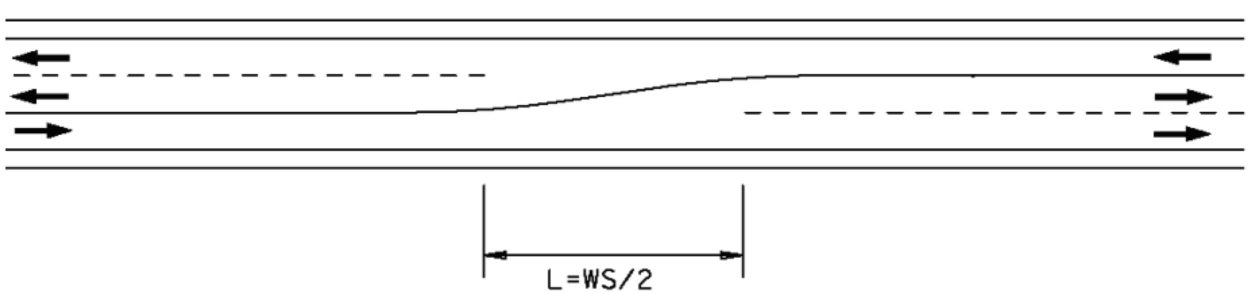

Figure 6. Opening the Passing Lane from One Direction to Another (Figure 4-3 in the RDM [*7*]).

When widening to the outside of the roadway to provide a passing lane opportunity (see Figure 7), provide an opening taper length based on L = WS/2 and a closing taper length based on L = WS.

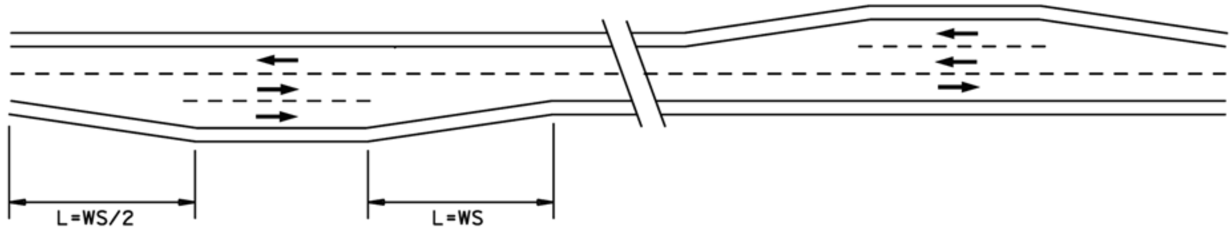

Figure 7. Separated Passing Lanes with Widening to the Outside of Roadway (Figure 4-4 in the RDM [*7*]).

Passing lanes in each direction may be side-by-side if ROW is sufficient (see Figure 8). Provide an opening taper length based on L = WS/2 and a closing taper length based on L = WS.

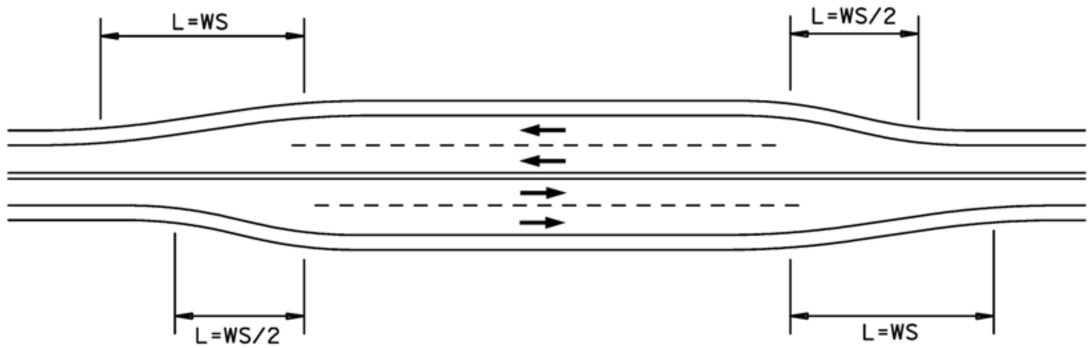

Figure 8. Side-by-Side Passing Lanes (Figure 4-5 in the RDM [*7*]).

CROSS-SECTION CONFIGURATIONS

As discussed in Chapter 1, configuration of the passing lanes in the cross-section of a Super 2 corridor can take many forms. Figure 1 illustrates nine general options, under which there are numerous variations. The RDM, as discussed in the previous section, provides guidance on beginning and ending passing lanes in each of the configurations found in Figure 1, so the designer has a great deal of latitude to produce a design that is tailored to meet the needs of a particular corridor. The benefit of having that flexibility in Super 2 design is that the designer can choose to place passing lanes where they will serve the greatest need while still accounting for budgetary constraints, ROW boundaries, and other corridor-specific limitations. The resulting cross-section can therefore look like any one of the nine configurations found in Figure 1, or it can change to resemble different configurations at different locations throughout the corridor.

Some considerations for where a designer should locate passing lanes and choose the resulting cross-section configuration are as follows:

- Consider existing ROW width, terrain, and structures to evaluate the feasibility of a Super 2 corridor and determine the best locations to install passing lanes with a minimum of ROW acquisition, earthwork, and structure widening.
- The location of major traffic generators, such as intersections with other state highways or driveways to large developments, should be identified when the proposed alignment is planned. It is preferable to avoid locating high-traffic intersections and driveways within the boundaries of a passing lane. When such generators are unavoidable, it is preferable that they be located near the midpoint of the passing lane to provide as much separation as possible from the opening and closing tapers. The designer should also consider providing auxiliary lanes for turning vehicles to decelerate, queue, and/or accelerate at access points that are major generators to reduce the likelihood of conflicts between low-speed turning vehicles and high-speed through (and passing) vehicles.
- Avoid locating passing lanes at locations with restrictive geometry (e.g., sharp horizontal curves) or other impediments to traffic flow (e.g., approaches to urbanized areas). However, providing passing lanes downstream of these features is beneficial for dispersing platoons.
- Where passing lanes are terminated, sufficient sight distance must be provided to avoid conflicts with oncoming traffic or constraints such as guard rails, guard fences, or narrow bridges. The minimum distances are provided in the RDM, as described in Figure 4 through Figure 8, but SSD is recommended. Avoid terminating passing lanes on substantial uphill grades.

LENGTH OF PASSING LANES

Passing lanes provided as part of a Super 2 corridor should generally be no shorter than 1 mile and no longer than 4 miles, with 2 to 3 miles often representing the optimum range of passing lane length. Research indicates that, for a continuous three-lane cross-section such as that shown in Figure 1g, the greatest benefits of passing lanes were observed in the first 0.9 mile (*11*). Between 0.9 and 1.9 miles, the benefits were less pronounced but were more likely to accrue as volumes increased. Similar research has shown that much of the passing activity in a passing lane in other configurations takes place in the first 2 miles or less, so simply adding length to existing passing lanes may not provide the best operational benefit. Rather, more frequent passing lanes can result in lower delay than longer passing lanes; thus, providing additional passing lanes in a Super 2 corridor is generally preferable to adding length to existing passing lanes (*6*).

SPACING OF PASSING LANES

The earliest design guidance for Super 2 corridors (*4*) recommended passing lanes at regular intervals, generally providing 4 to 9 miles between passing lanes. Depending on traffic demands, that can still be a useful distance range to provide passing opportunities on a regular basis but not so frequently that the corridor becomes a continuous four-lane cross-section. Although a regular spacing interval can still be used as a rule of thumb for a given corridor, passing lanes do not need to have uniform spacing between them. Spacing can be adjusted to account for constraints such as bridges and culverts, intersections and driveways, vertical grades, ROW limitations, or any other features that may increase the complexity of the design or reduce the effectiveness of the passing lane. Chapter 4 provides guidance on advance signing to inform drivers of upcoming passing lanes, which can encourage drivers to complete their passing maneuvers within the passing lanes instead of attempting those maneuvers in passing zones on a two-lane section of the corridor.

CHAPTER 4: TRAFFIC CONTROL DEVICES

Chapter 3 describes design elements such as length and spacing of passing lanes. Traffic characteristics such as volume, truck percentage, headway, and operating speed are important variables in determining what values to choose for those design elements. However, it is also necessary to evaluate the driver's perception of and reaction to the potential changes in design. This evaluation is especially important when determining the proper signing and marking, both at and in advance of the passing lane and at the entry and exit tapers. Differences in observed traffic patterns suggest that pavement markings and signing may have measurable effects on lane choice at the entrance to the passing lane section, which can affect the operational effectiveness of a Super 2 corridor (*4*, *5*).

TxDOT Traffic Standard Sheets TS2-1-18 (*12*) and TS2-2-18 (*13*) provide illustrations of signing and marking for Super 2 passing lanes. Those standard sheets are reproduced here as Figure 9 and Figure 10 for reference. Additional discussion of signing and marking detail is provided in the following sections of this chapter.

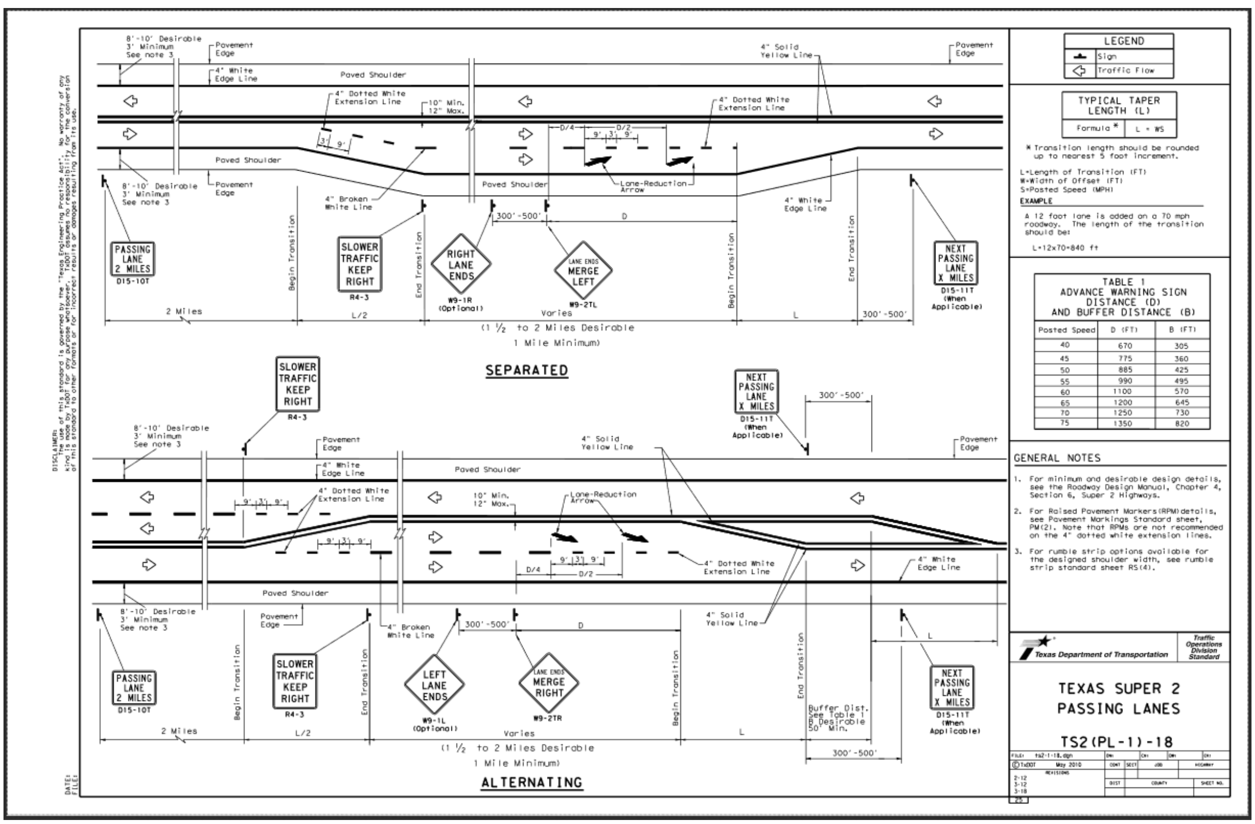

Figure 9. Traffic Standard Sheet TS2-1-18 (*12*).

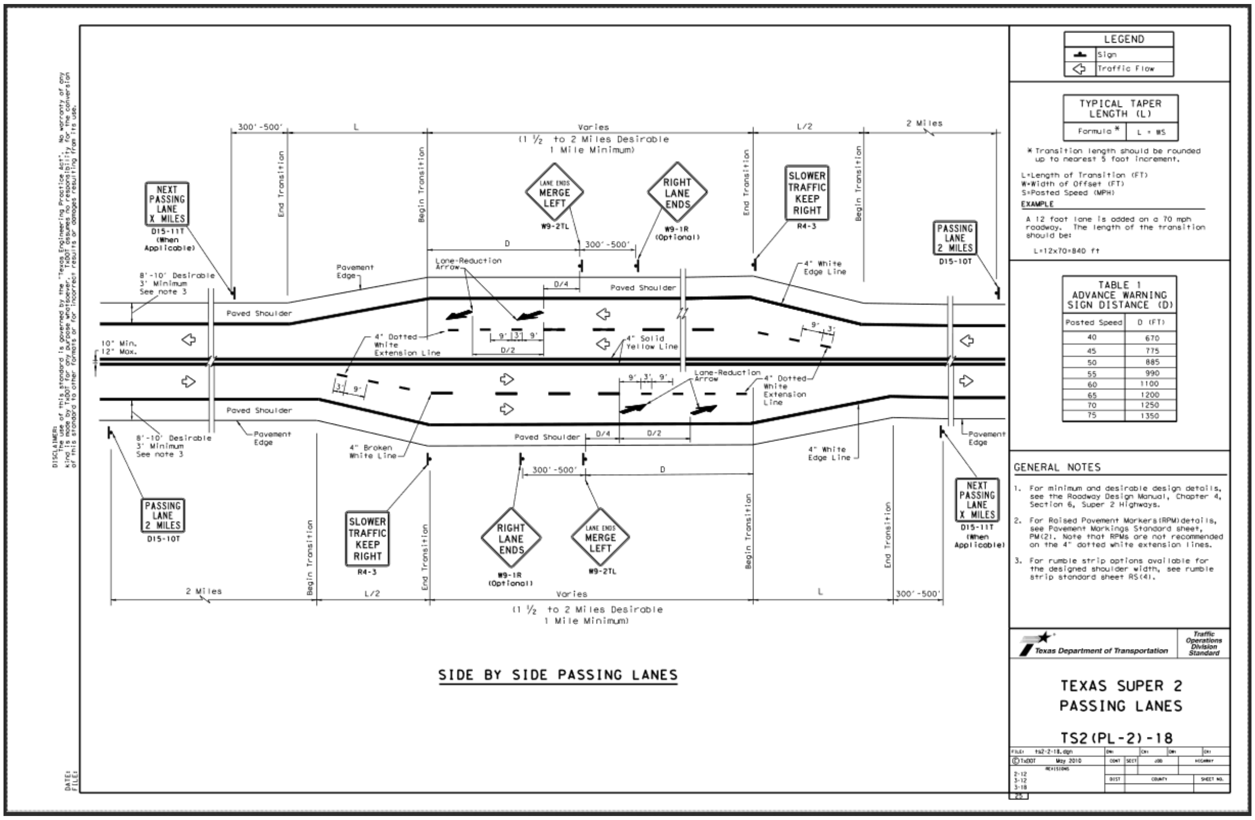

Figure 10. Traffic Standard Sheet TS2-2-18 (*13*).

SIGNING

The *Texas Manual on Uniform Traffic Control Devices* (TMUTCD) (*14*) provides the definitive standards, guidance, and support for appropriate traffic control devices within Texas. Signing that is typically found on rural two-lane highways also applies to Super 2 corridors, and the practitioner should consult the appropriate sections of the TMUTCD for the necessary details on those signs.

Signing in Passing Lane

In addition to typical signage found on rural two-lane highways, Super 2 corridors also have additional signs specific to passing lane operations. Sections 2B.29 and 2B.30 of the TMUTCD (*15*) describe the SLOWER TRAFFIC KEEP RIGHT (R4-3) sign and the LEFT LANE FOR PASSING ONLY (R4-2aT) sign, respectively. The two signs are shown in Figure 11. While early research recommended the LEFT LANE FOR PASSING ONLY sign for use in passing lanes on Super 2 corridors, the TMUTCD states that the sign may be used on multiple-lane roads and should not be used on roadways that are predominantly one lane in each direction.

Instead, the TMUTCD and the TxDOT standard sheets describe the use of the SLOWER TRAFFIC KEEP RIGHT sign to direct vehicles into an extra lane that has been provided for slow-moving vehicles.

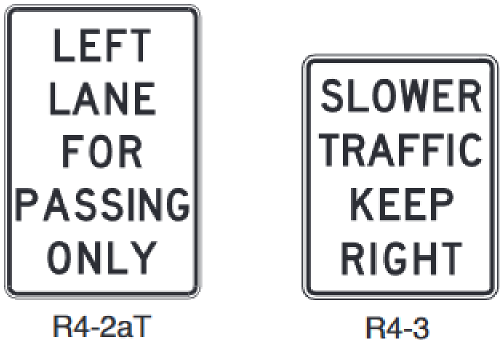

Figure 11. Passing-Lane-Related Signs in the TMUTCD (from Figure 2B-10 [*15*]).

Advance Signing

Advance signing should be provided regarding the upcoming passing lane so that drivers are aware of its presence. The appropriate sign is the PASSING LANE X MILES (D15-10T) sign. The preferred sign (and associated sign placement) indicates that the passing lane is upcoming in 2 miles (i.e., PASSING LANE 2 MILES), as shown in Figure 9 and Figure 10. This sign provides an encouragement to drivers to delay passing maneuvers until they can be made more comfortably, although passing may still be permitted prior to the passing lane section if there is a marked passing zone prior to the beginning of the passing lane.

A sign should also be provided near the end of each passing lane informing drivers when the next passing lane in the corridor will begin. That sign is the NEXT PASSING LANE X MILES (D15-11T) sign, shown in Figure 9 and Figure 10. As with the D15-10T, the D15-11T advance sign informs the driver that another passing lane opportunity will be provided soon, which also provides encouragement and positive reinforcement to delay passing maneuvers that would otherwise be attempted in the two-lane section of the corridor. This sign is typically not used at the end of the last passing lane in a Super 2 corridor; a rule of thumb is that the sign should be used if the distance to the next passing lane is 12 miles or less (*4*).

Section 2D.51 of the TMUTCD (*16*) describes both the PASSING LANE X MILES sign and the NEXT PASSING LANE X MILES sign. The two signs are shown in Figure 12.

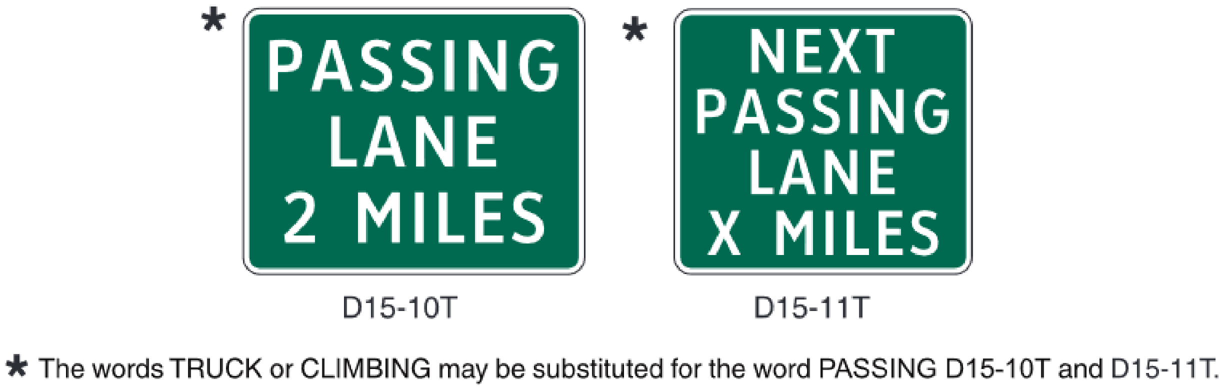

Figure 12. Super 2 Advance Signs in the TMUTCD (from Figure 2D-21 [*16*]).

Warning signs are also provided near the end of the passing lane, approaching the beginning of the lane-reduction taper. Figure 9 and Figure 10 show the use of the RIGHT LANE ENDS (W9-1) sign and the LANE ENDS MERGE LEFT (W9-2T) sign. Section 2C.42 of the TMUTCD (*17*) describes the use of these signs, and Figure 13 reproduces the corresponding figure from the TMUTCD for illustration.

Figure 13. Lane-Reduction Warning Signs in the TMUTCD (from Figure 2C-8 [*17*]).

MARKINGS

As with signing, much of the pavement marking typically associated with a rural two-lane highway (e.g., solid double yellow centerline, solid white shoulderline) also applies to Super 2 passing lanes; however, some additional markings provide positive guidance to drivers at the beginning and end of each passing lane. Figure 9 and Figure 10 show two distinct markings: a 4-inch white dotted extension line at the entrance to the passing lane, and two lane-reduction arrows prior to the beginning of the lane drop taper. Per the memo (*18*) accompanying the most recent revision to the standard sheets shown in Figure 9 and Figure 10, the extension lines and the lane-reduction arrows are required for new installations of passing lanes.

Section 3B.09 of the TMUTCD (*19*) describes the details and use of lane-reduction transition markings. Figure 14 is a reproduction of the figure used in the TMUTCD to illustrate examples of the lane-reduction arrows. Note that the TMUTCD also describes the lane-reduction taper having a length of L = WS for high-speed roads, in agreement with the taper length described in the RDM. Figure 14 also shows the placement of the LANE ENDS MERGE LEFT (W9-2T) sign described in the previous section of this chapter.

There is not an apparent section of the TMUTCD that specifically addresses the use of the dotted lane line extension at the beginning of the passing lane, but Section 3A.06 of the TMUTCD (*19*) describes the general characteristics of that pavement marking: it provides guidance or warning of a downstream change in lane function, and it consists of noticeably shorter line segments separated by shorter gaps than used for a broken line. The width of a dotted line extension shall be at least the same as the width of the line it extends. To provide the appropriate use of dotted line extensions in Super 2 passing lanes, the practitioner should use the details shown in the standard sheets in Figure 9 and Figure 10.

Section 3B.02 of the TMUTCD (*19*) describes the details and use of a no-passing buffer zone similar to the center buffer area shown in Figure 9 for alternating passing lanes where separation needs to be provided between the lane-reduction tapers of the two adjacent passing lanes. Section 3B.02 requires that, on three-lane roadways where the direction of travel in the center lane transitions from one direction to the other, a no-passing buffer zone shall be provided in the center lane, as shown in Figure 15. A lane-reduction transition (as described previously and in Section 3B.09) shall be provided at each end of the buffer zone. The buffer zone shall be a flush median island formed by two sets of double yellow centerline markings that are at least 50 feet in length. Yellow diagonal crosshatch markings may be placed in the flush median area between the two sets of no-passing zone markings, as shown in Figure 15. For high-speed roadways, the lane-transition taper length is described as L = WS, consistent with the lane-reduction taper dimension described in the RDM and in Section 3B.09 of the TMUTCD.

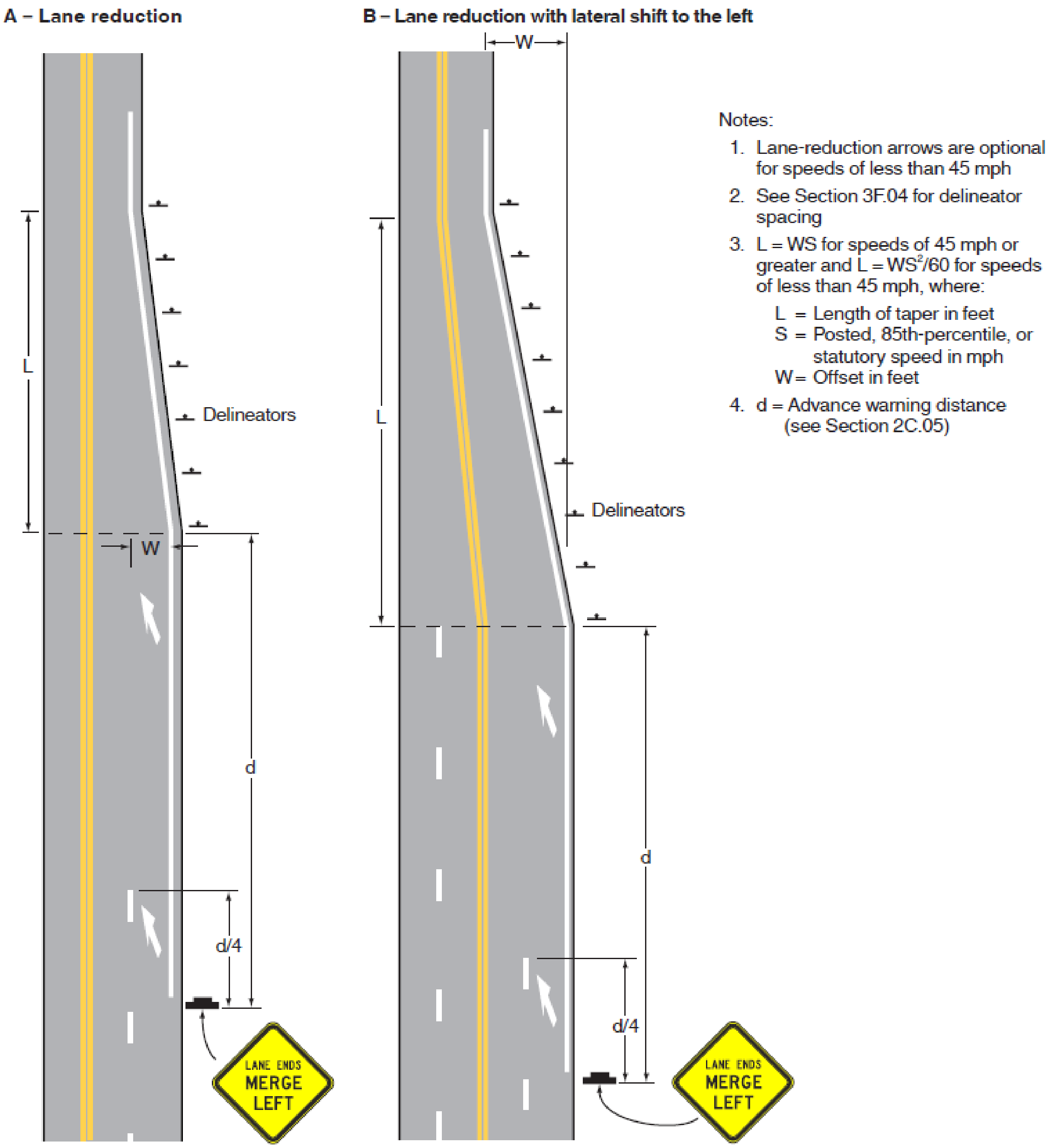

Figure 14. Examples of Applications of Lane-Reduction Transition Markings (Figure 3B-14 in the TMUTCD [*19*]).

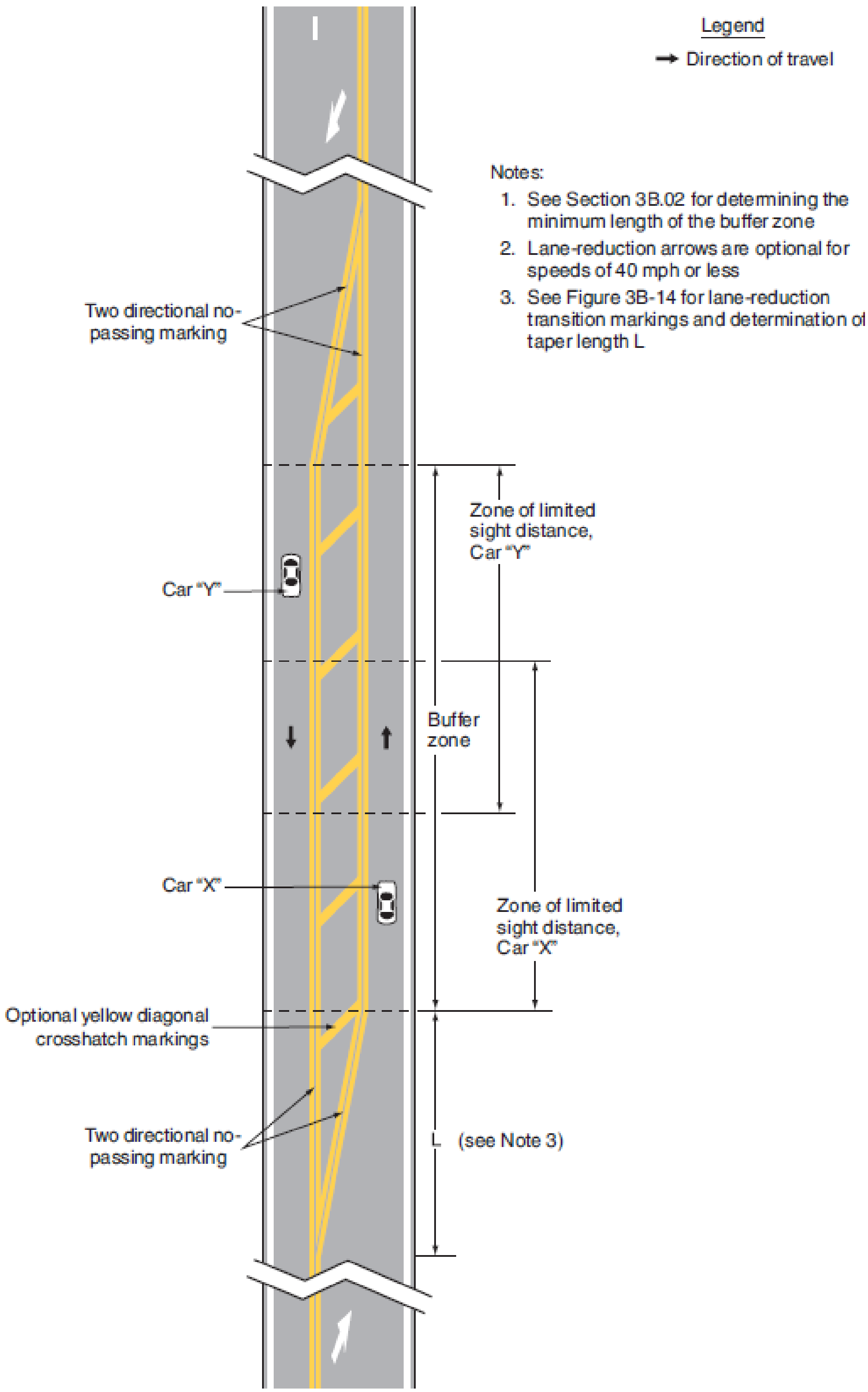

Figure 15. Example of Application of Three-Lane, Two-Way Marking for Changing Direction of the Center Lane (Figure 3B-5 in the TMUTCD [*19*]).

REFERENCES

1 Harwood, D.W. and A.D. St. John. *Operational Effectiveness of Passing Lanes on Two-Lane Highways.* Report No. FHWA/RD-86/195. U.S. Department of Transportation, Federal Highway Administration. June 1986.

2 Harwood, D.W. "Relationships Between Operational and Safety Considerations in Geometric Design Improvements." *Transportation Research Record No. 1512*. Transportation Research Board. Washington, DC. 1995.

3 Harwood, D.W. "Operational and Safety Experience with Passing Lanes." *ITE 1988 Compendium of Technical Papers*, September 25–29, 1988, pp. 321–325.

4 Wooldridge, M.D., C.J. Messer, B.D. Heard, S. Raghupathy, A.H. Parham, M.A. Brewer, and S. Lee. *Design Guidelines for Passing Lanes on Two-Lane Roadways (Super 2)*. Report No. FHWA/TX-02/4064-1. Texas Department of Transportation. Austin, TX. 2001.

5 Brewer, M.A., S.P. Venglar, L. Ding, K. Fitzpatrick, and B. Park. *Operations and Safety of Super 2 Corridors with Higher Volumes*. Report No. FHWA/TX-11/0-6135-1. Texas Department of Transportation. Austin, TX. 2011.

6 Brewer, M.A., T.D. Barrette, D. Florence, B. Glover, K. Fitzpatrick, and S.P. Venglar. *Capacity and Cost Benefits of Super 2 Corridors*. Report No. FHWA/TX-20/0-6997-R1. Texas Department of Transportation. Austin, TX. 2020.

7 *Roadway Design Manual*. Texas Department of Transportation. Austin, TX. 2018. http://onlinemanuals.txdot.gov/txdotmanuals/rdw/index.htm. Accessed July 2020.

8 Mutabazi, M.I., E.R. Russell, and R.W. Stokes. *Review of the Effectiveness, Location, Design, and Safety of Passing Lanes in Kansas*. Report No. K-TRAN: KSU-97-1. Kansas State University. Manhattan, KS. October 1999.

9 Harwood, D.W. and A.D. St. John. *Passing Lanes and Other Operational Improvements on Two-Lane Highways. Phase I Technical Report*. Report No. FHWA/RD-85-028. Federal Highway Administration. Washington, DC. July 1984.

10 Rinde, E.A. *Accident Rates vs. Shoulder Width: Two-Lane Roads, Two-Lane Roads with Passing Lanes*. Report No. CA-DOT-TR-3147-1-77-01. California Department of Transportation. Sacramento, CA. September 1977.

11 Gattis, J.L., R. Bhave, and L.K. Duncan. "Alternating Passing Lane Lengths." *Transportation Research Record No. 1961*. Transportation Research Board. Washington, DC. 2006.

12 "TxDOT Traffic Standard Sheet TS2(PL-1)-18: Texas Super 2 Passing Lanes (Separated and Alternating)." Texas Department of Transportation. Austin, TX. 2018. ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/traffic/ts2-1-18.pdf. Accessed July 2020.

13 "TxDOT Traffic Standard Sheet TS2(PL-2)-18: Texas Super 2 Passing Lanes (Side by Side Passing Lanes)." Texas Department of Transportation. Austin, TX. 2018. ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/traffic/ts2-2-18.pdf. Accessed July 2020.

14 *2011 Texas Manual on Uniform Traffic Control Devices (TMUTCD)—Revision 2*. Texas Department of Transportation. Austin, TX. 2014.

15 *TMUTCD Chapter 2B. Regulatory Signs, Barricades and Gates (Revised)*. Texas Department of Transportation. Austin, TX. 2014. http://ftp.dot.state.tx.us/pub/txdot-info/trf/tmutcd/2011-rev-2/2b.pdf. Accessed July 2020.

16 *TMUTCD Chapter 2D. Guide Signs—Conventional Roads*. Texas Department of Transportation. Austin, TX. 2014. http://ftp.dot.state.tx.us/pub/txdot-info/trf/tmutcd/2011-rev-2/2d.pdf. Accessed July 2020.

17 *TMUTCD Chapter 2C. Warning Signs and Object Markers*. Texas Department of Transportation. Austin, TX. 2014. http://ftp.dot.state.tx.us/pub/txdot-info/trf/tmutcd/2011-rev-2/2c.pdf. Accessed July 2020.

18 "Revision of Texas Super 2 (TS2) Standard Sheets." Texas Department of Transportation. Austin, TX. 2018. ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/traffic/memo3-16-18-1.pdf. Accessed July 2020.

19 *TMUTCD Chapter 3. Markings*. Texas Department of Transportation. Austin, TX. 2014. http://ftp.dot.state.tx.us/pub/txdot-info/trf/tmutcd/2011-rev-2/3.pdf. Accessed July 2020.