#	Date	Source	Name	Comment
1.	9/2/2025	Email	Randy M., PE, PTOE	Just read your supplement....a couple things to think about. 1. 25B-RW-01 and 25B-MKG-01 both are being reviewed by sponsors addressing lane drop and lane reduction issues - fyi (see attached) 2. Working with OSU we did some research on the stop line in advance of a marked crosswalk at a signal (see attached) - this is in review at TRB for potential presentation at the 2026 annual meeting 3. 24A-PED-02 was approved by council related to Section 4F.19 and pedestrian change interval (attached) 4. 25A-RW-01 addressed school when flashing and was approved by Council June 2025 (see attached) Randy [see attachments]
Follow-up	9/15/2025	Email	Randy M., PE, PTOE	Hi Eric - Hope you are doing well. I have attached my comments to the draft Oregon Supplement to the MUTCD. It focuses on the removal of the colored LRT signal indications (which were a part of the 2009 supplement). I understand the situation that FHWA has created for ODOT and this topic but felt it was important to comment. Safety issues of this type should not be taken simply as compliance issues unless research has demonstrated that basis in findings. This standard change in the 11th edition is a case that the safety for all road users is not well established. A draft of the type of research which could be undertaken is also attached. Please feel free to reach out to me if you have any questions. Take care and be safe Randy [see attachments]

National Committee on
Uniform Traffic Control Devices

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Item Number: 25B-MKG-01

NCUTCD PROPOSAL FOR CHANGES TO THE MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

COMMITTEE / TASK FORCE:	Markings Technical Committee
ITEM NUMBER:	25B-MKG-01
TOPIC:	Lane Reduction Markings
ORIGIN OF REQUEST:	Lane Reduction Signing and Markings MCTF
AFFECTED SECTIONS OF MUTCD:	3B.07, 3B12

DEVELOPMENT HISTORY:

Concurrence from RWSTC: 06/12/2025
Approved by Markings TC: 06/26/2025
Approved by NCUTCD Council: ....

This is a proposed change to the MUTCD that has been developed by a technical committee, joint committee, or joint task force of the NCUTCD. The NCUTCD is distributing this to its sponsoring organizations for review and comment. Sponsor comments will be considered in revising the proposal prior to NCUTCD Council consideration. This proposal does not represent a revision of the MUTCD and does not constitute official MUTCD standards, guidance, options, or support. If approved by the NCUTCD Council, the recommended changes will be submitted to FHWA for consideration for inclusion in a future MUTCD revision. The MUTCD can be revised only through the federal rulemaking process.

SUMMARY:

Since 2013, a joint effort between the Regulatory & Warning Signs Technical Committee and Markings Technical Committee has advanced research regarding lane reduction signing and markings. NCUTCD discussions regarding consistency of signing and differentiation of pavement marking types have informed the research cited in the preparation of this proposal. This proposal recommends retaining several changes made to the MUTCD with the release of the 11th Edition and implementing changes related to signing and pavement markings that are supported by research completed and released during the time the 11th Edition was in development.

This proposal only contains recommendations relating to markings; it is a companion to the Lane Reduction Signing proposal, 25B-RW-01.

DISCUSSION:

On freeways, expressways, and conventional roads, reductions in the number of lanes require the attention of road users. Where the reduction in the number of lanes is due to a “trap lane” or continuing lane terminating as a turning or exiting lane, guide signing provides the primary source of information for road users to make a choice regarding lane selection. Pavement markings provide information regarding the status of the lane and indicate the need to find and understand signing. Where the reduction in the number of lanes is due to a physical reduction in the number of lanes by means of a lane reduction taper, warning signs and pavement markings are the primary source of information.

Both types of lane reduction incur high workloads for road users, with increased intensity observed for both the Operation and Guidance Tasks. While the Navigation Task is not typically a factor in the second scenario, the physical reduction in the number of lanes, information acquisition for Guidance Task may be more intense, requiring frequent variations in seek distance, additional mirror glances, and head checks. For most free-flow roadways where a continuous right lane is terminated, these workload tasks affect more road users than if the left lane were terminated, and involve heavy vehicles and long vehicles, which use the right-most lane or lanes to promote order and reduce speed differentials in the left-most (passing) lanes. Typically, the left lane on free-flow roads such as freeways and expressways often exhibit lower occupancies due to the application of the basic rule, thus reducing the workload associated with lane change maneuvers required to vacate terminating left lanes.

Because there are two types of non-continuing lanes, it is crucial that pavement markings and signing are differentiated between physical reductions in the number of lanes and "lane drops," where a lane becomes a turn lane or exit-only lane. Further differentiation along the roadway segment leading into the lane reduction is accomplished using pavement marking and signing sequences that treat lane reductions and lane drops uniquely. The segments of roadway preceding, including, and following the lane reduction are divided into four zones, which are the upstream zone (ahead of the first warning sign), the approach zone (between the first warning sign and the beginning of the taper), the transition zone (along the lane reduction taper), and the downstream zone. The use of differing pavement markings in the approach zone and transition zone aids road users in discerning the presence of a non-continuing lane and the location of the beginning of the lane reduction taper. Corresponding differentiation in warning signs also allows for identification of the upstream advance warning and the beginning of the taper, the latter location requiring immediate action by the user. The length of the approach zone is typically congruent with Condition-A distance from Table 2C-3, and the taper length determined by applicable geometric design standards.

This proposal incorporates research results from the following study;

- Signing, in Combination with Lane Markings, in Advance of Lane Reduction Transitions, February 2019 (available at https://pooledfund.org/details/study/565 with download links under "Documents")

Proposed revisions to pavement markings in Part 3 are intended to increase the differentiation between continuing lanes, non-continuing lanes, and lane reduction tapers. This is accomplished by changing the pavement marking pattern adjacent to the terminating lane. Upstream of the high judgment distance in Table 2C-3, a broken lane line is indicated, no change from current practice. Within the approach zone to the lane reduction, a dotted lane line is used in conjunction with a solid lane line adjacent to the continuing lane, which indicates that movements out of the non-continuing lane are permissible, but movements into the lane are discouraged. This proposed marking pattern contrasts with the single dotted lane line used to separate a continuing lane from a non-continuing lane that does NOT terminate in a lane reduction but is instead a mandatory movement lane, where movement between the lanes is not discouraged. Along the length of the lane reduction taper, a dotted extension marking is proposed, indicating a change from a full-width lane to a lane reduction taper, consistent with existing practice in numerous states, including Illinois, Virginia, North Carolina, Florida, and other states that use these markings in areas where roadway geometry may not be apparent. The use of different patterns in the upstream, approach, and transition zones associated with a physical reduction in the number of lanes aids human and machine vehicle operators in differentiating between lane reductions and lane drops where the non-continuing lane does not terminate. Use of markings throughout the entire length of the sequence will aid vehicle operators in remaining centered in the continuing lane while also improving recognition of the lane reduction taper.

The proposed changes to Part 3 are summarized below:

- Modifying the text in Section 3B.07 for use of a dotted lane line in conjunction with a solid lane line adjacent to the continuing lane within the approach zone of entrance ramps
- Modifying Figure 3B-10 to match the proposed text changes in Section 3B.07
- Modifying the text in Section 3B.12 for use of a dotted lane line in conjunction with a solid lane line adjacent to the continuing lane within the approach zone of other lane reduction transitions
- Modifying Figure 3B-14 to match the proposed text changes in Section 3B.12

Proposed revisions by the Regulatory & Warning Signs Technical Committee in the companion proposal address the results of research related to the effectiveness of warnings signs for lane reductions. The R/W language proposes a new warning sign intended for use at the beginning of the lane reduction taper to clearly indicate the end of the full width of the non-continuing lane, reinforcing the change from the dotted lane line with solid line to the dotted extension line used along the length of the lane reduction taper. The use of taller delineator panels (similar to object markers) is addressed in the companion proposal while the use of chevrons in non-curvilinear segments is discouraged.

RECOMMENDED MUTCD CHANGES:

The following present the proposed changes to the current MUTCD within the context of the current MUTCD language. Proposed additions to the MUTCD are shown in blue underline and proposed deletions from the MUTCD are shown in ~~red strikethrough~~. Changes previously approved by NCUTCD Council (but not yet adopted by FHWA) are shown in green double underline for additions and ~~green double strikethrough~~ for deletions. In some cases, background comments may be provided with the MUTCD text. These comments are indicated by [bracketed white text in shaded green]. Deletions made by a technical committee, joint committee, or task force after initial distribution to sponsoring organizations are shown in ~~highlighted red strikethrough and sans-serif text~~. Additions made by a technical committee, joint committee, or task force after initial distribution to sponsoring organizations are shown in underline blue and sans-serif text.

PART 3
MARKINGS

CHAPTER 3B. PAVEMENT AND CURB MARKINGS

Section 3B.07 White Lane Line Markings for Non-Continuing Lanes

Standard:

01 **A normal width dotted white line marking shall be used as the lane line to separate a through lane that continues beyond the interchange or intersection from an adjacent deceleration or acceleration lane.**

02 **For exit ramps with a parallel deceleration lane, a normal width dotted white lane line extension shall be installed from the upstream end of the taper to the theoretical gore or to the upstream end of a solid white lane line, if used, that extends upstream from the theoretical gore as shown in Drawings A and C in Figure 3B-9.**

03 **For an exit ramp with a tapered deceleration lane, a normal width dotted white line extension shall be installed from the theoretical gore through the taper area such that it meets the edge line at the upstream end of the taper as shown in Drawing B in Figure 3B-9.**

04 **For entrance ramps with a parallel acceleration lane, a normal width dotted white lane line shall be installed from the theoretical gore or from the downstream end of a solid white lane line, if used, that extends downstream from the theoretical gore, to a point at least one-half the distance from the theoretical gore to the downstream end of the acceleration taper, as shown in Drawing A in Figure 3B-10.**

Option:

04a For entrance ramps with a parallel acceleration lane, a double white line consisting of a normal width solid white line adjacent to traffic traveling in the continuing lane, and a normal width dotted white lane line adjacent to traffic traveling in the acceleration lane, may be installed from the theoretical gore or from the downstream end of a solid white lane line, if used, that extends downstream from the theoretical gore, to a point at least one-half the distance from the theoretical gore to the upstream end of the acceleration taper, as shown in Drawing A in Figure 3B-10.

05 For entrance ramps with a parallel acceleration lane, a normal width dotted white line extension may be installed from the downstream end of the dotted white lane line to the downstream end of the acceleration taper, as shown in Drawing A in Figure 3B-10.

06 For entrance ramps with a tapered acceleration lane, a normal width dotted white line extension may be installed from the downstream end of the channelizing line adjacent to the through lane to the downstream end of the acceleration taper, as shown in Drawings B and C in Figure 3B-10.

Standard:

07 **A wide dotted white lane line shall be used:**

A. As a lane drop marking in advance of lane drops at exit ramps to distinguish a lane drop from a normal exit ramp (see Drawings A, B, and C in Figure 3B-11),

B. In advance of freeway route splits with dedicated lanes (see Drawing D in Figure 3B-11),

C. In advance of freeway route splits with an option lane (see Drawing E in Figure 3B-11),

D. To separate a through lane that continues beyond an interchange from an adjacent continuous auxiliary lane between an entrance ramp and an exit ramp (see Drawing F in Figure 3B-11),

E. As a lane drop marking in advance of lane drops at intersections to distinguish a lane drop from an intersection through lane (see Drawing A in Figure 3B-12), and

F. To separate a through lane that continues beyond an intersection from an adjacent auxiliary lane between two intersections (see Drawing B in Figure 3B-12).

Guidance:

08 *Lane drop markings used in advance of lane drops at freeway and expressway exit ramps should begin at least ½ mile in advance of the theoretical gore.*

09 *On the approach to a multi-lane exit ramp having an optional exit lane that also carries through traffic, lane line markings should be used as illustrated in Drawing B in Figure 3B-11.*

10 *Lane drop markings used in advance of lane drops at intersections should begin a distance in advance of the intersection that is determined by engineering judgment as suitable to enable drivers who do not desire to make the mandatory turn to move out of the lane being dropped prior to reaching the queue of vehicles that are waiting to make the turn. The lane drop markings should begin no closer to the intersection than the most upstream regulatory or warning sign associated with the lane drop.*

11 *The dotted white lane lines that are used for lane drop markings and that are used as a lane line separating through lanes from auxiliary lanes should consist of line segments that are 3 feet in length separated by 9-foot gaps.*

Support:

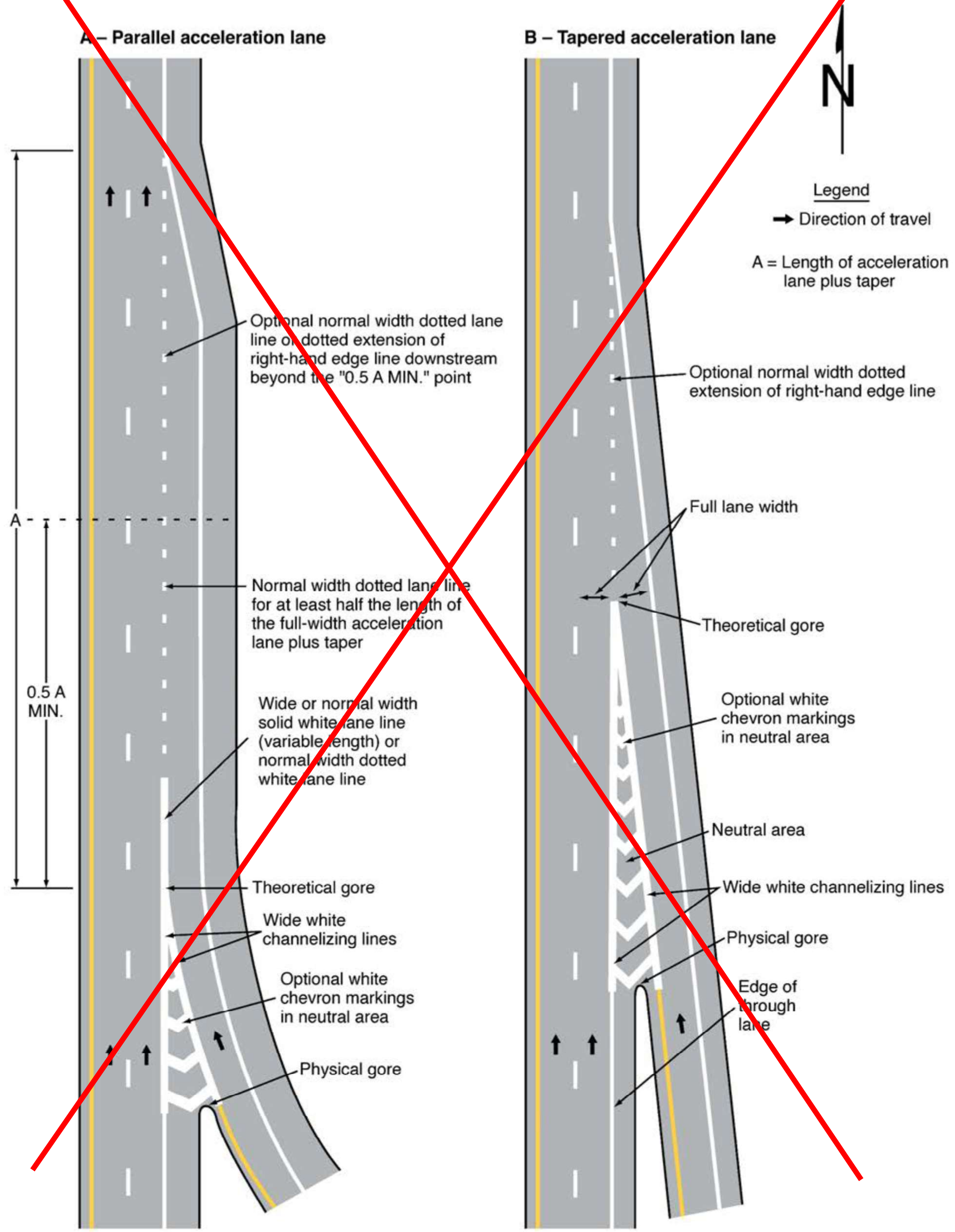
12 Sections 3B.21 and 3B.23 contain information regarding other markings that are associated with lane drops, such as ONLY word pavement markings and lane-use arrows.

13 Section 3B.12 contains information about the lane line markings that are to be used for transition areas where the number of through lanes is reduced at a location that is not at an interchange or intersection.

Option:

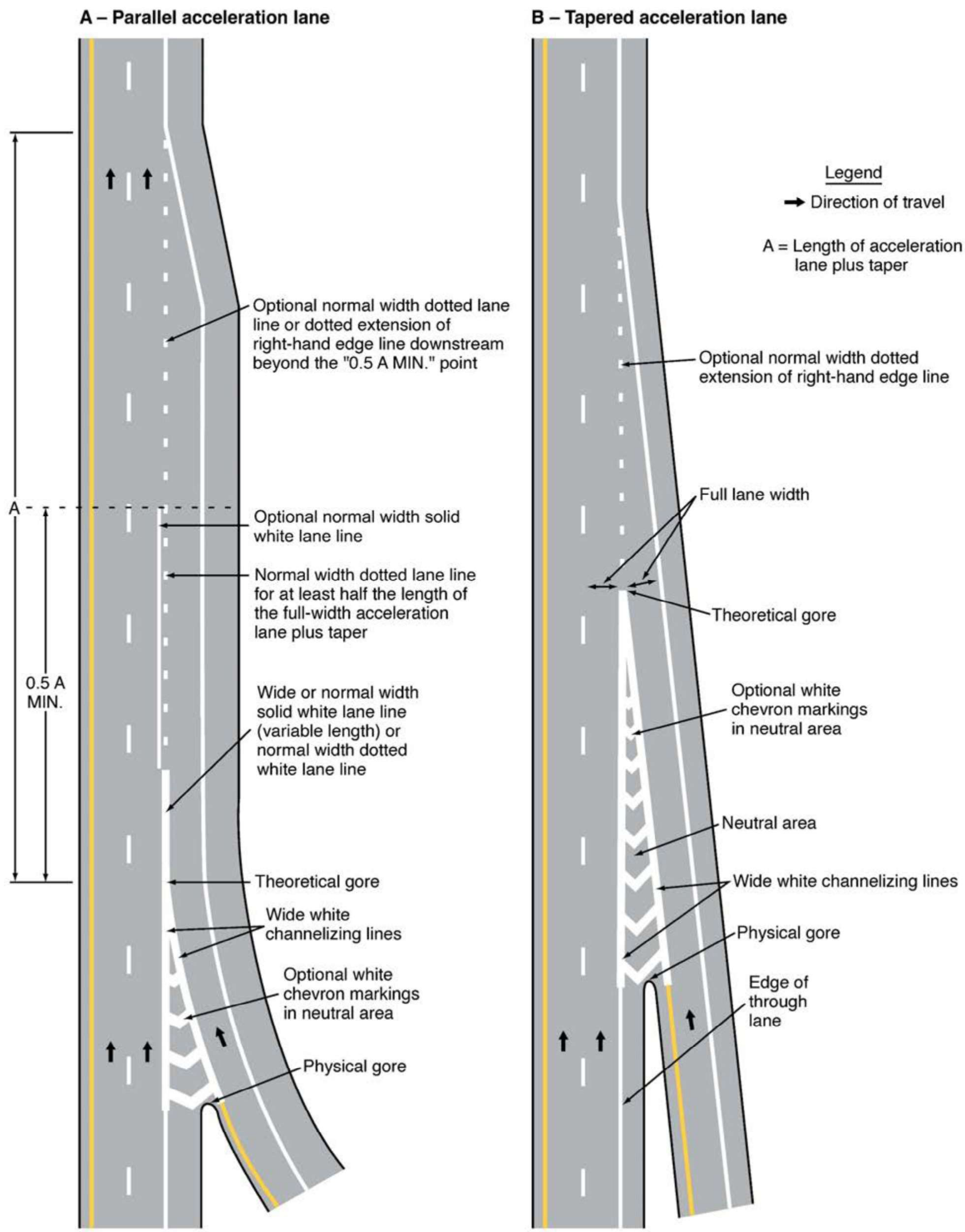
14 In the case of a lane drop at an exit ramp or intersection, a solid white line may replace a portion, but not all of the length, of the wide dotted white lane line.

Figure 3B-10. Examples of Dotted Line and Channelizing Line Applications for Entrance Ramp Markings (Sheet 1 of 2)



202

Figure 3B-10. Examples of Dotted Line and Channelizing Line Applications for Entrance Ramp Markings (Sheet 1 of 2)



203

Section 3B.12 Lane-Reduction Transitions

Support:

01 A lane-reduction is where the number of through lanes is reduced at a location that is not at an interchange or intersection because of narrowing of the roadway or because of a section of on-street parking in what would otherwise be a through lane.

02 Section 3B.07 contains information on pavement markings for lane drops and splits.

03 Section 2C.47 contains information for warning signing used for lane reductions.

Standard:

04 Lane-reduction transitions (see Figure 3B-14) shall include the following elements:

A. A no-passing zone (see Section 3B.03) to prohibit passing in the direction of the convergence and through the transition area except where not applicable such as one-way streets, expressways, and freeways; and

B. An edge line (see Section 3B.09) in the direction of the convergence and through the transition area, except as provided in Paragraph 6 of this Section.

Guidance:

05 *Except as provided in Paragraph 6 of this Section, the edge line marking should be installed from the location of the Lane Ends warning sign to beyond the beginning of the narrower roadway.*

Option:

06 On roadways with operating speeds less than 25 mph where curbs clearly define the roadway edge in the lane-reduction transition, or where a through lane becomes a parking lane, the edge line may be omitted as determined by engineering judgment.

Guidance:

07 *Lane-reduction transitions should include the following elements:*

A. Delineators installed adjacent to the lane or lanes reduced for the full length of the transition and should be so placed and spaced (see Section 3G.04) to show the reduction except as provided in Paragraph 13 of this Section and except as provided in Paragraph 2 of Section 3G.03 for freeways and expressways,

B. Lane-reduction arrow markings (see Drawing ~~F~~ I in Figure 3B-21) [Listed as a known error by FHWA] *on the roadway with a speed limit of 45 mph or more, and*

C. A termination of the broken white lane line at ~~a point that is ¼ of~~ the advance placement distance (see Section 2C.04) between the Lane Ends sign (see Section 2C.47) and the point where the transition taper begins.

D. A double white line consisting of a normal width solid white line adjacent to traffic traveling in the continuing lane, and a normal width dotted white lane line adjacent to traffic traveling in the non-continuing lane, between the point where the broken white line is terminated to the point where the transition taper begins.

08 *For roadways having a speed limit of 45 mph or greater, the transition taper length for a lane-reduction transition should be computed by the formula L = WS, where L equals the taper length in feet, W equals the width of the offset distance in feet, and S equals the 85th-percentile speed or the speed limit in mph, whichever is higher. For roadways where the speed limit is less than 45 mph, the formula* $L = WS^2/60$ *should be used to compute the taper length.*

09 *The minimum lane reduction transition taper length should be 100 feet in urban areas and 200 feet in rural areas.*

10 *Where observed speeds exceed speed limits, longer tapers should be used.*

Option:

10a A normal width dotted white lane line or dotted white line extension may be installed from the point where the transition taper begins to the point where the transition taper ends.

11 The minimum taper length may be less than 100 feet on roadways where the operating speed is less than 25 mph.

12 On new construction, where no speed limit has been established, the design speed may be used in the transition taper length formula.

13 On low-speed urban roadways where curbs clearly define the roadway edge in the lane-reduction transition, or where a through lane becomes a parking lane, delineators may be omitted as determined by engineering judgment.

14 Where a lane-reduction transition occurs on a roadway with a speed limit of less than 45 mph, lane-reduction arrow markings may be used.

15 Lane-reduction arrow markings may be used in long acceleration lanes based on engineering judgment.

~~16 A dotted white line may be used between the point where the broken white lane line is terminated to the point where the transition taper begins.~~ [Text included as part of Paragraph 07 Part D and changed from a “may” to a “should” condition]

Figure 3B-14. Examples of Applications of Lane-Reduction Transition Markings

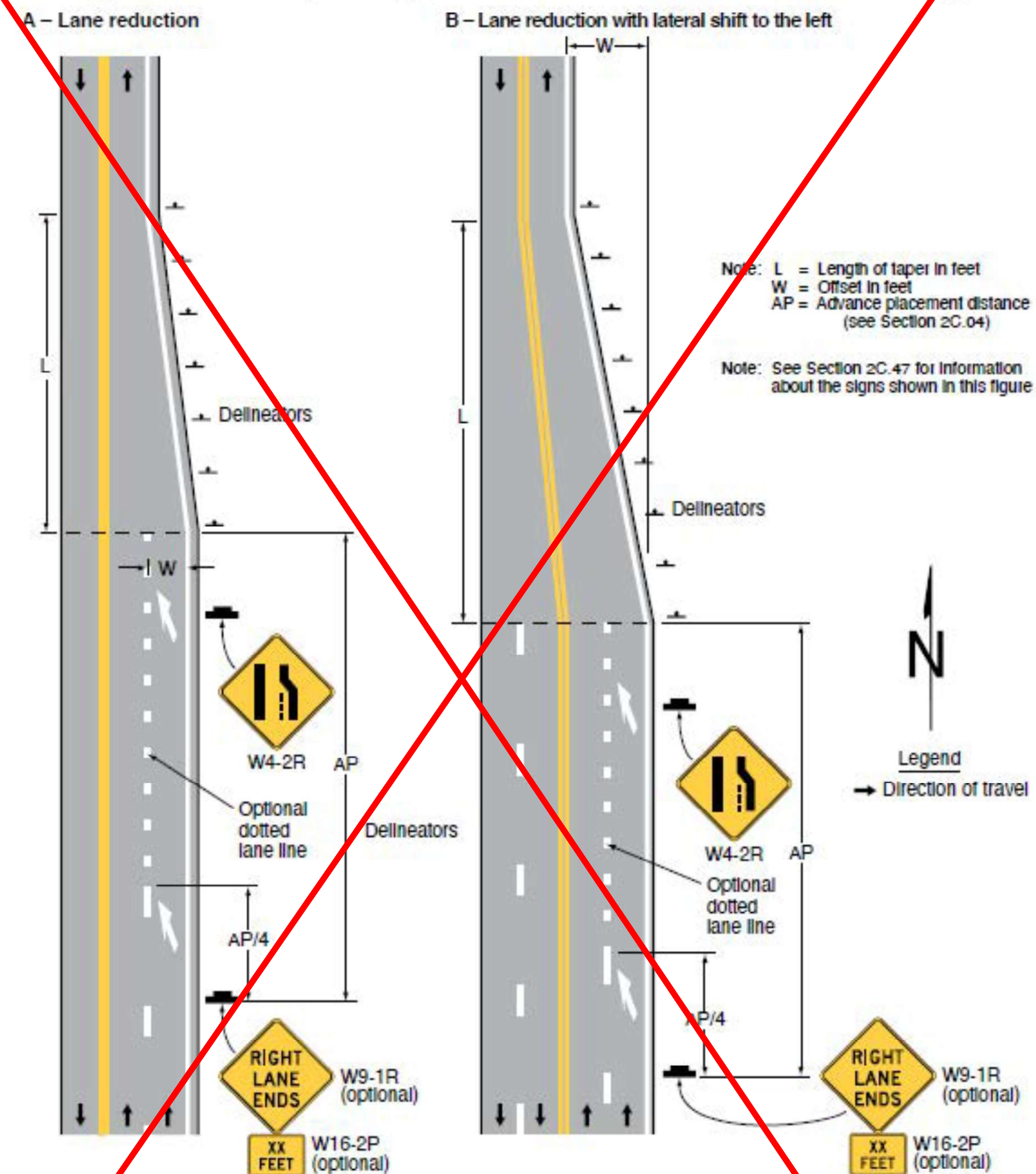


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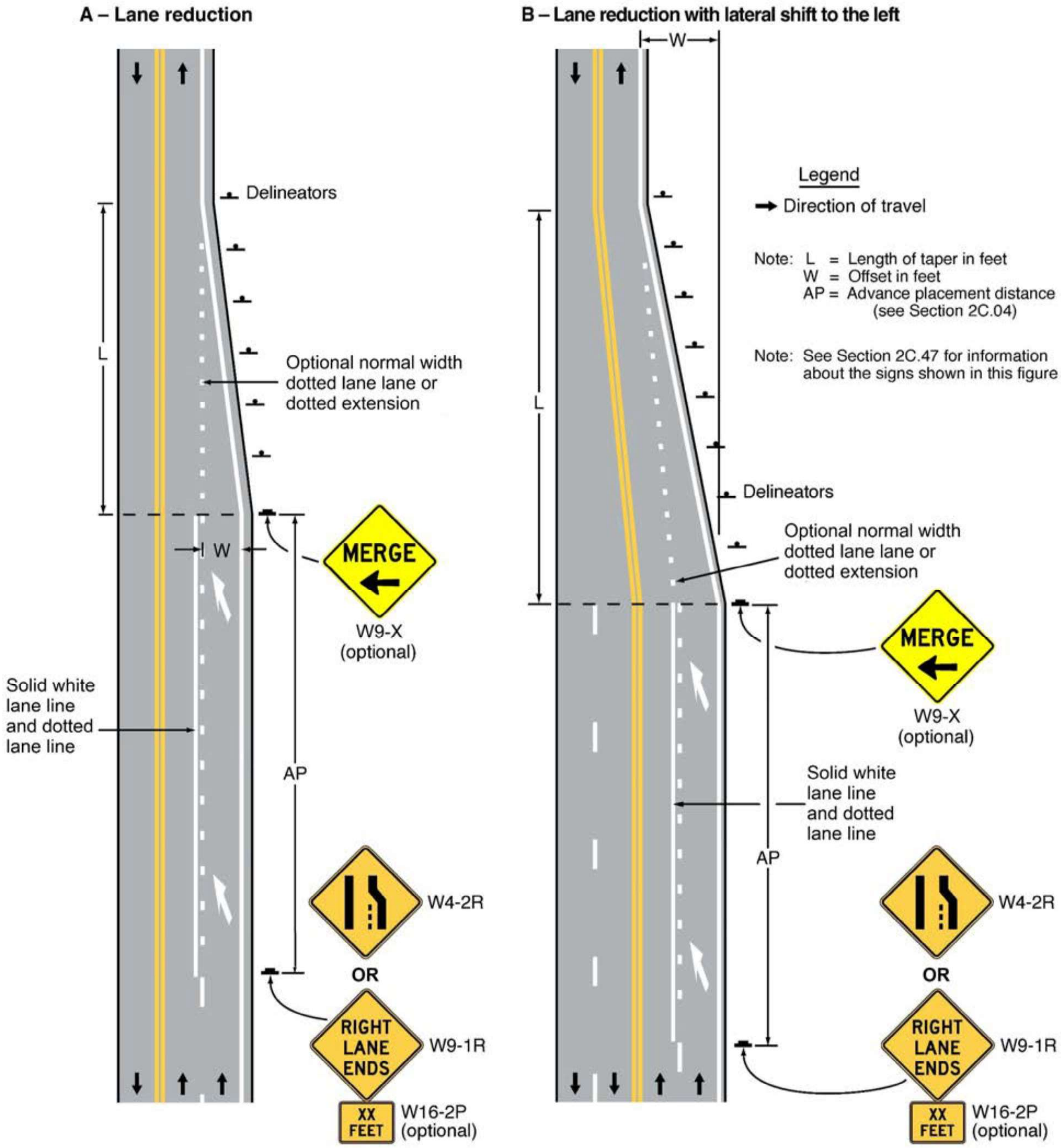
Figure 3B-14. Examples of Applications of Lane-Reduction Transition Markings



[Similar changes will be made to markings and sign type/location on Figure 2C-13 in the 25B-RW-01 companion proposal]

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Item Number: 25B-RW-01

NCUTCD PROPOSAL FOR CHANGES TO THE MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

COMMITTEE / TASK FORCE:	Regulatory and Warning Sign Technical Committee
ITEM NUMBER:	25B-RW-01
TOPIC:	Lane Reduction Signing
ORIGIN OF REQUEST:	Lane Reduction Signing and Markings MCTF
AFFECTED SECTIONS OF MUTCD:	2C.08, 2C.47 Figures 2B-16, 2C-11, 2C-13A-E, 2C-16

DEVELOPMENT HISTORY:

Approved by RWSTC: 06/12/2025
Concurrence from Markings TC:...06/26/2025
Approved by NCUTCD Council: ....

This is a proposed change to the MUTCD that has been developed by a technical committee, joint committee, or joint task force of the NCUTCD. The NCUTCD is distributing this to its sponsoring organizations for review and comment. Sponsor comments will be considered in revising the proposal prior to NCUTCD Council consideration. This proposal does not represent a revision of the MUTCD and does not constitute official MUTCD standards, guidance, options, or support. If approved by the NCUTCD Council, the recommended changes will be submitted to FHWA for consideration for inclusion in a future MUTCD revision. The MUTCD can be revised only through the federal rulemaking process.

SUMMARY:

Termination of a continuing lane or lanes often incurs high workloads on road users. Road users in the terminating lane must change lanes or execute a merge maneuver, often in traffic moving at free-flow speeds. Research conducted through the Traffic Control Devices Pooled Fund Study indicates opportunities to improve the consistency and differentiation of current signing and pavement marking practices, providing clarity with regard to the end state of the non-continuing lane.

DISCUSSION:

Where road users cannot readily determine the end state of a non-continuing lane, increases in workload are likely to incur characteristic patterns of crashes. Prevalence of certain crash types is further exacerbated by horizontal alignment, vertical alignment, large volumes of truck traffic, lane width, and the absence of shoulders.

Differentiated approaches to signing and pavement markings ahead of a lane termination can be used to identify the ultimate state of the non-continuing lane, whether it is a lane drop (a mandatory turn or exiting lane) or a lane reduction. Depictions of the differences between lane drops and lane reductions for various scenarios are included in Figure 1.

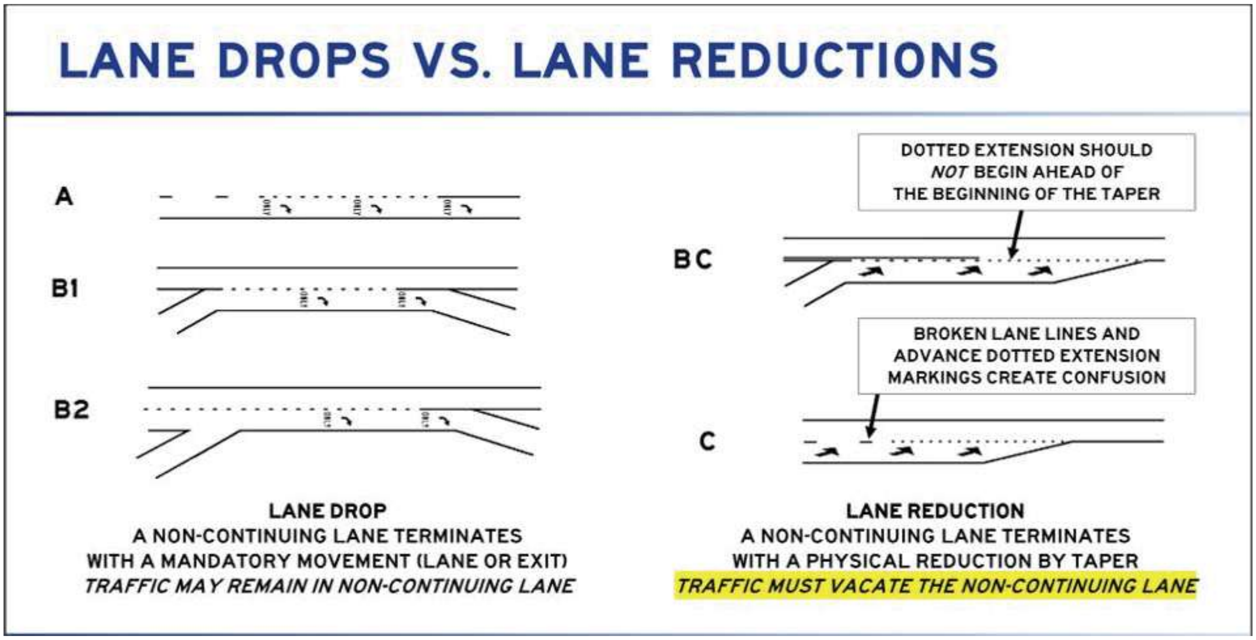


Figure 1. Illustrations comparing lane drops and lane reductions

Road users approaching any lane termination typically exhibit frequent variations in seek distance, additional mirror glances, head turns for conflict checks, and adjustments in speed. Observed workload is higher for right lane terminations due to increased fraction of heavy vehicles in the right lane. Clear identification of the distance to the beginning of the lane reduction taper can help users manage workload and plan ahead to mitigate conflicts.

Existing practices for signing lane reductions (a physical reduction in the number of lanes by means of a taper) continue to vary, despite changes incorporated in the 11th Edition of the MUTCD. While the RIGHT LANE ENDS (W9-1) sign is intended for placement at an upstream location (typically the advance placement distance) some network operators substitute the "Lane Ends" (W4-2) symbol sign at the advance placement distance. Inconsistencies occur when the W4-2 symbol sign is also used closer to the lane reduction taper, often supplementing an upstream sign or alone in locations where warning signs cannot be installed at the distance specified in Table 2C-3, such as ahead of lane reduction tapers on short entrance ramps and on single-direction roadways departing an intersection.

Differentiated signing and markings on the approach to the lane reduction taper can further clarify the location of the beginning of the taper itself, facilitating road user recognition of anticipated workload according to the various segments identified in Figure 2 on the following page. The segment of roadway preceding and including the lane reduction is divided into three segments, illustrated in Figure 2. The characteristics of user workload within each segment vary, with increases in workload beginning in the upstream zone (ahead of the first warning sign, typically placed at the distance specified in Table 2C-3) and diversifying in the approach zone (between the warning sign at the conforming advance placement distance and the beginning of the taper). Depending on conditions, workload is maximized in the transition zone (along the lane reduction taper) and tapers at various rates in the downstream zone.

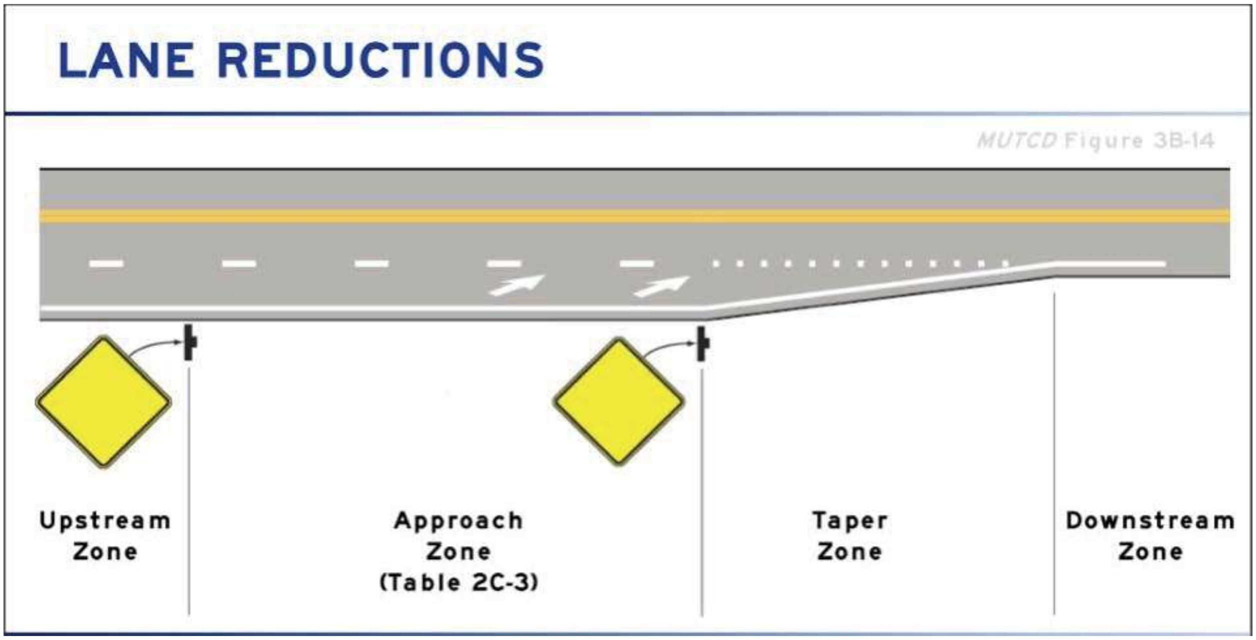


Figure 2. Workload zones approaching a lane reduction taper, where the "Taper Zone" is also referred to as a "transition taper" or "Transition Zone". (This figure displays pavement markings from a previous edition of the *MUTCD.*)

Consistency of information display between locations with similar characteristics can reduce the prevalence of unnecessary or erratic lane changes, unnecessary late merging, and overall workload and stress for road users. When signing and markings are varied according to the distance to lane reduction taper, road users will identify a relationship between sign placement and the *time* available before the vehicle passes the beginning of the lane reduction taper.

Proposed Changes advanced by the Regulatory & Warning Signs TC allow for a variety of existing practices, incurring few changes for agencies that use either sign or a combination of both signs. The proposal also introduces a sign that research indicated performs exceptionally well and is intended solely for use at the beginning of the lane reduction taper. Proposed Changes advanced by the Markings TC will address the results of research related to differentiating between a broken lane line and a dotted lane line to identify the beginning of the lane reduction taper and using a solid line to differentiate between locations where the non-continuing lane is a lane reduction and not a lane drop.

Summary of Related Research Results

Since 2013, a joint effort between the Regulatory & Warning Signs Technical Committee (RWSTC) and Markings Technical Committee (MTC) has advanced research regarding lane reduction signing and pavement markings. NCUTCD discussions regarding consistency of signing and differentiation of pavement marking types have informed the research cited in the preparation of proposed changes.

This Proposed Change incorporates ongoing and related research results published within the past ten years, including four Traffic Control Devices Pooled Fund Studies, listed below.

- Lane Line Markings in Advance of Lane-Reduction Transitions, February 2016
- Comprehension and Legibility of Selected Symbol Signs Phase IV, December 2017
- Signing, in Combination with Lane Markings, in Advance of Lane Reduction Transitions, February 2019
- Sign Guidance for Late Merge, June 2023

These studies are available at https://pooledfund.org/details/study/565 with download links.

The research cited above produced results related to the performance of a variety of warning signs used by agencies in the United States. Specifically, the "Comprehension and Legibility of Selected Symbol Signs" report provided results associated with the performance of signs most commonly used in the United States, including the RIGHT LANE ENDS (W9-1) word message sign and the Lane Reduction (W4-2) symbol sign, which closely resembles the symbol sign used to warn of lane reductions in Canada. Additionally, the researchers examined the performance of signs commonly used in the vicinity of the beginning of the lane reduction taper, including a sign featuring the legend MERGE with a Type A Arrow pointing in the direction of the merging maneuver. Signs from the research that tested most positively are displayed in Figure 3, with both versions of the MERGE with Type A Arrow signs included for clarity.

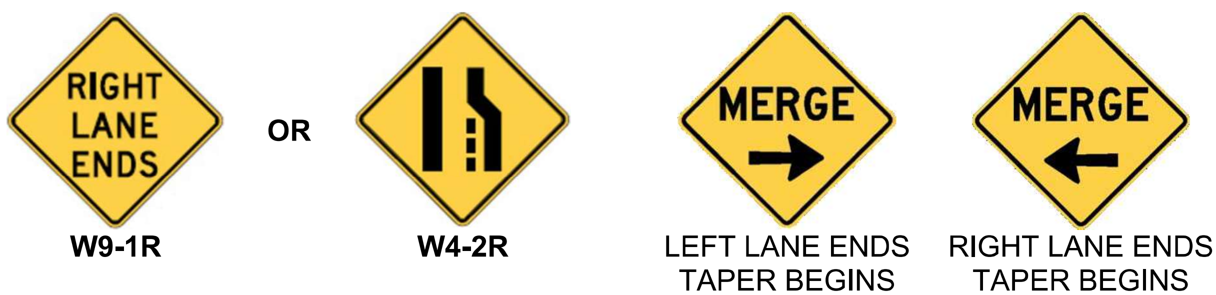


Figure 3. Illustrations of the highest-performing existing signing and the Mn/DOT MERGE with Type A Arrow sign.

Among existing signs, the W9-1 RIGHT LANE ENDS sign scored highest for clarity and consistency with the roadway geometry. The RIGHT LANE ENDS sign was ranked highest among more than three-quarters of the participants for conveying the meaning that a physical lane reduction would be occurring downstream and accumulated the lowest number of overall incorrect responses in comprehension and response testing. In current practice, the RIGHT LANE ENDS sign is typically placed at the conforming advance placement distance even as some agencies substitute the W4-2 Lane Reduction symbol sign.

The W4-2 "Lane Reduction" symbol sign, used interchangeably with the RIGHT LANE ENDS sign and occasionally used along the transition zone, incurred some confusion regarding the immediacy of its message. While this sign did score highly for the message "right lane ends", respondents confused the meanings of "right lane ends" and "merge", indicating that its message failed to consistently contrast with the immediacy of a forced merge. The W4-2 symbol sign was frequently mistaken for the message of "lanes narrow", which does not produce the same response, that is, respondents vacating the non-continuing lane. This sign did produce the longest visibility distance, however, likely on account of the graphical display.

The “MERGE with Type Arrow” sign, as illustrated in Figure 3, has been used by the Minnesota Department of Transportation for temporary traffic control applications and in permanent installations since the 1990s. Observed installations from agencies throughout the region exhibit consistency with regard to limiting placement in locations adjacent to the beginning of the taper. Field observations in Minnesota indicate a desirable road user response in both permanent and temporary traffic control applications while the robust simplicity of the consistently-applied message exhibits similar results in “zipper merge” applications.

Agencies using this sign typically provide advance warning signs whenever possible, as this sign is not intended to be used as an advance warning sign. It can, however, be used alone in locations where advance warning signs are not installed. MERGE with Type A Arrow signs featuring a left-facing arrow are intended for placement on the right-hand side of the roadway in locations where the right lane ends. Correspondingly, the sign with the left arrow is intended for placement on the left-hand side of the roadway in locations where the left lane ends.

Respondents in the study stated that this sign means “merge” or “lane ends, merge”, demonstrating the sign’s applicability to the transition zone. Furthermore, researchers concluded that a high fraction of responses indicating solely the message of “merge” indicates a strong likelihood of immediate action by the road user. While dissimilar to the RIGHT LANE ENDS sign in terms of the perceived immediacy of the message, the MERGE with Type A Arrow sign performed highly with regard to a low likelihood of mistaking between right and left, a shortcoming of other tested signs. These results suggest that this sign is not intended as a replacement for the RIGHT LANE ENDS sign and is not interchangeable with the W4-2 Lane Reduction symbol sign.

Allowing for the use of both the W9-1 and W4-2 signs as advance warning signs accommodates most existing practices and aids users in consistently assessing the location of the taper with regard to time, a factor in the calculation of the advance placement distances listed in Table 2C-3. Research indicated that these signs performed well when used in advance of the condition and solely to warn traffic approaching locations where continuing lanes terminate in a lane reduction.

These three recommended signs and the associated pavement markings appear to produce the largest fraction of high-performing responses in both comprehension and road user response in testing. The patterns of those responses indicate the presence of these three logic-based relationships associated with the use of research-recommended traffic control devices.
- Differentiation of action by the road user can be achieved by illustrating a contrast between non-continuing lanes terminated with a mandatory movement (“lane drop”) and lanes terminated by a physical reduction by taper in the number of lanes (“lane reduction)”.
- Differentiation regarding the location of the beginning of the taper can be achieved by using a sequence of unique sign installations associated in various stages of workload that produce responses associated with a desired action and degree of primacy.
- Differentiation in message primacy (*time* to a forced maneuver) can be achieved through the consistency in applying associated specific signs and specific pavement markings in locations most associated with the desired user understanding and response.

Summary of Proposed Changes

This proposal contains recommendations relating solely to signing. The pavement markings depicted in the figures in this proposal are representative of the research results associated with the signing and pavement markings proposed for lane reductions in the cited studies. Figures shown in this proposal will be modified as needed to match the configuration of pavement markings upon approval of the companion MTC item by the NCUTCD Council.

Proposed revisions to signing in Chapter 2C are summarized in this list, which is arranged by the order in which signs would appear in sequence. These changes apply signing in locations where users inferred a related message and meaning, indicating the need to accentuate differentiation of messages among signs placed at various distances.

- Restricting the use of the RIGHT LANE ENDS sign to installation at the specified advance placement distance for a high-judgment maneuver in Table 2C-3
- Renaming the Lane Ends sign to the Lane Reduction Symbol sign and limiting its use as a replacement for the RIGHT (LEFT) LANE ENDS sign, harmonizing the use of this sign with the corresponding and similar symbol sign used in Canada, which is typically used solely as an advance warning sign
- Increasing the Level of Mandate for the use of distance plaques (W16-series) in conjunction with advance warning signs (W9-1 and W4-2) placed further in advance or at an alternative location not consistent with the distance specified in Table 2C-3, to provide increased awareness that the distance to the lane reduction taper is atypical
- Adding a new sign, the W9-X MERGE WITH ARROW sign, intended for placement at or near the beginning of the lane reduction taper, to clearly indicate the location of the taper, particularly in locations where an advance warning sign cannot be provided or where sight distance or traffic characteristics limit the visibility of the beginning of the lane reduction transition
- Adding a new sign, the W-16X BEYOND INTERSECTION plaque, intended for placement beneath W9-1 installed in advance of an intersection preceding a lane reduction occurring on the other side of the intersection
- Prohibiting the use of chevrons for lane reduction tapers and clarifying the use of chevrons for curvilinear geometric features
- Revising all of the depictions in Figure 2C-13 to display changes in the use of warning signs, displaying pavement markings indicated by the results of the cited research

RECOMMENDED MUTCD CHANGES:

The following present the proposed changes to the current MUTCD within the context of the current MUTCD language. Proposed additions to the MUTCD are shown in blue underline and proposed deletions from the MUTCD are shown in ~~red strikethrough~~. Changes previously approved by NCUTCD Council (but not yet adopted by FHWA) are shown in green double underline for additions and ~~green double strikethrough~~ for deletions. In some cases, background comments may be provided with the MUTCD text. These comments are indicated by [bracketed white text in shaded green]. Deletions made by a technical committee, joint committee, or task force after initial distribution to sponsoring organizations are shown in ~~highlighted red strikethrough and sans-serif text~~. Additions made by a technical committee, joint committee, or task force after initial distribution to sponsoring organizations are shown in underline blue and sans-serif text.

PART 2

SIGNS

CHAPTER 2C. WARNING SIGNS AND OBJECT MARKERS

Section 2C.08 Chevron Alignment Sign (W1-8)

Standard:

01 The use of the Chevron Alignment (W1-8) sign (see Figures 2C-1 and 2C-2) to provide additional emphasis and guidance for a change in horizontal alignment shall be in accordance with the information shown in Table 2C-4.

Option:

02 Chevron Alignment signs may be used instead of or in addition to standard delineators~~.~~ to emphasize curvilinear changes in roadway alignment.

Standard:

03 The Chevron Alignment sign shall be a vertical rectangle. No border shall be used on the Chevron Alignment sign.

04 If used, Chevron Alignment signs shall be installed on the outside of a turn or curve, in line with and at approximately a right angle to approaching traffic. Chevron Alignment signs shall be installed at a minimum height of 4 feet, measured vertically from the bottom of the sign to the elevation of the near edge of the traveled way.

Guidance:

05 The approximate spacing of Chevron Alignment signs on the turn or curve measured from the point of curvature (PC) should be as shown in Table 2C-5.

06 The Chevron Alignment signs should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.

Option:

07 LEDs may be used to enhance the conspicuity of Chevron Alignment signs (see Section 2A.12).

Standard:

08 The LEDs used in the Chevron Alignment sign shall consist of yellow LEDs outlining the chevron symbol.

09 Chevron Alignment signs shall not be placed on the far side of a T-intersection facing traffic on the stem approach to warn drivers that a through movement is not physically possible, as this is the function of a Two-Direction (or One-Direction) Large Arrow sign.

10 Chevron Alignment signs shall not be used to mark obstructions within or adjacent to the roadway, including the beginning of guardrails or barriers, as this is the function of an object marker (see Section 2C.70).

11 Chevron Alignment signs directing traffic to the right shall not be used in the central island of a roundabout or a neighborhood traffic circle.

Standard:

12 Chevron Alignment signs shall not be used along lane reduction transitions or in conjunction with other linear tapers such as lane width transition tapers or offset transition tapers.

Section 2C.47 Lane Ends Signs (W4-2 ~~and~~ or W9-1, W9-X, and W16-XP)

Support:

01 The RIGHT (LEFT) LANE ENDS (W9-1) sign and Lane ~~Ends~~ Reduction (W4-2) symbol sign ~~and RIGHT (LEFT) LANE ENDS (W9-1) signs~~ (see Figure 2C-11) are used to provide advance warning of the reduction in the number of traffic lanes in the direction of travel. The W9-X MERGE with arrow sign is used to indicate the beginning of a lane reduction taper.

02 The sequence of the W4-2 ~~and~~ or W9-1 and the W9-X signs is illustrated in Figure 2C-13.

02a The W4-2 sign is not considered interchangeable with the W9-X sign.

Guidance:

03 A RIGHT (LEFT) LANE ENDS (W9-1) ~~The Lane Ends (W4-2) sign~~ should be installed at the advance placement distance in accordance with Table 2C-3.

Option:

04 An additional RIGHT (LEFT) LANE ENDS (W9-1) sign may be installed upstream in advance of the ~~Lane Ends~~ sign posted at the distance specified in Table 2C-3 to provide additional warning that a lane is ending and that a merging maneuver will be required.

04a The Lane Reduction (W4-2) symbol sign may be installed as an alternative to the RIGHT (LEFT) LANE ENDS (W9-1) sign.

Guidance:

05 If an additional upstream or downstream W4-2 or W9-1 sign is installed, a Distance (W16-2P series or W16-3P series) plaque (see Figure 2C-16) should be installed below the W4-2 or W9-1 sign.

06 On one-way streets or on divided highways where the left-hand lane is ending and the width of the median will permit, the W9-1L and/or W4-2L signs should be placed facing approaching traffic on ~~the left-hand side or median~~ both sides of the roadway facing approaching traffic.

06a If a W9-1 (or W4-2) sign cannot be placed at the distance specified in Table 2C-3 and must be placed closer to the beginning of the taper, a Distance (W16-2P series or W16-3P series) plaque should be installed below the warning sign.

Option:

~~07 Where a lane ends a distance beyond the intersection that is less than the advance placement distance indicated in Table 2C-3, the W4-2 sign may be located at the far side of the intersection (see Sheet 4 of Figure 2C-13).~~ [Content relocated to new Paragraph 11c]

07a A single MERGE with arrow (W9-X) sign may be installed as the final sign in the sequence approaching a lane reduction, as near as practical to the beginning of the lane reduction taper.

07b In locations where a W9-1 (or W4-2) sign cannot be installed in advance of the lane reduction, such as along short acceleration lanes, a MERGE with arrow (W9-X) sign may be installed as near as practical to the beginning of the lane reduction taper.

~~*Guidance:*~~

~~*08 When the W4-2 sign is located at the far side of the intersection in accordance with Paragraph 7 of this Section, the W9-1 sign should be placed upstream of the intersection with the appropriate distance plaque.*~~ *[Content relocated to new Paragraph 11b]*

~~Support:~~

~~09 Section 3B.12 contains information regarding the use of pavement markings in conjunction with a lane reduction.~~ [Content relocated to new Paragraph 11d]

Guidance:

10 Lane ~~Ends~~ Reduction symbol (W4-2) signs should not be installed in advance of the downstream end of an acceleration lane.

Standard:

11 The W4-2 and W9-1 signs shall not be used in dropped lane situations, including EXIT ONLY lanes. In dropped lane situations on conventional roads at intersections, regulatory signs (see Section 2B.28) shall be used to inform road users that a through lane becomes a mandatory turn lane.

11a Installations of the W9-X sign shall be limited to the side of the road nearest the non-continuing lane such that the arrow displayed on the sign points into the roadway.

Option:

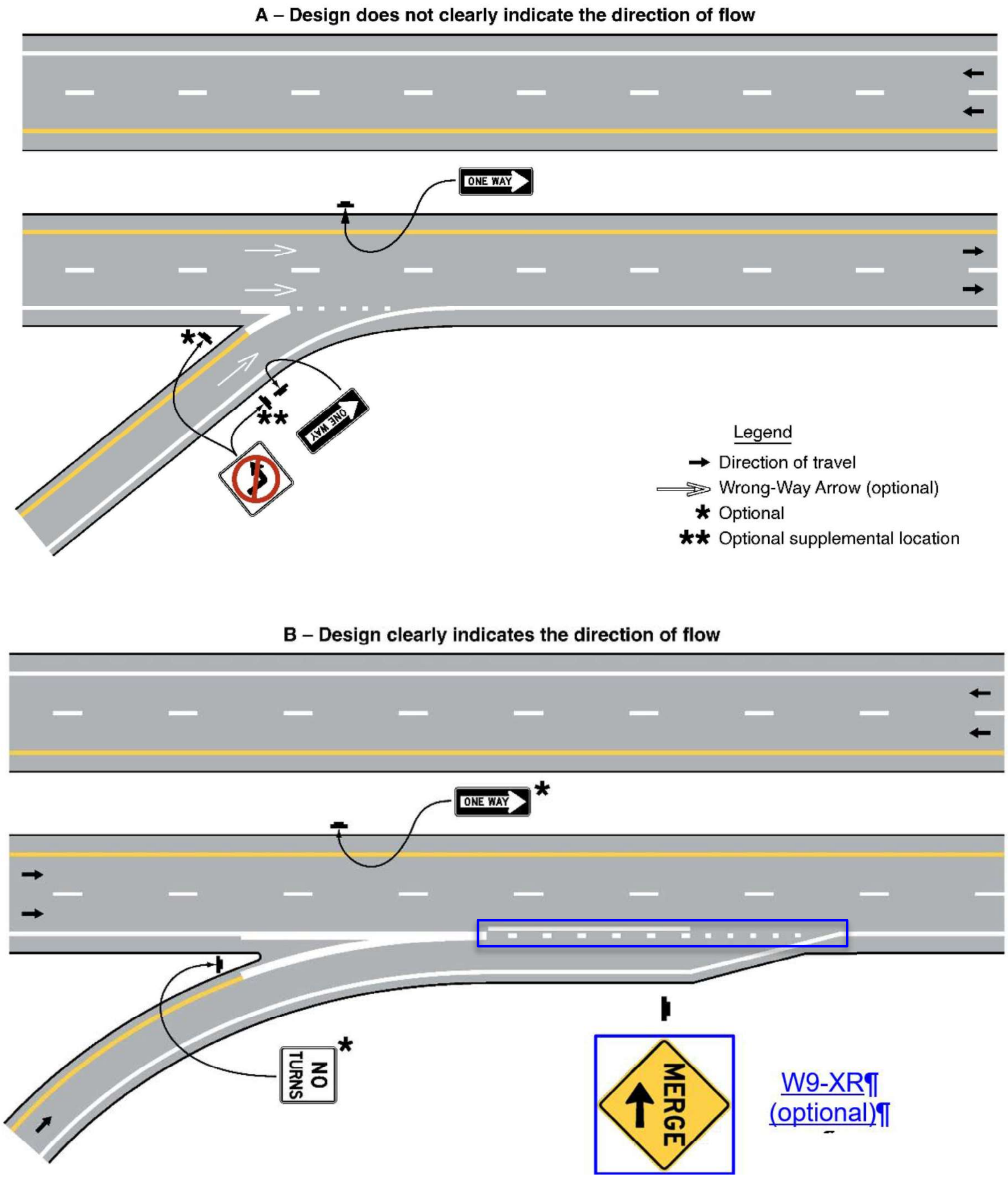
11b When the W4-2 sign is located at the far side of the intersection in accordance with Paragraph 11c of this Section, the W9-1 sign should be placed upstream of the intersection with a W16-X BEYOND INTERSECTION plaque or the appropriate distance plaque.

11c Where a lane ends a distance beyond the intersection that is less than the advance placement distance indicated in Table 2C-3, a W4-2 sign may be located at the far side of the intersection with a Distance (W16-2P-series or W16-3P-series) plaque mounted underneath the sign (see Sheet 4 of Figure 2C-13).

Support:

11d Section 3B.12 contains information regarding the use of pavement markings in conjunction with a lane reduction.

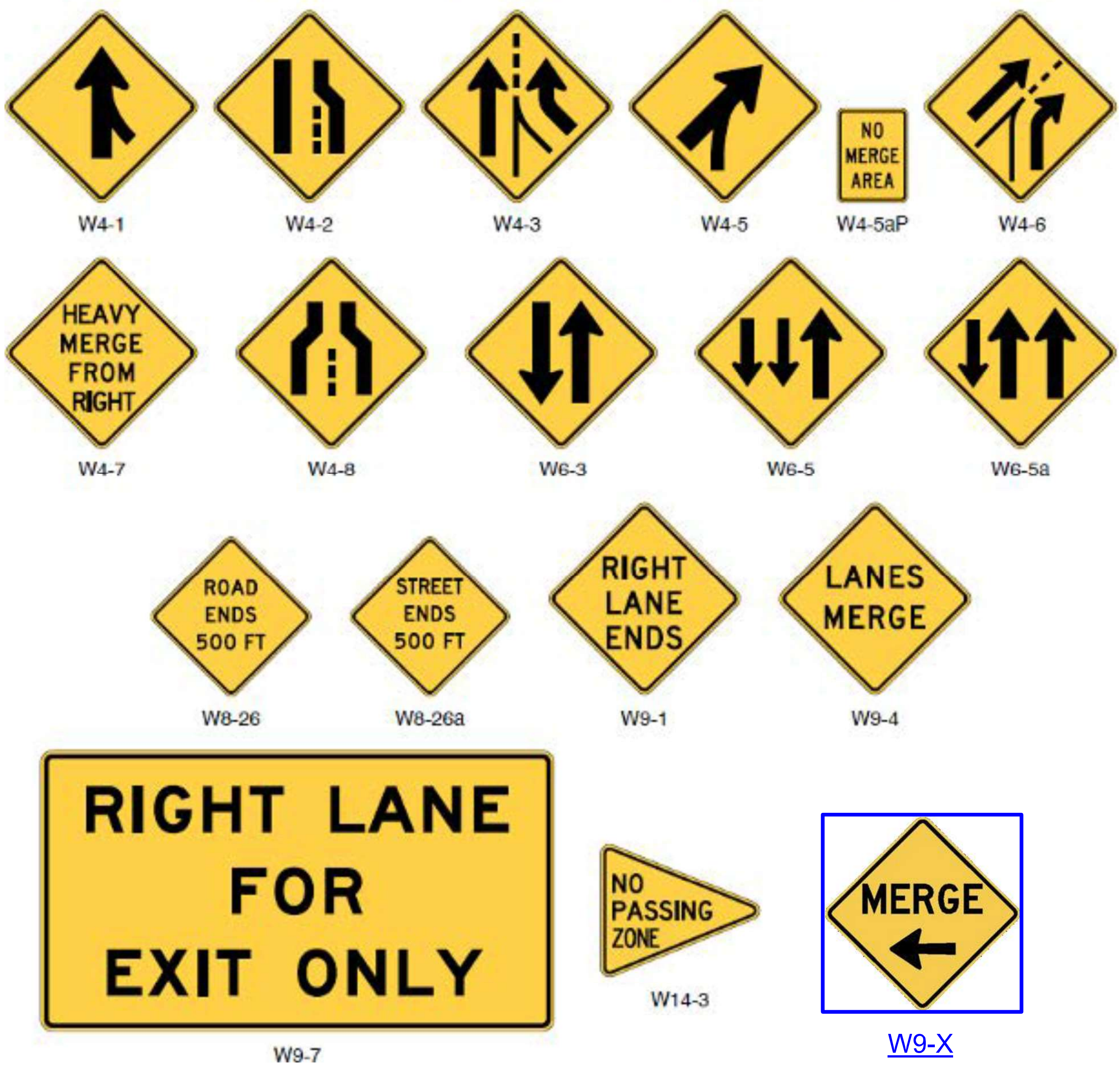
Figure 2B-16. Example of Application of Regulatory Signing and Pavement Markings at an Entrance Ramp Terminal



PROPOSED CHANGES TO FIGURE

1. Add Optional W9-X MERGE WITH ARROW sign at beginning of taper.
2. Interim depiction of pavement marking patterns and lane reduction arrows reflect existing content in the MUTCD that is harmonized with research results with the addition of the solid line consistent with the research report. These depictions are subject to change pending Council approval of the MTC proposal addressing this research.

Figure 2C-11. Merging and Passing Signs and Plaques

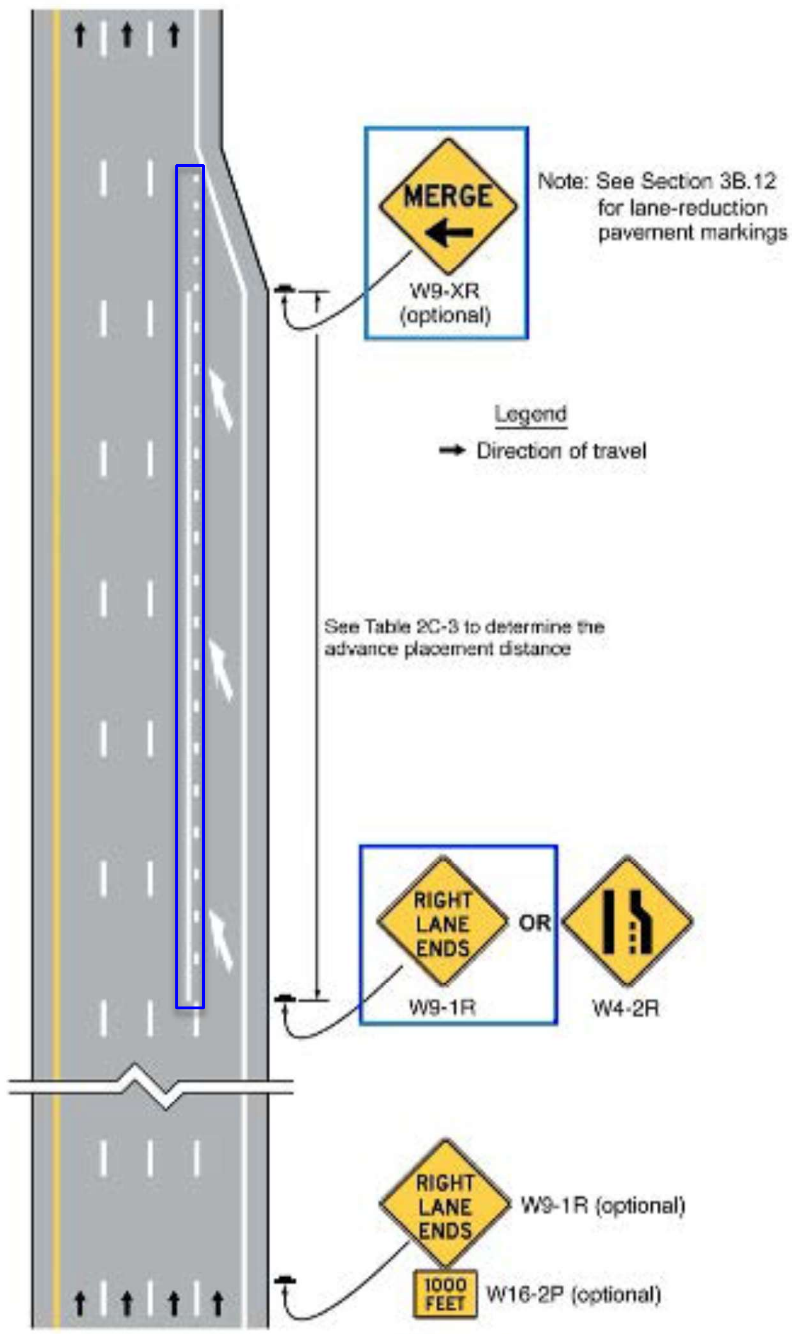


PROPOSED CHANGES TO FIGURE

1. Added W9-X MERGE with arrow sign, recommending W9-2 designation

ure 2C-13. **Example Sequences for Lane Ends and Lane Merge Signs** (Sheet 1 of 5)

A – Freeway or expressway - lane ends

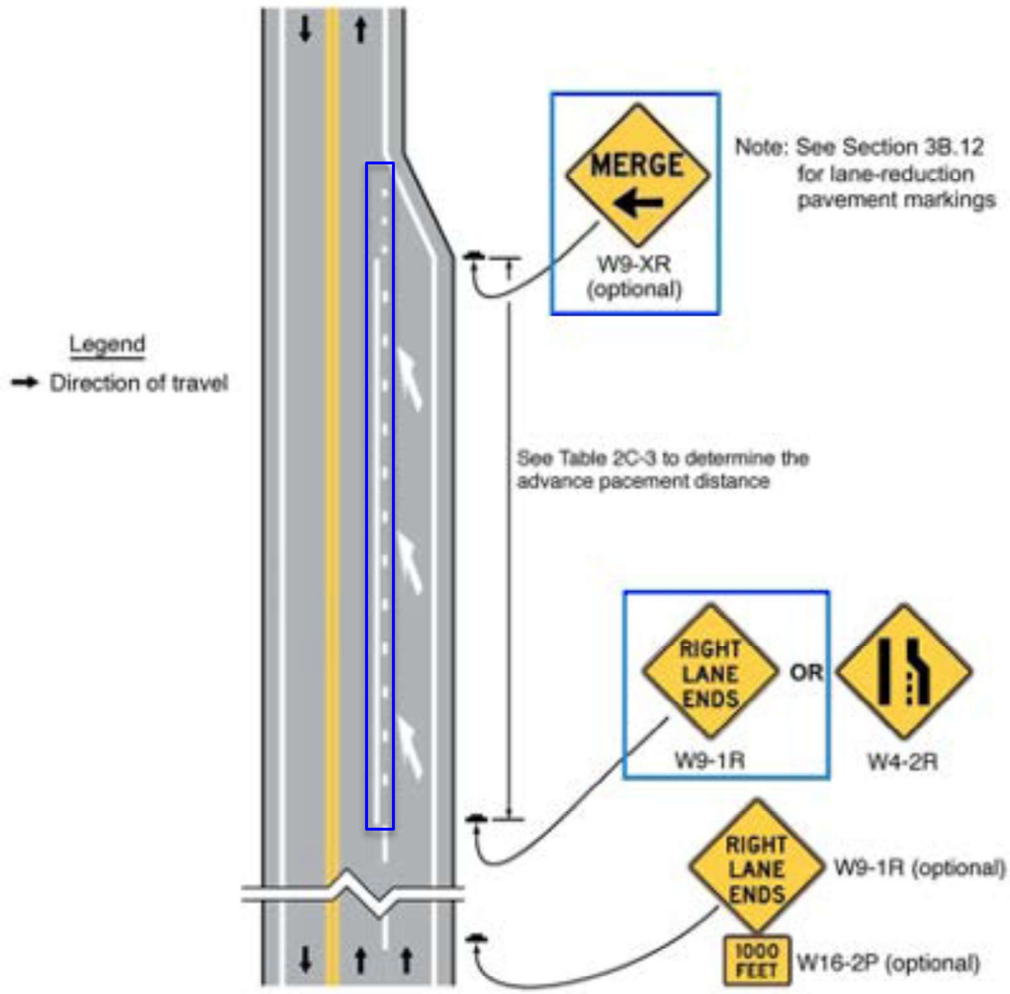


PROPOSED CHANGES TO FIGURE

1. Added W9-1R sign at conforming advance placement location
2. Added optional W9-XR MERGE with arrow sign at beginning of taper
3. Interim depiction of pavement marking patterns and lane reduction arrows reflect existing content in the MUTCD that is harmonized with research results with the addition of the solid line consistent with the research report. These depictions are subject to change pending Council approval of the MTC proposal addressing this research.

Figure 2C-13. Example Sequences for Lane Ends and Lane Merge Signs (Sheet 2 of 5)

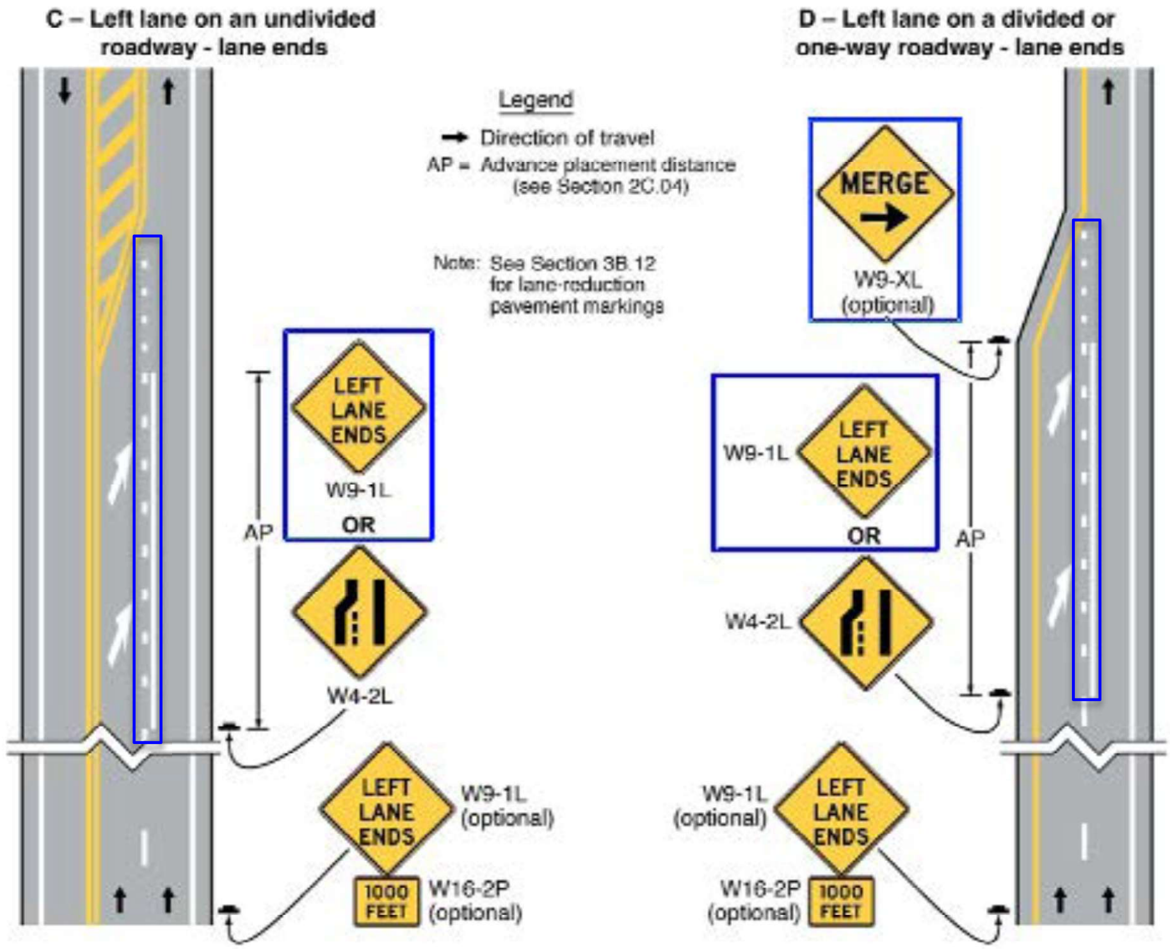
B – Right lane on conventional road - lane ends



PROPOSED CHANGES TO FIGURE

1. Added W9-1R sign at conforming advance placement location
2. Added optional W9-XR MERGE with arrow sign at beginning of taper
3. Interim depiction of pavement marking patterns and lane reduction arrows reflect existing content in the MUTCD that is harmonized with research results with the addition of the solid line consistent with the research report. These depictions are subject to change pending Council approval of the MTC proposal addressing this research.

Figure 2C-13. Example Sequences for Lane Ends and Lane Merge Signs (Sheet 3 of 5)

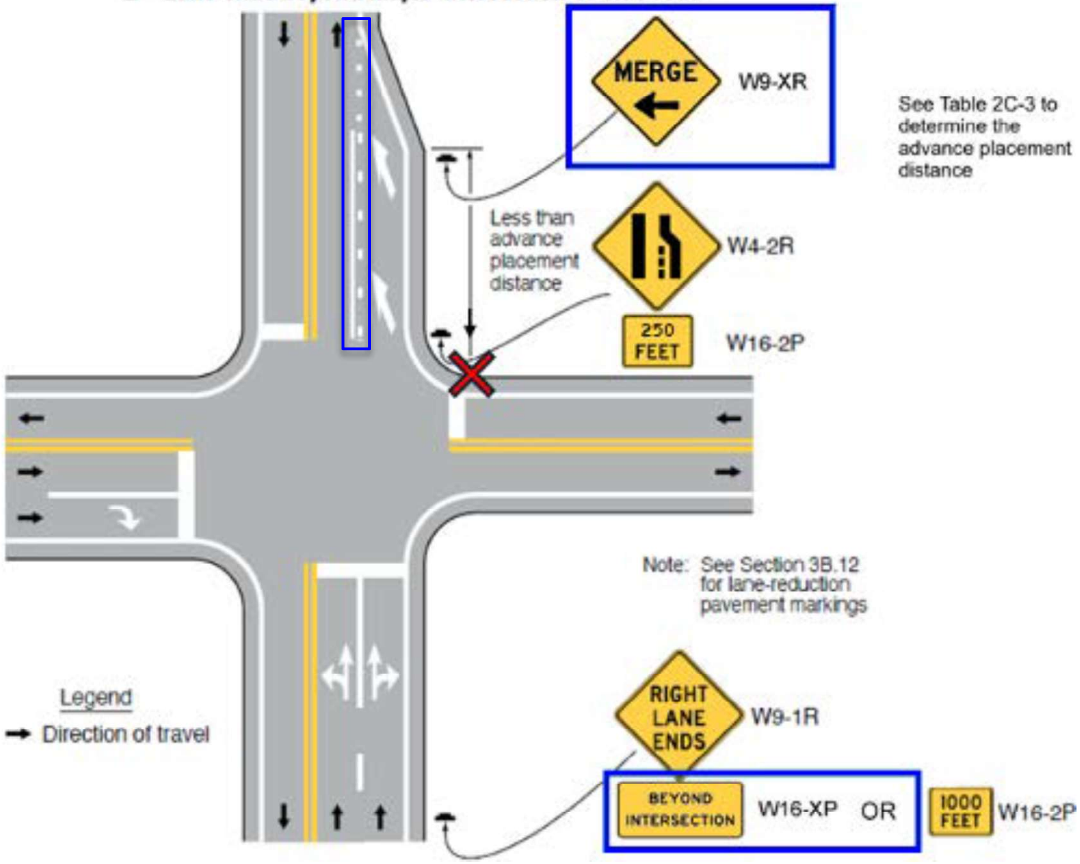


PROPOSED CHANGES TO FIGURE

1. Added W9-1L signs at conforming advance placement locations.
2. Added optional W9-XL MERGE with arrow sign at beginning of taper in Depiction D only.
3. Interim depiction of pavement marking patterns and lane reduction arrows reflect existing content in the MUTCD that is harmonized with research results with the addition of the solid line consistent with the research report. These depictions are subject to change pending Council approval of the MTC proposal addressing this research.

Figure 2C-13. Example Sequences for Lane Ends and Lane Merge Signs (Sheet 4 of 5)

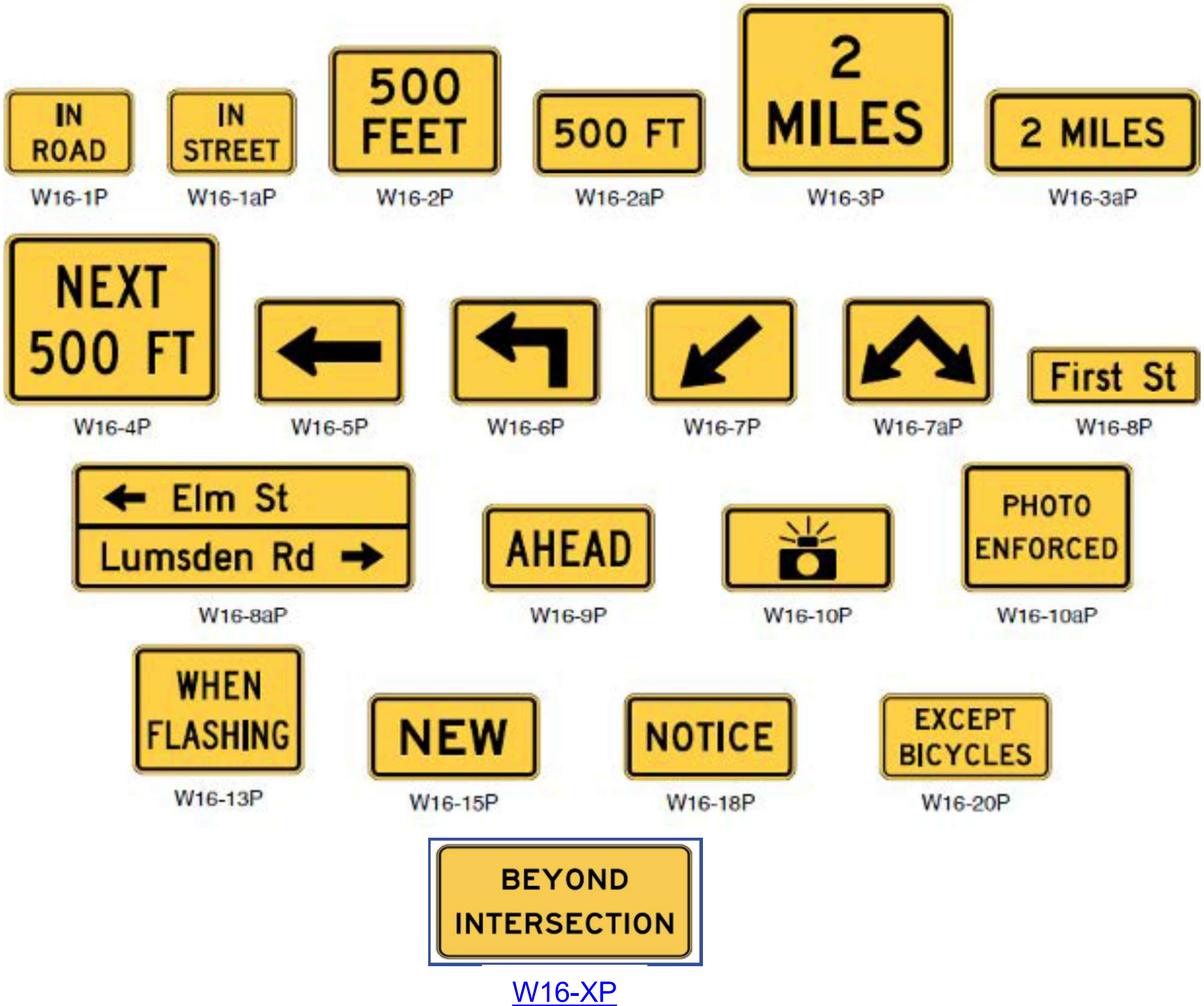
E – Lane ends beyond major intersection or side road



PROPOSED CHANGES TO FIGURE

1. Added recommended W16-XP “BEYOND INTERSECTION” plaque beneath W9-1R sign with alternative of W16-2P distance plaque.
2. Added recommended W16-2P distance plaque beneath W4-2R sign.
3. Added optional W9-XR MERGE with arrow sign at beginning of taper.
4. Corrected dimensioning line between W4-2R sign and beginning of taper to place the upstream arrow adjacent to the location of the warning sign and not the projection of the traveled way
5. Altered the distance shown in the plaque so that it is less than a typical advance placement distance for low-speed roadways, to match the circumstances where this sign would be used
6. Interim depiction of pavement marking patterns and lane reduction arrows reflect existing content in the MUTCD that is harmonized with research results with the addition of the solid line consistent with the research report. These depictions are subject to change pending Council approval of the MTC proposal addressing this research.

Figure 2C-16. Supplemental Warning Plaques



Note: The background color (yellow or fluorescent yellow-green) shall match the color of the warning sign that it supplements.

PROPOSED CHANGES TO FIGURE

1. Added W16-XP “BEYOND INTERSECTION” plaque.

TRB Annual Meeting

Are There Visual Consequences due to Greater Hood Heights of Larger Pickup Trucks and SUVs?

--Manuscript Draft--

Full Title:	Are There Visual Consequences due to Greater Hood Heights of Larger Pickup Trucks and SUVs?
Abstract:	The height of hoods on pickups and sport utility vehicles (SUVs) has increased in the last twenty years as consumers demand has shifted toward larger vehicles. Current models have hood heights as tall as nearly 5-feet. The ability of drivers to see objects, including pedestrians, in the area occluded by the hood present potential issues like those that resulted in back-up cameras in vehicles today. It could also affect the design of pavement markings at signalized intersections. This research reviewed the hood heights of various vehicles, reviewed literature on the topic of hood heights, conducted field studies of a driver's visibility of pedestrians for various combinations of hood height, driver height, advance stop line position and pedestrian location at a signalized intersection, reviewed MUTCD background related to advance stop line use and provides a case study of advance stop line placement in a city in Colorado. The field study created a "visibility index" to compare various scenarios and suggests the visibility of pedestrians by drivers is affected by hood height, windshield area design (large rearview mirror/sensor packages), driver height, and vehicle stopping position (close to crosswalk). Higher hood heights result in roughly a one percent loss in visibility index per increased inch of hood height. With no advance stop line, high hood height can fully obscure the visibility of a pedestrian in a wheelchair. Setting-back the stop line improves visibility index, but after 4-feet of setback, the improvement in visibility index is much less meaningful.
Additional Information:	
Question	**Response**
The total word count limit is 7500 words including tables. Each table equals 250 words and must be included in your count. Papers exceeding the word limit may be rejected. My word count is:	7499
Manuscript Classifications:	Safety, Human Factors, Pedestrians, Bicycles; Human Factors in Vehicle Design; Pedestrian Safety; Infrastructure Design; Intersection design
Manuscript Number:	
Article Type:	Presentation and Publication
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Are There Visual Consequences due to Greater Hood Heights of Larger Pickup Trucks and SUVs?

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Word Count: 5,249 words + 9 table (250 words per table) = 7,499 words

Submitted July 31, 2025
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ABSTRACT

The height of hoods on pickups and sport utility vehicles (SUVs) has increased as consumer demand has shifted toward larger vehicles. The largest current models have hood heights up to 5-feet tall. The ability of drivers to see objects, including pedestrians, in the area occluded by the hood present potential issues like those that resulted in back-up cameras. These vison limitations could also affect the design of pavement markings at signalized intersections. This research reviewed the hood heights of various vehicles, reviewed literature on the topic of hood heights, conducted field studies of driver's visibility of pedestrians for various combinations of hood height, driver height, advance stop line position and pedestrian location at a signalized intersection, and provides a case study of advance stop line placement in a city in Colorado. The field study created a "visibility index" to compare various scenarios and suggests the visibility of pedestrians by drivers is affected by hood height, windshield area design (large rearview mirror/sensor packages), driver height, and vehicle stopping position (close to crosswalk). Higher hood heights result in roughly a one percent loss in visibility index per increased inch of hood height. With no advance stop line, high hood height can fully obscure the visibility of a pedestrian in a wheelchair. Setting-back the stop line improves visibility index, but after 4-feet of setback, the improvement in visibility index is much less meaningful.

Keywords: Hood Height, Forward Blind Zones, Driver Visibility, Pedestrian Visibility

INTRODUCTION

Consumers' preferences for vehicles have changed as the demand for pickup trucks and sport utility vehicles (SUVs) has grown. Beyond consumer preference, financial considerations have also contributed to this change (greater profit margins on trucks and SUVs plus reduced fuel emissions requirements). The number of sedans has been declining and eight of the top ten vehicle purchases in the past year are now pickup trucks or SUVs (*1*), as noted in bold in **Table 1**.

TABLE 1 Top 25 Selling Vehicle Models in the USA

1. Ford F-Series Pickups	**9. Nissan Rouge**	**18. Subaru Crosstrek**
2. Chevy Silverado Series Pickups	10. Honda Civic	**19. Subaru Forester**
3. Toyota RAV4	11. Toyota Corolla	**20. Toyota Highlander**
4. Tesla Y	**12. Jeep Grand Cherokee**	**21. Subaru Outback**
5. Honda CR-V	**13. Chevy Equinox**	22. Honda Accord
6. RAM Series Pickups	**14. Hyundai Tucson**	**23. Kia Sportage**
7. GMC Sierra Series Pickups	**15. Chevy Trax**	**24. Toyota Tundra**
8. Toyota Cambry	**16. Ford Explorer**	25. Nissan Centra
	17. Toyota Tacoma	

This is reflected in the percentage of smaller vehicle sales in the United States which is at or near all-time lows (*2*) (**Figure 1**).

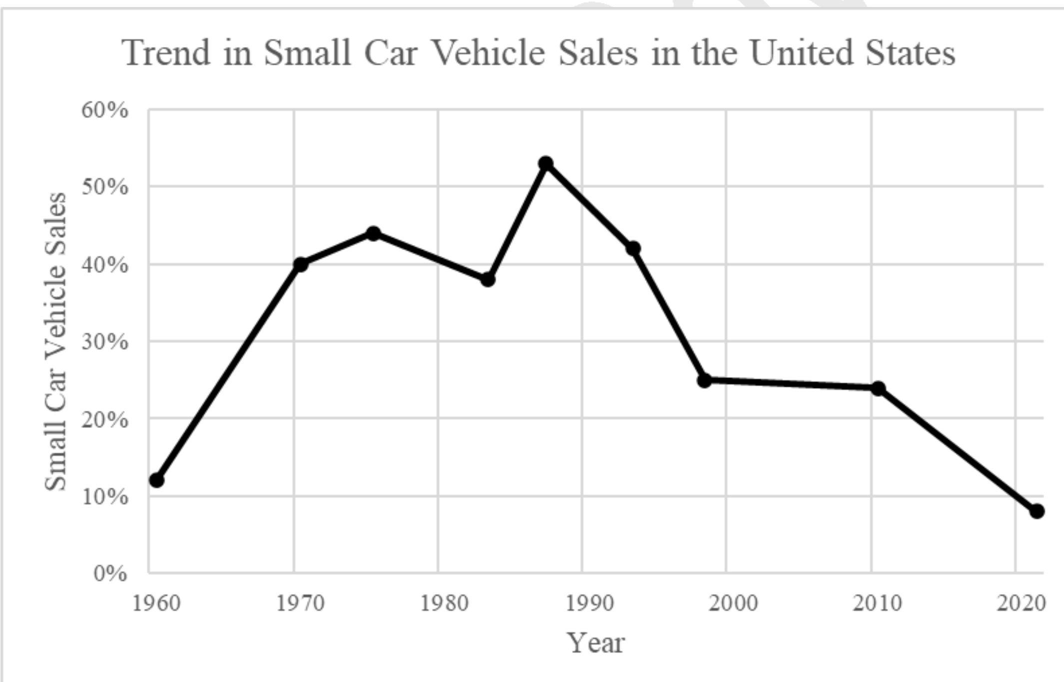

Figure 1 Percentage of Small Vehicles Sold in the United States

With this shift in the vehicle fleet there has also been an increase in the vertical dimensions of the vehicle hood as drivers have desired higher seating positions. Anecdotally this consumer desire has been associated with a perceived sense of safety and security from greater forward visibility. Hood heights have been increasing from a range of 30 to 50 inches to some approaching as high as 60 inches. A comparison of hood heights for various popular pickup trucks, SUVs and sedans has been provided (**Table 2**). All measurements were conducted on February 4, 2024 by Randy McCourt at various dealerships in Beaverton, Oregon. The hood center measurement was taken at the center of the vehicle hood for forward visibility, while the right fender measurement was taken at the right corner of the hood, as this affects pedestrian visibility toward the sidewalk. Interesting hood height examples include the Ford F250 increasing from 47 inches in 1997 to 52.5 inches in 2024. Even the Honda CRV from 2009 to 2023 saw a hood height increase from 36 to 39 inches.

TABLE 2 Hood Heights of Various Pickups, SUVs, and Sedans

Vehicle (*Pickup Trucks*)	**Hood – center (in)**	**Hood – right fender (in)**
Chevrolet		
2024 Silverado 3500 SWR Crew LTZ	56	54
2024 Silverado Crew LT Trailboss	51/53	51.5
2024 Silverado Crew High Country	50.5	50.5
2024 Silverado 1500 Crew LTZ	50	50
Chrysler		
2024 RAM 2500 Power Wagon Crew Cab	56.5/58	52
2024 RAM 1500 Laramie Crew Cab	49	45.5
Ford		
2024 F350 SRW Crew Cab Lariat	54	53
2024 F250 Super Duty SRW Super Cab	52.5	51
2023 F150 Lightening	49.5	49
2020 Ranger XLT	47	48
2018 F150 XL	47	46.5
1997 F250	44	44
GMC		
2024 Sierra 2500 Crew Cab AT4X	59	55
2024 Sierra 3500 Crew Denali	56	53
2023 Canyon AT4 Crew Cab	49.5	47.5
Honda		
2023 Ridgeline Sport	44.5	44
2023 Ridgeline ED	44	44
Toyota		
2024 Tundra HV 4x4	50.5	51.5
2023 Tacoma TRD	46	45.5
2012 Tacoma	46	44
Vehicle (*SUVs*)	**Hood – center (in)**	**Hood – right fender (in)**
Chevrolet		
2021 Suburban LT	48	49.5
2024 Tahoe LS	49	48.5
2024 Equinox LS	38	39
2024 TRAX Activ	38	38.5
Chrysler		
2024 Jeep Wrangler 4-door Sport	45	44
2024 Jeep Cherokee Altitude X	45.5	44.5
2024 Jeep Cherokee 4XE Anniversary	44.5	44
2023 Pacifica Touring (van)	37	36.5
Ford		
2024 Bronco	49	50
2024 Bronco Sport Big Bend	45	44.5

2021 Bronco Sport Outer Banks	43	43
2024 Explorer	43.5	44
2023 Escape ST Elite	37	37.5
GMC		
2024 Cadillac Escalade ESV	50	49.5
2024 Yukon XL Denali	50	49
2021 Yukon XL SLT	49.5	48.5
2024 Buick Encore GX Sport Touring	40	38.5
2024 Buick Envista Sport Touring	38	37
Honda		
2012 Pilot Touring	43	43
2024 CR-V	38	39
2018 CR-V	38	39
Toyota		
2024 4-Runner	50	50
2024 Highlander Platinum	41	41.5
2024 RAV 4 Prime	39.5	40.5
2023 BZ4X Limited (EV)	36	38
Other Vehicles (*Sedans*)	**Hood – center (in)**	**Hood – right fender (in)**
2019 Maserati Ghibli	33	31
2022 Tesla Y	32	33
2024 Honda Civic Sport	32.5	33.5
2024 Toyota Camry XLE	32	33
2024 Toyota Prius Prime XLE	32	32
2024 Toyota Corolla Hybrid	31	31

Increasing hood height creates a blind spot in front of the vehicle that can occlude parts of or entire pedestrians (**Figure 2**). A child (commonly 3 to 5-feet tall) would not be visible up to six feet in front of the vehicle. By comparison an average male is about 5-foot, 9-inches (69 inches), an average female is about 5-foot, 4 inches (64 inches). The impact area where the vehicle would strike a pedestrian for the tall pickup is shown in red, while the average sedan impact area is in gold. The blind spot for the tall pickup is shown in gray. A larger pick-up truck hood is nearly higher than a person in a wheelchair (**Figure 3**).

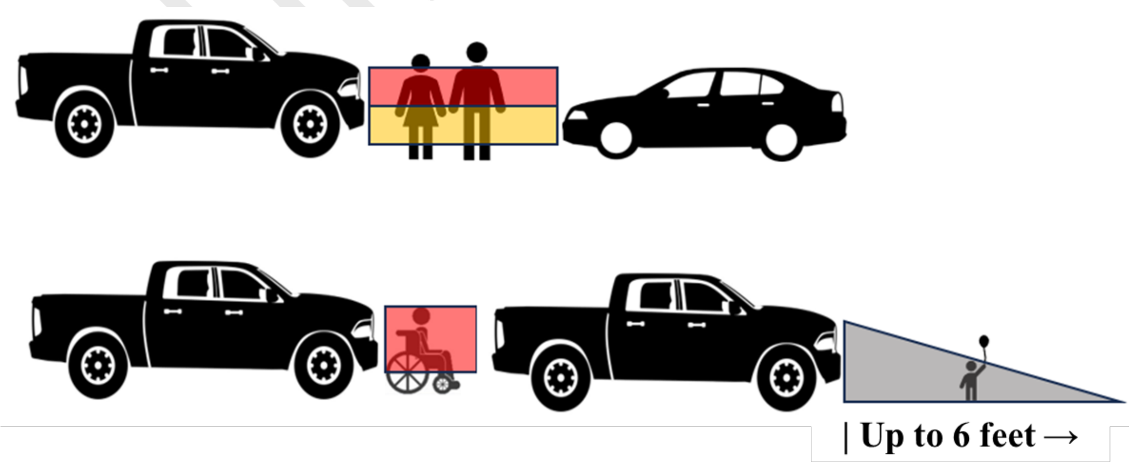

Figure 2 Relationship Between Hood Heights and Average Pedestrians

Figure 3 Pickup Hood Height in Comparison to a Person in a Wheelchair

This study expands the understanding of this issue. It includes a review of research related to driver visibility and hood heights, a field study of driver visibility conducted in Corvallis, Oregon, review of the Manual on Uniform Traffic Control Devices (MUTCD) guidance related to advance stop line placement, a case study from Lakewood, Colorado where stop lines were set back from the crosswalk, and documentation of research needs.

LITERATURE REVIEW

Scholarly literature, documented in TRIS/TRID, Web of Science, and Google Scholar, were reviewed to identify studies related to increasing vehicle hood heights. Search terms included but were not limited to: “hood height”, “forward blind zones”, “driver visibility”, “trucks”, and “SUVs”. Most research examines the relationship between hood height and pedestrian injury severity, especially regarding impact location and transfer of kinetic energy. There is little research that examines how hood height affects driver’s forward visibility and pedestrian detection. Additionally, no studies were found that evaluated vehicle stopping position at intersections as a factor influencing forward visibility. The present paper summarizes the key findings from the limited research conducted in this specific area.

Recent research confirmed that height and shape of vehicle front ends influences the severity of pedestrian injuries in crashes. One study analyzing police-reported crash data from 7 U.S. states showed vehicles in crashes with tall and blunt, tall and sloped, and medium-height and blunt front-end profiles are associated with higher pedestrian fatality rates than vehicles with low and sloped designs (*3-4*) (**Figure 4**). Interestingly, a relatively flat hood was also found to significantly increase pedestrian fatality risk. Earlier work reported similar findings by analyzing 82 single-vehicle crashes finding SUVs were disproportionately more prone to injuring or killing a pedestrian in a crash, compared to passenger cars (*5*). The data suggests that where SUV crashes result in disproportionate injuries and fatalities compared to passenger cars were primarily for crashes of intermediate speed.

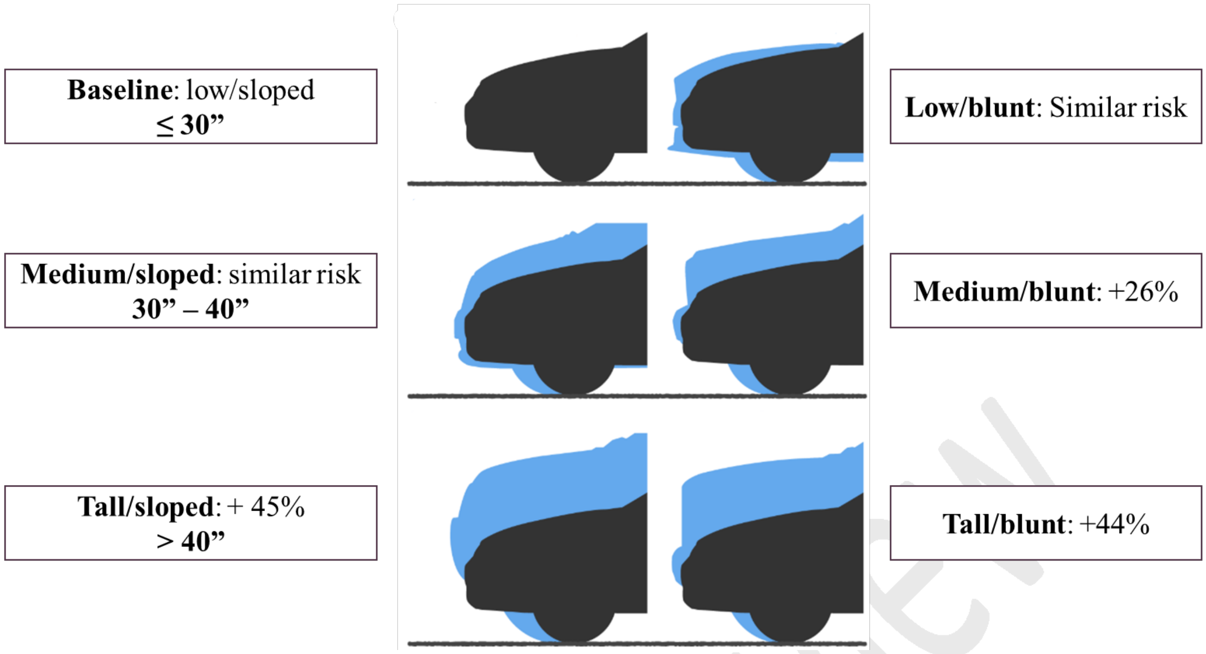

Figure 4 Comparative Risk of Pedestrian Fatality by Hood Leading Edge Height and Shape

Matching national crash data with vehicle dimensions, one study found that increasing the front-end height by 4 inches leads to a 22% increase in the likelihood of pedestrian fatality (*6*). The study's author estimated that capping the vehicle front end height at 49 inches could potentially prevent over 500 annual pedestrian deaths in the United States. The author also completed a complementary analysis finding that the widespread replacement of sedans with light trucks between 2000 and 2019 was associated with over 8,000 additional pedestrian deaths (*7*).

A smaller body of research focused on how differing vehicle designs impact driver's forward visibility and pedestrian detection. One study created a method for mapping forward blind zones based on the driver's eye position and hood height of the vehicle (*8*). The findings revealed that drivers with a direct line of sight react about 0.7 seconds faster and can respond to objects up to 50% more quickly in comparison to those relying on indirect vision. These conclusions are supported by simulator-based studies. One study comparing "high-vision" truck cabs in the UK to conventional "low-vision" cabs found in the U.S., found that drivers in high-vision designs were significantly less likely to crash with crossing pedestrians (*9*). The same study also found that drivers in low-vision cabs who relied on crossover mirrors were 9 times more likely to fail at detecting a pedestrian directly in front of their vehicle at an intersection. Although mirrors provide additional visibility, they also create new blind spots and increase the driver's perception and response times, especially when the vehicle is stopped.

The Boston Blind Zone Safety Initiative conducted field observations of large vehicles that further support these findings. Through documenting visibility conditions around a variety of heavy vehicle types, they found that 87% of fatal bicycle crashes occurred at the front, front-end, or rear-right quadrants of the vehicle, areas where direct visibility is often limited (*10*).

Despite the growing body of evidence, current U.S. pedestrian safety guidance has not kept pace with vehicle design trends. NCHRP Report 500 Volume 10 has recommendations for improving pedestrian visibility at crossings, however these improvements focus on infrastructure treatments such as lighting, signage, and pavement markings. The report does not mention vehicle size or hood height as an influence on pedestrian visibility (*11*). Given this gap, a recent Transportation Research Board workshop called for a more integrated approach that considers vehicle size and mass with roadway design, crash outcomes, and policy development (*12*).

There is little research directly analyzing driver forward visibility on pedestrian recognition. Furthermore, none of the studies identified consider the influence of stopped vehicle's position at an intersection in pedestrian visibility. This research seeks to advance understanding in this area and offers a practical strategy to improve pedestrian safety at signalized intersections.

METHODS

Quick response research was conducted to inventory drivers eye perspective given various hood heights, driver heights, stop line positions and pedestrian positions. The study was conducted in Corvallis, Oregon at the signalized intersection of SW 3rd Street (OR 99W) and SW Adams Avenue (**Figure 5**). OR 99W is one way (going northeast) with a posted 25 mph and the location is in a business district which has a statutory speed limit of 20 mph. The traffic signal is 2-phase, fixed time with a cycle length of 75 seconds. The intersection has transverse line crosswalk markings with no advance stop line. The crosswalk is 11 feet wide, and the crossing distance (curb-to-curb) is 52 feet.

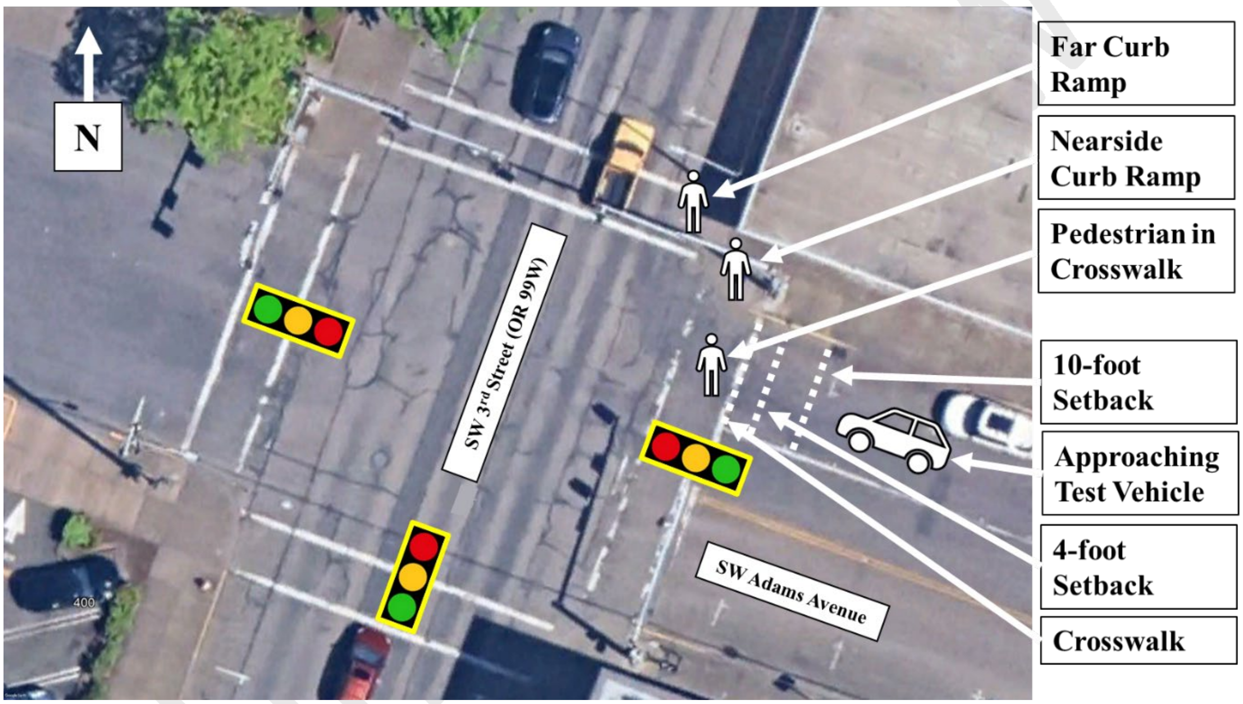

Figure 5 Aerial View of Test Site

Field work was conducted on two dates: a pilot on March 13, 2024, and full data collection on August 14, 2024. The March visit served to assess the feasibility of the study design, verify the suitability of the site, and refine data collection procedures. Sixty practice observations were conducted, which provided validation of the full study measurements. Both March and August observations were conducted under daylight, dry conditions during midday hours. A set of vehicles, drivers, pedestrian positions and vehicle positions were established at the field site (**Table 3**). The westbound approach right turn lane was used to position the vehicles at the study site's signalized intersection.

TABLE 3 Field Variables for Testing

Vehicle / Hood Height	Driver Height (inches)	Pedestrian Positions	Vehicle Positions
2018 Honda CRV / 38 inches	71	Crosswalk	Zero Setback
2022 Ford Maverick pickup / 41 inches	68	Nearside Curb Ramp	Crosswalk
2018 Ford F250 pickup / 52 inches	60	Far Curb Ramp	4-foot Setback
			10-foot Setback

Each driver adjusted the position of the driver's seat such that they would be comfortable and placed the vehicle at different positions (**Table 4**). The eye position relative to the stop line was about 2-feet greater for the F250 than the other vehicles. For the zero-setback position, the bumper of the vehicle was placed on top of the crosswalk line. For the other three positions, the driver was told to stop where they deemed appropriate, commonly 2 to 5 feet behind the actual setback line (**Figure 4**). Of note, each driver was hesitant and stopped several times before reaching the actual crosswalk line point for the zero-setback position, as from their perspective, they felt they were encroaching upon the crosswalk.

TABLE 4 Horizontal Position of Driver's Eyes and Bumper to Stop Line

	Vehicle Position			
Eye Distance to Stop Line	**Zero Setback**	**Crosswalk Stop Line**	**4' Setback**	**10' Setback**
Honda CRV	7'4"	10'9"	10'3"	9'6"
Ford Maverick Pickup	7'6"	11'3"	10'10"	10'8"
Ford F250 Pickup	8'6"	13'4"	12'5"	12'0"
Bumper Distance to Setback Line				
Honda CRV	0	3'3"	2'8"	2'0"
Ford Maverick Pickup	0	3'8"	3'4"	3'0"
Ford F250 Pickup	0	5'0"	4'0"	4'0"

Figure 6 In-Situ View of Test Site

The drivers then held an iPhone 13 mini at eye position and took photos for various scenarios of vehicle type, pedestrian placement, stop line position and driver height. Vertical measurements were taken of the eye height of each of the drivers in each of the vehicles after they adjusted seat position (**Table 5**).

TABLE 5 Eye Height for Each Test Driver and Variable

	Driver 1 (Shorter)	Driver 2 (Average)	Driver 3 (Taller)
Honda CRV	52.0	52.0	52.5
Ford Maverick Pickup	51.5	53.0	53.0
Ford F250 Pickup	64.0	65.0	66.5

Measurements were also taken of the person seated in the wheelchair from the pavement to the top of their head. This dimension varied from a low of 48-inches for the shortest person to a high of 51-inches for the tallest person. Eighteen of the vehicles noted in **Table 2** exceed 48-inches of hood height (many of the pickups and a few of the larger SUVs).

A series of visibility matrices were created to organize the images obtained to compare pedestrian visibility for each driver in each vehicle type at each stop line and pedestrian position at the intersection. A sample matrix with the corresponding images is provided to show examples of the experimental variables (**Figure 7**).

Figure 7 Sample Image Matrix

From these matrices, the driver's view of each pedestrian position was analyzed independently by two researchers and grouped into six view categories. Each category was assigned a numeric rating by the researchers. The image and description of the pedestrian visibility categories were standardized (**Figure 8**). A matrix for each vehicle stop position was created. Within each image there were three pedestrian positions visible. This created a matrix for each stop line condition with 54 visibility rating entries. The inter-rater reliability measure was 90%, indicating that they agreed on 195 of the 216 unique scenario's ratings. All discrepancies were then resolved in a meeting with a third researcher.

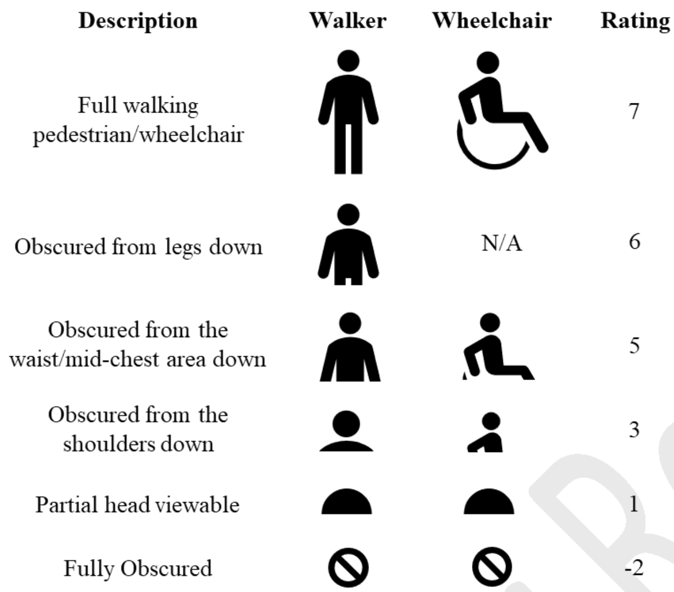

Figure 8 Pedestrian Visibility Categories

RESULTS

During the data analysis, driver visibility was sometimes partially or significantly obstructed by the rearview mirror or sensor assembly in certain scenarios. Also, pedestrians standing at the nearside curb ramp occasionally partially or fully blocked the view of pedestrians at the far curb ramp. To account for this, the pedestrian visibility categories were adjusted by decreasing their score given how much of the pedestrian was obstructed. Additionally, obstruction-related data was removed to focus on the variables of interest. The difference between average visibility index ratings for all the data versus the obstruction removed data is noted in the tables by the increase percentage.

Groups of pedestrian visibility ratings were averaged to compare various scenarios (such as driver height or stop line position) creating a visibility index (**Table 6**). The sample sizes represented in the visibility index are highlighted within parenthesis. Comparing various driver heights, the visibility index was mostly unchanged. However, comparing vehicle stopping positions it was found that visibility index improved as the stopping position of the vehicle moved back from the crosswalk line (**Figure 9**).

TABLE 6 Average Visibility Index for Driver Height and Vehicle Position

Driver Height	Visibility Index Rating			Vehicle Stopped Position	Visibility Index Rating		
	All Data	Obstruction Data Removed	Increase (%)		All Data	Obstruction Data Removed	Increase (%)
Shorter	5.3 (72)	6.3 (62)	19	**Zero Setback**	2.8 (54)	5.2 (34)	86
Average	5.4 (72)	6.3 (63)	17	**Crosswalk**	5.3 (54)	6.0 (43)	13
Taller	5.2 (72)	6.2 (44)	19	**4-foot Setback**	6.4 (54)	6.7 (46)	5
				10-foot Setback	6.7 (54)	7.0 (46)	4

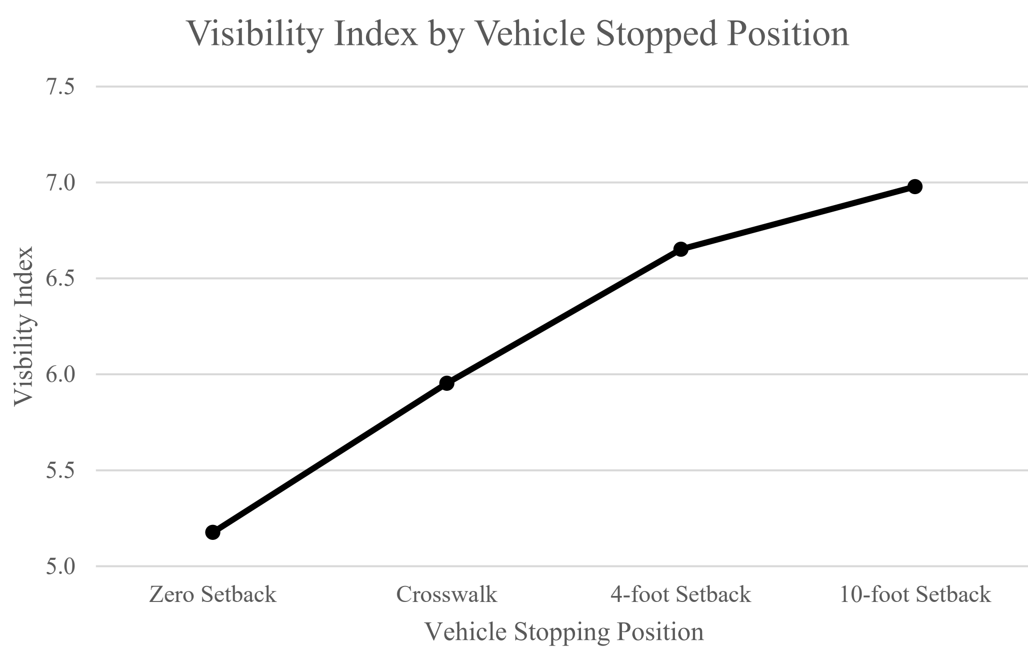

Figure 9 Average Visibility Index by Vehicle Stopped Position

View obstructions (particularly the rear-view mirror/sensor package) had a significant effect on some ratings. To address this the data set was analyzed separately with the view obstructed data points removed. This allows for a comparison between the different vehicle stopping positions, and the subsequent visibility of the pedestrian. The general findings stayed the same (little variance due to driver height, greater variation due to stop-line position); however, the variation in index rating lessened between positions with the obstruction data removed.

A separate visibility index analysis was performed to assess hood height (**Table 7**). The analysis is given for the entire dataset, as well as with view obstructions removed. The percentage increase of the index rating for the full dataset to the dataset where obstructions were removed is also included. The full dataset visibility index ratings provide confounding results due to the significant impact of view obstructions caused by rearview mirrors/sensor placement in the windshield area and the position of the pedestrians at street corners. With the obstruction data removed the visibility index decreases with hood height (**Figure 10**).

TABLE 7 Average Visibility Index for Vehicle Types (Hood Height)

Vehicle Type	Hood Height (inches)	Visibility Index Rating		
		All Data	Obstruction Data Removed	Increase (%)
Honda CRV	38.0	5.1 (72)	6.6 (48)	29
Ford Maverick Pickup	41.0	5.5 (72)	6.4 (55)	16
F250 Pickup	52.0	5.3 (72)	5.9 (66)	11

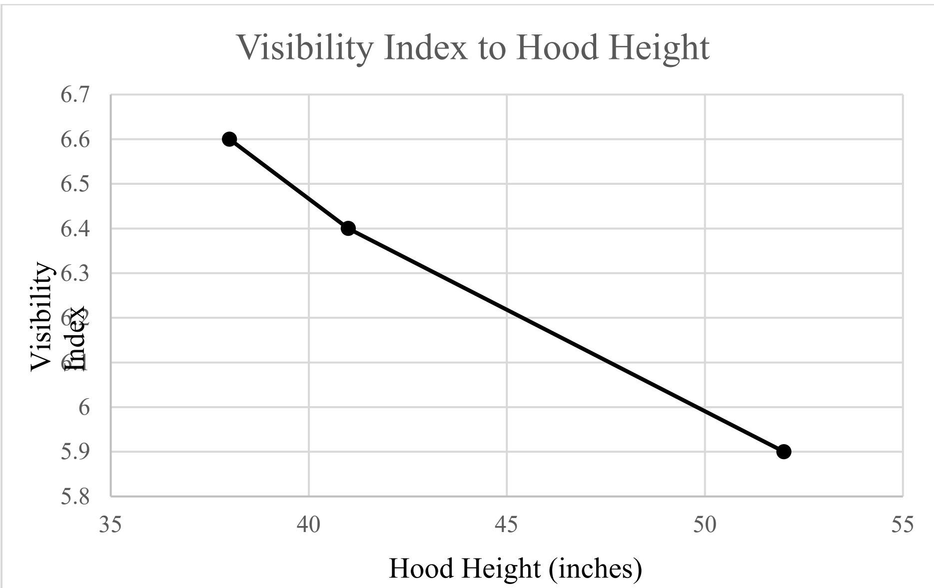

Figure 10 Average Visibility Index by Hood Height

Analysis of pedestrian and wheelchair position was also conducted (**Table 8)**. The far curb ramp position was most affected by view obstructions. Without obstruction data (which isolates the effect of hood height), the far curb ramp position has the highest visibility index. The crosswalk pedestrian and wheelchair position is most affected by hood height. Including the obstruction data, the far curb ramp pedestrian and wheelchair positions are the worst. Pedestrians in the crosswalk were not impacted by view obstructions as they are directly in front of the driver's line of sight. There was a 15-40% reduction in data for the near side and far side crosswalk pedestrian positions, respectively, for factors not related to hood height. Walking pedestrians have a higher visibility index than wheelchairs by about 8%.

TABLE 8 Average Visibility Index for Pedestrian Position at the Intersection

Pedestrian Position	Walker			Wheelchair		
	All Data	Obstruction Data Removed	Increase (%)	All Data	Obstruction Data Removed	Increase (%)
Crosswalk	6.1 (47)	6.1 (36)	0	5.1 (36)	5.1 (36)	0
Nearside Curb Ramp	6.4 (36)	6.6 (27)	3	6.4 (36)	6.6 (31)	3
Far Curb Ramp	4.0 (36)	7.0 (20)	75	3.9 (36)	7.0 (19)	79

To better understand the data and account for all the variables, a series of statistical analyses was performed. A machine learning technique was applied to assess the importance of the variables and their levels. The dependent variable was the visibility index score, while the independent variables included driver height with three levels (60, 68, and 71 inches), pedestrian type (walker and wheelchair), hood height (38, 41, and 52 inches), vehicle position relative to the crosswalk (zero setback, before the crosswalk, 4-foot setback, and 10-foot setback), and pedestrian position with three levels (at the crosswalk, nearside curb ramp, far curb ramp).

To determine the importance of each variable to the overall model and to avoid overfitting, a random forest analysis with a permutation technique (repeated 100 times) was performed. This technique reduced the influence of variables that contribute to overfitting in the dataset. If the drop in accuracy score was above zero for a specific input variable, it indicated that the model was more sensitive to that variable and that it should remain. In contrast, a negative or zero score implied that the model's performance remained the same even when there were changes in that variable.

From the empirical correlations, the permutation importance of each input variable was evaluated in relation to predicting the visibility index score (the higher the better). The results of the random forest analysis (15 levels) are shown in Figure 11. As seen in the figure, visibility was most sensitive to changes in pedestrian at crosswalk and vehicle positions with zero setback, followed by taller hood height and pedestrian type. Driver height showed the least influence, with a score below zero.

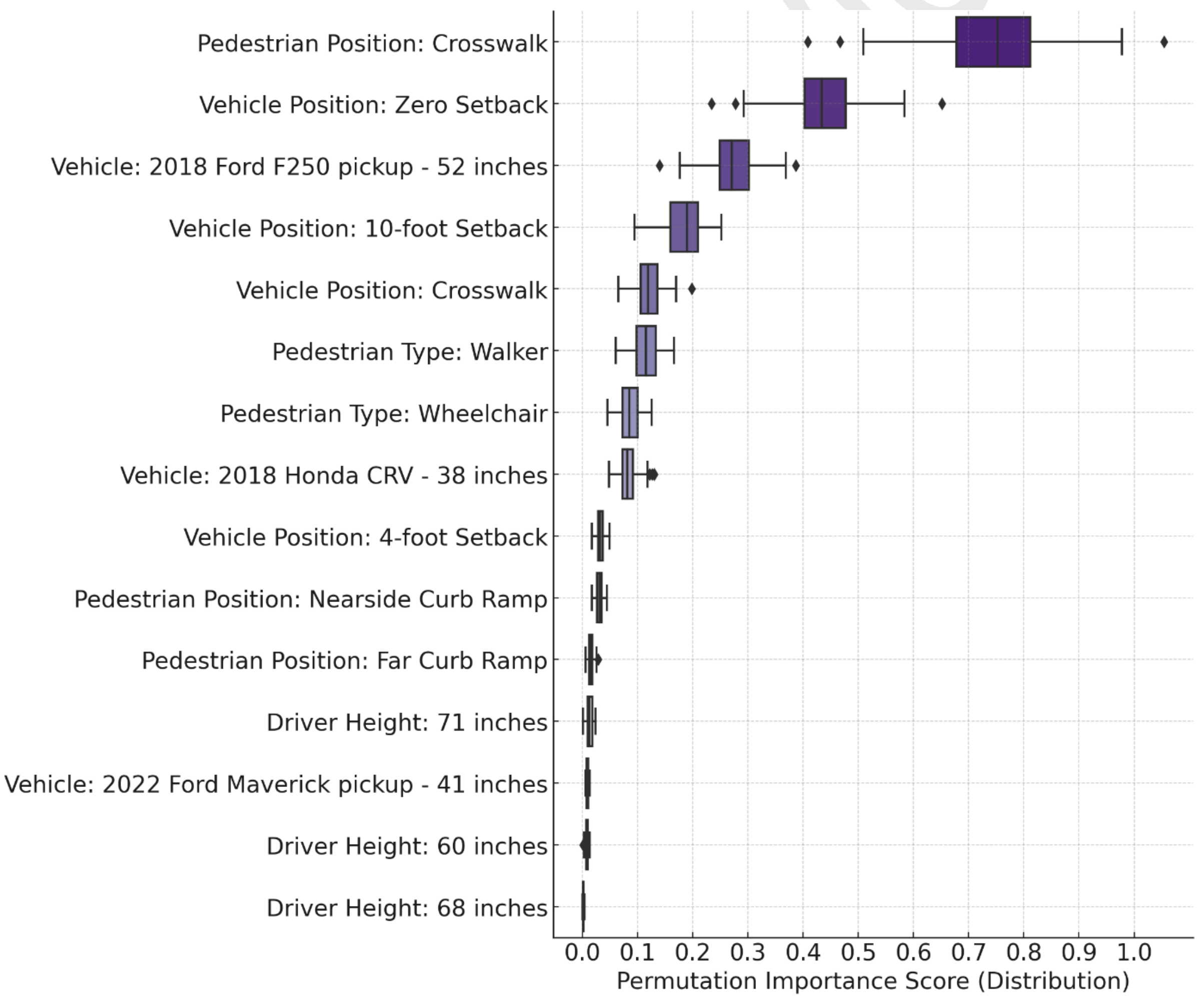

Figure 11 Random Forest Model Sensitivity Analysis (by importance)

Following the random forest technique, a linear mixed model was developed to account for the random effect introduced by driver height, since each driver completed multiple runs. However, because the random effect was not statistically significant, a general linear model was produced treating driver height as a fixed effect in addition to other variables (**Table 9**). Building on the variable importance results from the random forest variable selection technique, the regression model showed consistent trends. To that end, all variables were statistically significant (p-value < 0.01) compared to their baselines, except for drivers with a height of 68 inches, which showed an approximately similar visibility index to 60 inches (p = 0.64), and the Ford Maverick (41 inches) when compared to the 38-inch Honda CRV (p = 0.14). Even though the 68-inch driver height was not statistically significant, it showed a positive relationship compared to the 60-inch baseline. Similarly, while the Maverick was not significant at a 95% confidence level, its p-value falls within an 84% CI, and the negative coefficient suggests a decline in visibility when compared to the Honda vehicle.

TABLE 9 Regression model outputs of the Visibility Index

Variable	Coefficients	SE	T-Value	P-Value
Constant	5.10	0.21	24.73	0.00*
Driver Height				
60 inches	*Baseline*			
68 inches	0.07	0.14	0.47	0.64
71 inches	0.35	0.16	2.21	0.03*
Pedestrian Type				
Walker	*Baseline*			
Wheelchair	-0.45	0.12	-3.74	0.00*
Vehicle - Hood Height				
2018 Honda CRV - 38 inches	*Baseline*			
2022 Ford Maverick pickup - 41 inches	-0.23	0.16	-1.47	0.14
2018 Ford F250 pickup - 52 inches	-0.85	0.15	-5.56	0.00*
Vehicle Positions				
Zero Setback	*Baseline*			
Crosswalk	0.70	0.19	3.75	0.00*
4-foot Setback	1.35	0.19	7.29	0.00*
10-foot Setback	1.67	0.19	9.05	0.00*
Pedestrian Positions				
Crosswalk	*Baseline*			
Nearside Curb Ramp	1.19	0.14	8.41	0.00*
Far Curb Ramp	1.21	0.16	7.36	0.00*

**Statistically significant at the 0.01 level*

DISCUSSION

Among the various factors, vehicle stopping position had the most significant effect on visibility index. As shown in **Figure 9** and **Table 6**, visibility index scores improved substantially as the vehicle was positioned farther from the crosswalk. The zero-setback position produced the lowest visibility score, while the 10-foot setback position had an average visibility index rating of 7.0, representing full visibility of the pedestrian. Notably, visibility index rating improvements diminish between the 4-foot and 10-foot setback positions, suggesting that a 4-foot stop line setback may be a practical threshold for achieving meaningful visibility gains.

Hood height also played a role in determining pedestrian visibility for the different scenarios. Higher hood heights result in roughly a one percent loss in visibility index per increased inch of hood height. When considering wheelchairs in crosswalks, higher hood height vehicles are associated with much lower visibility index than pedestrians (a visibility index of 1 for wheelchairs compared to 5 for pedestrians in the crosswalk with the F-250).

The location of the pedestrian's positioning at the intersection also influenced their visibility to drivers. Pedestrians positioned directly in the crosswalk were consistently the least visible across vehicle types and stopping positions. In contrast, those positioned at the far curb ramp were always fully visible, unless blocked by a mirror or the other pedestrian. These differences in visibility findings were reflected with an average visibility index rating of 6.1 for walkers and 5.1 for wheelchairs in the crosswalk, versus scores of 7 for both walkers and wheelchairs at the far curb ramp. When these obstructed scenarios were not removed from the dataset, the far curb ramp position yielded the lowest visibility index, suggesting that this position might be influenced more by inherent driver blind spots, rather than the hood height or stopping position of the vehicle.

Obstructions caused by non-hood related design elements, such as the rearview mirrors and sensor packages on the windshield or the other pedestrian at the intersection, were found to significantly affect driver visibility. These obstructions were especially problematic when pedestrians were located at the nearside or far curb ramps, as the pedestrian at the nearside curb ramp often partially obstructed their view to the driver. The zero-setback condition was most affected, with visibility index scores increasing by 86% after such obstructions were removed. These obstructing features did not disproportionately impact taller drivers. Instead, the visibility index ratings increased by the same 19% for both shorter and taller drivers when the obstruction data was removed, with average driver height only seeing an increase of 17% for their average visibility index rating.

Driver height had little variation in visibility index rating with or without obstructions. Drivers produced about the same visibility index ratings after being told to adjust their seats to a comfortable driving position. Vertical eye height measurements (**Table 4**) confirmed that drivers naturally positioned themselves at roughly the same height in the vehicle. This finding indicates that differences in visibility were not due to driver height, consistent with modeling results.

When taken together, these results emphasize the importance of vehicle design and design characteristics of intersections for pedestrian safety. Specifically, considering a 4-foot stop line setback could significantly improve pedestrian visibility at intersections.

Past Applications of Advanced Stop Lines

The MUTCD includes the application of a 4-foot advance stop line to a crosswalk as guidance (*13*). Guidance refers to a statement of recommended practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate. It has been a part of the MUTCD since 1948. More recently use of advanced stop lines has become a common means of providing space for bicyclists (bike box) at busy urban intersections to allow cyclists to be positioned ahead of other traffic.

Past FHWA studies indicated that marked crosswalks alone are insufficient in situations where speed limits exceed 40 mph, roadways with four or more lanes with or without raised medians where volumes exceed 12,000 and 15,000 respectively (*14 – 15*). This has led some practitioners to consider advance stop lines only with higher speed to avoid impacts on lost time for traffic signals due to greater clearance time. However, in this study vehicles were stopped, and the visibility issues were associated with transitions from stopped conditions to moving (such as a right turn on red where the driver looks away from the pedestrian conflict area and then proceeds into space where visibility may be impacted due to hood height). Because of this, the issue of advanced stop lines would not appear to be as associated with speed as intersection visibility.

Case Study: Lakewood, Colorado

The City of Lakewood, Colorado has a pavement management program that repaves and restripes many of their arterial streets. Given the regular snow conditions, striping is re-applied every one to two years. The city had been placing advanced stop lines using the MUTCD minimum setback of 4-feet (no stop lines were use on approaches that were residential streets or roads posted ≤ 30 mph). In response to a crash investigation, the city began in 2024 and 2025 to place advance stop lines for all signalized intersections. They have been using high visibility longitudinal bars (continental pattern) that are nine feet wide with an eight-foot gap between the crosswalk markings and the stop line. For locations that did not have advance stop lines (typically locations ≤30 mph) they are adding them and for locations that had them four-feet in advance of the crosswalk they moved them back and additional four-feet.

Video cameras observed stopping behavior before and after some of the initial changes from 4-foot to 8-foot in advance of the crosswalk (*16*). Approximately 50 signal cycles were reviewed for each condition, representing three hours of cumulative signal activity across two days of footage (one before and one after the change using the same time window of 2:00 to 4:00 p.m. on similar days of the week). Observations were conducted by reviewing archived traffic footage at 16x speed. About 65% did not encroach the stop line positioned 4-feet in advance of the crosswalk. Line pavement marking conditions were good. With the stop-line move back to 8-feet in advance of the crosswalk about 70% did not encroach beyond the stop-line. The pavement line marking condition was excellent in this scenario.

Drivers did not change stop position behavior substantially with a change in the position of the stop line between 4 and 8-feet. Casual observations by operations staff and pool drivers indicated that the change was not noticeable relative to their expectations for stopping at a signalized intersection. It found that “concerns” that drivers might violate the stop line at greater frequency if advance stop lines are used (at or beyond 4-feet) was not warranted.

CONCLUSIONS

Consumers in the U.S. have significantly shifted toward purchasing vehicles with larger hood heights, such as pickup trucks and SUVs. This has led to many popular vehicles having hood heights greater than 50 inches, contributing to forward visibility issues and reduced pedestrian visibility. The goal of this study was to quantitatively assess how hood height, vehicle stopping position, pedestrian location at the intersection, and driver eye height affect the driver’s ability to see pedestrians, including pedestrians using wheelchairs. A field study was conducted at a signalized intersection in Corvallis, Oregon using three vehicles with varying hood heights, multiple driver heights, and staged pedestrian positions at the intersection. Observations were collected at four designated stopping positions: zero setback (front bumper of vehicle on leading edge of crosswalk line), and driver’s natural stopping positions at the crosswalk line, 4-foot setback line, and 10-foot setback line. A visibility index was created based on photographs to quantify pedestrian visibility for each scenario.

Results show that vehicle stopping position had the greatest influence on pedestrian visibility of the variables tested. Drivers who stopped at the 4-foot or 10-foot setback line consistently had higher visibility scores, while those that were at the zero-setback line had lower visibility of pedestrians. A relationship was observed between increasing hood height of the vehicle and decreasing visibility index scores particularly for wheelchairs in the crosswalk, demonstrating lower forward visibility of higher hood vehicles. Pedestrian location within the intersection also influenced visibility outcomes as pedestrians in the crosswalk were consistently the least visible across all vehicle types and stopping positions. Driver height had little influence on visibility index scores. Obstructions caused by rearview mirrors or other sensor packages in the windshield, as well as the obstruction that the pedestrian at the nearside curb ramp had on the far curb ramp pedestrian, created additional difficulties for drivers in seeing pedestrians at intersections. These findings support the implementation of advance stop lines, especially at 4-foot setbacks, as a practical countermeasure to improve pedestrian visibility amid the growing presence of higher hood vehicles.

Areas for Future Research

Based on the field findings, there are several areas that merit further investigation related to how vehicle design and roadway features affect pedestrian visibility. Additional research is needed on pedestrian visibility for vehicles with hood heights that range between 50 and 60 inches, as these are increasingly common. Analyzing windshield design and the cases where space is occupied by large sensor packages potentially obstructing forward vision also merits attention. There is also an absence of a standardized visibility testing method, such as the visibility index developed in this study. Another open question is how taller drivers experience visibility in smaller vehicles, and how this could differ from typical driver-vehicle configurations.

At the intersection level, further research is needed on how various curb return radii affect pedestrian visibility, as the current study was only conducted with 15-ft curb return radii. There is also a need for a more refined understanding of the advance stop line position in the greater than 4-foot range in relation to safety.

Human factors testing of the driver in the vehicle for the purpose of assessing and identify the best, most uniform way(s) to inform drivers of the visibility limitation they experience is warranted for high hood vehicles (>50-inches). This could include visual or auditory warning, dashboard alerts, or forward-facing camera systems that are similar in function to back-up cameras, especially when the vehicle is stopped or travelling at low speeds. These systems should consider the differences in direct and indirect vision to pedestrians and how this influences driver response time.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: RM, DH; data collection: WB, RM, DH; analysis and interpretation of results: WB, HJ, RM, DH.; draft manuscript preparation: WB, HJ, RM, DH. All authors reviewed the results and approved the final version of the manuscript.

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DECLARATION OF CONFLICTING INTERESTS

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Item No.: 24A-PED-02

NCUTCD PROPOSAL FOR CHANGES TO THE MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

COMMITTEE / TASK FORCE:	Pedestrian Joint Task Force
ITEM NUMBER:	24A-PED-02
TOPIC:	Pedestrian Change Interval with Preemption
ORIGIN OF REQUEST:	Pedestrian Clearance Interval Working Group Bob Garbacz (SIG), Rob Ziemba (SIG), Eagan Foster (SIG), Jay Jackson (SIG), Fred Mills (RR), Randy McCourt (PED)
AFFECTED SECTIONS OF MUTCD:	4F.19 Preemption Control of Traffic Control Signals

DEVELOPMENT HISTORY:

Approved by Joint Task Force:	02/09/2024 Pedestrian Joint Task Force
Approved by Technical Committee:	06/27/2024 Signals Technical Committee
Approved by NCUTCD Council:	06/28/2024

This is a proposal for recommended changes to the MUTCD that has been approved by the NCUTCD Council. This proposal does not represent a revision of the MUTCD and does not constitute official MUTCD standards, guidance, or options. It will be submitted to FHWA for consideration for inclusion in a future MUTCD revision. The MUTCD can be revised only through the federal rulemaking process.

SUMMARY:
In the 2023 MUTCD, FHWA changed a standard to option regarding truncation of pedestrian clearance intervals. The current language allows for an option to truncate pedestrian intervals without limitation. Additional text is provided to align the 2023 text with the Federal Register preamble explanation of what was changed.

DISCUSSION:
Truncating pedestrian change interval in the transition to preemption does not improve the safety of vulnerable users at grade crossings. Allowing for the shortening or omitting of the pedestrian change interval potentially exposes vulnerable road users, especially those with vision and/or mobility disabilities, to significant risk. The risk is created when they are crossing the street and their pedestrian indication is terminated mid-crossing to permit the signal to change to green on that approach in preparation for an approaching emergency response vehicle. It does not allow adequate clearance time for pedestrians to complete a crossing that has already commenced. The 2023 MUTCD text modification for Section 4F.19 converts what was a standard statement to an option statement related to truncation of pedestrian clearance intervals transitioning into preemption. The text as modified from the 2020 NPA opens the potential for unlimited truncation of pedestrian change intervals with preemption. The description

provided in the June 2013 (12B-STC-02) approved recommended change to the 2009 MUTCD explains the need for change, addressing vulnerable user safety in crossing streets after a walk indication has already allowed them to enter the street. To address this concern, it is proposed that similar language which was used in the NCUTCD Council approved change (approved three times by Council in 12B-STC-02,14A-STC-01 and NPA item #414/Chapter 4F Docket Comment May 2021) and 2020 NPA be used within the FHWAs desire to convert this information to an option statement. By an option statement this does not fully limit or control the practice. The proposal simply outlines the preferred practice for practitioner consideration and provides greater clarity regarding the omission of pedestrian change interval.

The following sections display the progression this text from the 2009 MUTCD, the NCUTCD approved recommendation of June 2013 (with changes noted) and the December 2020 FHWA NPA text for this paragraph for reference. As can been seen, the use of the exclusionary text, converted to option, simply clarifies the practice but does not establish it as either standard or guidance as advanced by FHWA in the final rule for the 2023 MUTCD. That may be subject to future study and considerations, particularly as FHWA considers adoption of PROWAG (specifically Section R306.2) into the MUTCD through future rule making.

2009 MUTCD

Standard:

During the transition into preemption control:

A. The yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.

B. The shortening or omission of any pedestrian walk interval and/or pedestrian change interval shall be permitted.

C. The return to the previous green signal indication shall be permitted following a steady yellow signal indication in the same signal face, omitting the red clearance interval, if any.

June 2013 NCUTCD 12B-STC-02

Standard:

During the transition into preemption control:

A. The yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.

B. The shortening or omission of any pedestrian walk interval ~~and/or pedestrian change interval~~ shall be permitted.

C. The shortening or omission of any pedestrian change interval shall be permitted only for boats at movable bridges and for rail traffic to which other traffic is required to yield the right-of-way by law.

~~C~~D. The return to the previous green signal indication shall be permitted following a steady yellow signal indication in the same signal face, omitting the red clearance interval, if any.

June 2014 NCUTCD 14A-STC-01 (showing only items B. and C.)

Standard:

B. The shortening or omission of any pedestrian walk interval ~~and/or pedestrian change interval~~ shall be permitted.

C. The shortening or omission of any pedestrian change interval shall be permitted only when the traffic control signal is being preempted because a boat is approaching a movable bridge or because rail traffic is approaching a grade crossing.

December 2020 FHWA NPA (also approved by NCUTCD Council as a part of FHWA-2020-0001 Chapter 4F Docket Comments)

Standard:

During the transition into preemption control:

A. The yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.
B. The shortening or omission of any pedestrian walk interval shall be permitted.
C. The shortening or omission of any pedestrian change interval shall be permitted only when the traffic control signal is being preempted because a boat is approaching a movable bridge or because rail traffic is approaching a grade crossing.
D. The return to the previous green signal indication shall be permitted following a steady yellow signal indication in the same signal face, omitting the red clearance interval, if any.

This following proposal takes the NCUTCD Council approved (three times) and reuses it in the new 2023 MUTCD language by folding it into the option language. It segregates out the omission of the pedestrian clearance interval as linked to the omission of the pedestrian walk interval. In doing so the carve outs for due to rail or boat preemption on pedestrian change interval truncation are reinstated as options which do not affect the concerns noted in the Federal Register preamble regarding emergency service effectiveness. Terminology from "shall be **permitted**" is updated using the 2023 MUTCD language.

Further research regarding the concerns of emergency service being "greatly diminished and completely ineffective due to increased delay" is needed as some agencies have effectively instituted the pedestrian clearance interval protection for these preemption systems. The protection of vulnerable users is of high importance in the design of signal preemption systems and this change helps clarify that importance.

RECOMMENDED MUTCD CHANGES:

The following present the proposed changes to the current MUTCD within the context of the current MUTCD language. Proposed additions to the MUTCD are shown in blue underline and proposed deletions from the MUTCD are shown in ~~red strikethrough~~. Changes previously approved by NCUTCD Council (but not yet adopted by FHWA) are shown in green double underline for additions and ~~green double strikethrough~~ for deletions. In some cases, background comments may be provided with the MUTCD text. These comments are indicated by [bracketed white text in shaded green]. Deletions made by a technical committee or task force after initial distribution to sponsoring organizations are shown in ~~highlighted red strikethrough and Helvetica text~~. Additions made by a technical committee or task force after initial distribution to sponsoring organizations are shown in underline blue and Helvetica text.

PART 4. HIGHWAY TRAFFIC SIGNALS

CHAPTER 4F. STEADY (STOP-AND-GO) OPERATION OF TRAFFIC CONTROL SIGNALS

Section 4F.19 Preemption Control of Traffic Control Signals Support:

Support:

01 Preemption control (see definition in Section 1C.02) is typically given to trains, boats, emergency vehicles, and light rail transit.

02 Examples of preemption control include the following:

A. The prompt displaying of green signal indications at signalized locations ahead of fire vehicles, law enforcement vehicles, ambulances, and other official emergency vehicles;

B. A special sequence of signal phases and timing to expedite and/or provide additional clearance time for vehicles to clear the tracks prior to the arrival of rail traffic; and

C. A special sequence of signal phases to display a steady red indication to prohibit turning movements toward the tracks during the approach or passage of rail traffic.

Standard:

03 During the transition into preemption control, the yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.

Option:

04 During the transition into preemption control:

A. ~~A. Any pedestrian~~ The walk interval ~~and/or pedestrian change interval~~ may be shortened ~~or omitted.~~ if the walk interval has begun.

B. The walk interval together with its associated pedestrian change interval may be omitted if the walk interval has not begun.

C. The pedestrian change interval may be shortened or omitted only for a boat approaching a moveable bridge or for rail traffic approaching a grade crossing.

~~B~~D. The red clearance interval, if any, may be omitted so that the return to the previous green signal indication follows a steady yellow signal indication in the same signal face.

Standard:

05 During preemption control and during the transition out of preemption control:

A. Any yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.

B. A signal indication sequence from a steady yellow signal indication to a green signal indication shall not be permitted.

Option:

06 A distinctive indication may be provided at the intersection to inform law enforcement personnel who are escorting traffic (such as a parade or funeral procession) that the traffic control signal has changed to a red indication not because of normal cycling, but because it has been preempted by rail traffic approaching an adjacent grade crossing or by boat traffic approaching an adjacent movable bridge.

07 A distinctive indication may be provided at the intersection to show that an emergency vehicle has been given control of the traffic control signal (see Section 11-106 of the "Uniform Vehicle Code"). In order to assist in the understanding of the control of the traffic control signal, a common distinctive indication may be used where drivers from different agencies travel through the same intersection when responding to emergencies.

Guidance:

08 *Except for traffic control signals interconnected with light rail transit systems, traffic control signals with railroad preemption or coordinated with flashing-light signal systems should be provided with a back-up power supply.*

09 *If a traffic control signal or hybrid beacon is installed near or within a grade crossing or if a grade crossing with active traffic control devices is within or near a signalized highway intersection, Chapter 8D should be consulted.*

Support:

10 Section 8D.09 contains additional information regarding preemption for grade crossings. Section 8D.10 contains information regarding prohibiting movements toward the grade crossing during preemption. Sections 8D.11 and 8D.12 contain additional information regarding pre-signals and queue cutter signals, respectively, for grade crossings.

National Committee on
Uniform Traffic Control Devices

13236 North 7th Street, Suite 4-259, Phoenix, Arizona 85022
Phone/Text: 231-4-NCUTCD (231-462-8823)
E-mail: secretary@ncutcd.org Website: https://ncutcd.org

Item No.: 25A-RW-01

NCUTCD PROPOSAL FOR CHANGES TO THE MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

COMMITTEE / TASK FORCE:	Regulatory and Warning Signs Technical Committee
ITEM NUMBER:	25A-RW-01
TOPIC:	School Zone When Flashing for CAV
ORIGIN OF REQUEST:	Signs For CAV – CAV Joint Task Force (Randy McCourt-RW, Terry Haukom-GMI, Roxane Mukai-GMI, Steve Alpert – GMI, Amanda Hamm-BTC)
AFFECTED SECTIONS OF MUTCD:	7B.05

DEVELOPMENT HISTORY:

Approved by RWSTC:	01/08/2025
Approved by CAVJTF	01/08/2025
Approved by NCUTCD Council:	

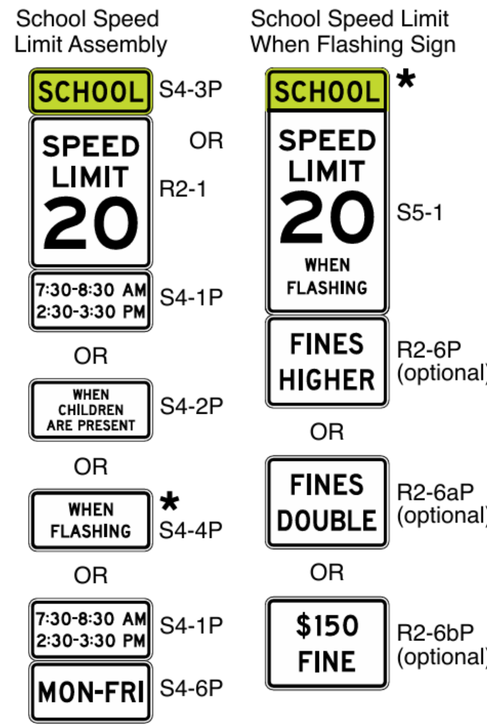
This is a proposed change to the MUTCD that has been developed by a technical committee, joint committee, or joint task force of the NCUTCD. The NCUTCD is distributing this to its sponsoring organizations for review and comment. Sponsor comments will be considered in revising the proposal prior to NCUTCD Council consideration. This proposal does not represent a revision of the MUTCD and does not constitute official MUTCD standards, guidance, options, or support. If approved by the NCUTCD Council, the recommended changes will be submitted to FHWA for consideration for inclusion in a future MUTCD revision. The MUTCD can be revised only through the federal rulemaking process.

SUMMARY:
The practice of utilizing hour, day and "when children present" text plaques to define the presence of a school speed limit for a School Speed Limit Assembly (Figure 7B-1) is inconsistent with 11th Edition MUTCD language in Part 5. To clarify intent, a new support statement is proposed for Part 7.

DISCUSSION:
The 11th Edition of the MUTCD Section 1A.03 states that "traffic control devices can be targeted at operators of motor vehicles, including driving automation systems, and at vulnerable road users." ~~includes a new road user (automated vehicles).~~ The need for uniformity and consistency in sign applications are a key aspect for all road users (Section 1.A01) and for~~of~~ driving automation systems (Section 5A.04). In Part 7 the use of school speed limit assemblies offers at least four options to address the periods of the day that the speed limit applies. In 1971 when school speed limit signs first were introduced to the MUTCD, states had (and continue

today) with various laws regarding school zone speed limits and required signing. This has resulted in various applications using the options afforded in the MUTCD.

The various plaques (S4-1P, 4-2P, S4-4P and S4-1P with S4-6P) all approach the definition of when the speed limit is in effect in different manners. For a human driver, driving automation systems (DAS), and enforcement understanding ~~what~~ "when children are present" is difficult (for example a person dressed in a hoody and jeans could be an adult or child).~~means may be interpreted but for driving automation systems (DAS) it may be nearly impossible~~. The unwritten understanding of 7:30-8:30 AM during school days is a common understanding but drivers and DAS requires literal interpretation. Even MON-FRI (during summer or teacher service days) requires interpretation. ~~that to be~~ Clearly defining~~ed for~~ every circumstance and school district operation (and schools~~those~~ with ball fields and parks) creates lack of clarity for both human drivers and DAS. Use of plaques of this nature can be~~This Is~~ inconsistent with stated objectives of the MUTCD 11th Edition (Section 1A.01 B. and C.) and Chapter 5 (Section 5A.04 P06A and 5B.01, P03A) where guidance calls for:



- Applying uniform and consistent traffic control devices on each type of roadway, and applying a similar approach to traffic control at similar locations in similar situations.
- Clearly associating the sign application with the displayed messaged to the specific road to which it applies with different speed limits or restrictions.

The "when flashing" application does not suffer from these shortcomings and should be emphasized. While it is not the intent to change all state laws, if the MUTCD is to be the guidance for traffic control devices for all road users (including DAS) the priorities and emphasis of applications should be reflected in the Part 7 text. This proposal seeks to place the order and priority of the School Speed Limit When Flashing Sign and the School Speed Limit Assembly so as to:

1. Emphasize the preferred application for all road users first
2. Clarifying support for the preferred application
3. Retaining existing language for other options, as part of the transition to eventual uniformity as State laws evolve.

RECOMMENDED MUTCD CHANGES:

The following present the proposed changes to the current MUTCD within the context of the current MUTCD language. Proposed additions to the MUTCD are shown in blue underline and proposed deletions from the MUTCD are shown in ~~red strikethrough~~. Changes previously approved by NCUTCD Council (but not yet adopted by FHWA) are shown in green double underline for additions and ~~green double strikethrough~~ for deletions. In some cases, background comments may be provided with the MUTCD text. These comments are indicated by [bracketed white text in shaded green]. Deletions made by a technical committee or task force after initial distribution to sponsoring organizations are shown in ~~highlighted red strikethrough and Helvetica text~~. Additions made by a technical committee or task force after initial distribution to sponsoring organizations are shown in underline blue and Helvetica text.

PART 7. TRAFFIC CONTROL FOR SCHOOL AREAS

CHAPTER 7B. SIGNS

Section 7B.05 School Speed Limit Signs and Plaques

Standard:

01 **A ~~School Speed Limit assembly (see Figure 7B-1) or a~~ School Speed Limit When Flashing (S5-1) sign (see Figure 7B-1) or School Speed Limit assembly (see Figure 7B-1) shall be used to indicate the speed limit where a reduced school speed limit zone has been established based upon an engineering study or where a reduced school speed limit is specified for such areas by statute. The ~~School Speed Limit assembly or~~ School Speed Limit When Flashing sign or School Speed Limit assembly shall be placed at or as near as practicable to the point where the reduced school speed limit zone begins (see Figures 7B-2 and 7B-4).**

02 **If a reduced school speed limit zone has been established, a School (S1-1) sign shall be installed in advance (see Table 2C-3 for advance placement guidelines) of the first ~~School Speed Limit sign assembly or~~ S5-1 sign or School Speed Limit assembly that is encountered in each direction as traffic approaches the reduced school speed limit zone (see Figures 7B-2 and 7B-4).**

03 **Except as provided in Paragraph 4 of this Section, the downstream end of an authorized and posted reduced school speed limit zone shall be identified with an END SCHOOL SPEED LIMIT (S5-3) sign (see Figures 7B-1, 7B-2, and 7B-4).**

Option:

04 If a reduced school speed limit zone ends at the same point as a designated school zone (see Section 7B.02), an END SCHOOL ZONE (S5-2) sign may be used instead of an END SCHOOL SPEED LIMIT (S5-3) sign. A standard Speed Limit sign showing the speed limit for the section of highway that is downstream from the authorized and posted reduced school speed limit zone may be mounted on the same post above the END SCHOOL SPEED LIMIT (S5-3) sign or the END SCHOOL ZONE (S5-2) sign.

Guidance:

05 *The beginning point of a reduced school speed limit zone should be at least 200 feet in advance of the school grounds or a school crossing; however, this 200-foot distance should be increased if the reduced school speed limit is 30 mph or higher. The maximum beginning point of a reduced school speed limit zone should not be greater than 500 feet in advance of the school grounds or a school crossing.*

Standard:

[Switch locations of paragraph 7 to follow paragraph 8 to emphasize its application & add support statement related to drivers, enforcement and CAV]

06 **The School Speed Limit assembly shall be one of the following:~~either~~**

A. a static sign assembly with Speed Limit Sign Beacons,

B. a blank-out sign, ~~or~~

C. a changeable message sign (see Chapter 2L), or

D. static sign assembly.

[This paragraph has been placed back in its original location compared to the proposal to sponsors]

~~07 **The static School Speed Limit assembly shall consist of a top plaque (S4-3P) with the legend SCHOOL, a Speed Limit (R2-1) sign, and a bottom plaque (S4-1P, S4-2P, S4-4P, or S4-6P) indicating the specific periods of the day and/or days of the week that the special school speed limit is in effect (see Figure 7B-1).**~~

~~08~~07 **When a School Speed Limit When Flashing (S5-1) sign or a School Speed Limit assembly ~~(R2-1) sign~~ with a ~~supplemental~~ WHEN FLASHING (S4-4P) plaque is used, a Speed Limit Sign Beacon (see Section 4S.04) shall be used to identify the periods that the school speed limit is in effect. ~~(see Sections 2A.12 and 4S.03).~~**

Support:

0~~6~~7a School Speed Limit When Flashing (S5-1) sign, School Speed Limit assembly with WHEN FLASHING (S4-4) plaque, ~~B~~blank-out sign~~s~~, or changeable message sign~~s and Speed Limit Sign Beacons with WHEN FLASHING (S4-4P) plaques support driving automation systems by~~ provide clear~~,~~ and simple meaning of when the school speed limit is in effect for all drivers, driving automation systems (see Section 5B.01) and enforcement.

07b ~~State~~ Laws, regulations and ordinances can ~~affect~~ inform school speed limit sign and plaque applications.

Standard:

~~**0607 The School Speed Limit assembly shall be either a static sign assembly, a blank-out sign, or a changeable message sign (see Chapter 2L).**~~

[Moved back to its original position]

~~07~~08 **~~T~~If used, the static School Speed Limit assembly (see Figure 7B-1) shall consist of a top plaque (S4-3P) with the legend SCHOOL, a Speed Limit (R2-1) sign, and a bottom plaque (S4-1P, S4-2P, ~~S4-4P,~~ or S4-1P with a S4-6P). The bottom plaque(s) shall indicate the ~~specific~~ conditions specifying ~~that address~~ when the ~~special~~ school speed limit is in effect.**

09 **Fluorescent yellow-green pixels shall be used when the "SCHOOL" message is displayed on a changeable message sign for a school speed limit.**

Option:

10 Changeable message signs may use blank-out messages or other methods in order to display the school speed limit only during the periods it applies.

11 A Vehicle Speed Feedback (W13-20aP) plaque that displays the speed of approaching drivers (see Sections 2B.21 and 2C.13), that is part of a School Speed Limit assembly or a School Speed Limit When Flashing (S5-1) sign, may be used in a school speed limit zone.

Guidance:

12 *If used, the Vehicle Speed Feedback (W13-20aP) plaque should only be used during the time period when the school speed limit is in effect.*

13 *A Reduced School Speed Limit Ahead (S4-5or S4-5a) sign (see Figure 7B-1) should be used to inform road users of a reduced speed zone where the speed limit is being reduced by more than 10 mph, or where engineering judgment indicates that advance notice would be appropriate.*

Standard:

14 **If used, the Reduced School Speed Limit Ahead sign shall be followed by a School Speed Limit sign or a School Speed Limit assembly.**

15 **The speed limit displayed on the Reduced School Speed Limit Ahead sign shall be identical to the speed limit displayed on the subsequent School Speed Limit sign or School Speed Limit assembly.**

Ransford S. McCourt, PE, PTOE
[address redacted]

September 12, 2025

Eric Leaming
Oregon Department of Transportation, Traffic Standards Unit
333 13th Street NE
Salem, OR 97301

SUBJECT: Draft Oregon Supplement to the MUTCD 11th Edition (2023)
Public Comment

Dear Eric:

Thank you for the opportunity to comment on the draft Oregon Supplement to the MUTCD (version August 15, 2025). I know substantial effort and collaboration have gone into this effort and it is greatly appreciated. One item that I wanted to address in public comment is an item that was a part of the Oregon Supplement to the 2009 MUTCD in part 8. It relates to the light rail transit (LRT) signal indications.

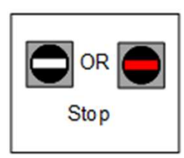
In section 8D.15 of the 2023 MUTCD a modification was made to the figure showing train signals (Figure 8D-3, Light Rail Transit Signal Indications). This new figure simplified the prior Figure 8C-3 showing just four indications and the notes changed language regarding the signal aspects "are white" (2009) to indications "shall be white" (2023). In item 571 of the Federal Register on notice of proposed amendment (December 14, 2020) it states: FHWA proposes these changes to improve consistency in the use of LRT signal indications. It does not offer any research or findings as to the change to standard language. No further mention of this change is made in the Federal Register for final rule making in 2023 (Vol. 88, No. 242, page 87691-87692, December 19, 2023) nor in the Supplement Summary of Disposition for Final Rule changes (beyond stating "adopted as proposed").

The underlying research that established the bars and white color (TCRP Report 17 Integration of Light Rail Transit into City Streets, 1996, page 83) focused on an issue of possible motorist confusion with the meaning of the LRT (noting a green "T" signal as the concern with left turn movements). No mention of the stop display being a part of the possible confusion. In Appendix A of TCRP 17 (pages 10-49 to 10-51) included suggested changes/additions to the MUTCD for LRT grade crossings. It highlights the following:

- The light rail signal indication should convey the intended message to the LRV operator without any supplementary signs. It should contrast with vehicular signals in size, shape, color, aspect, and placement.

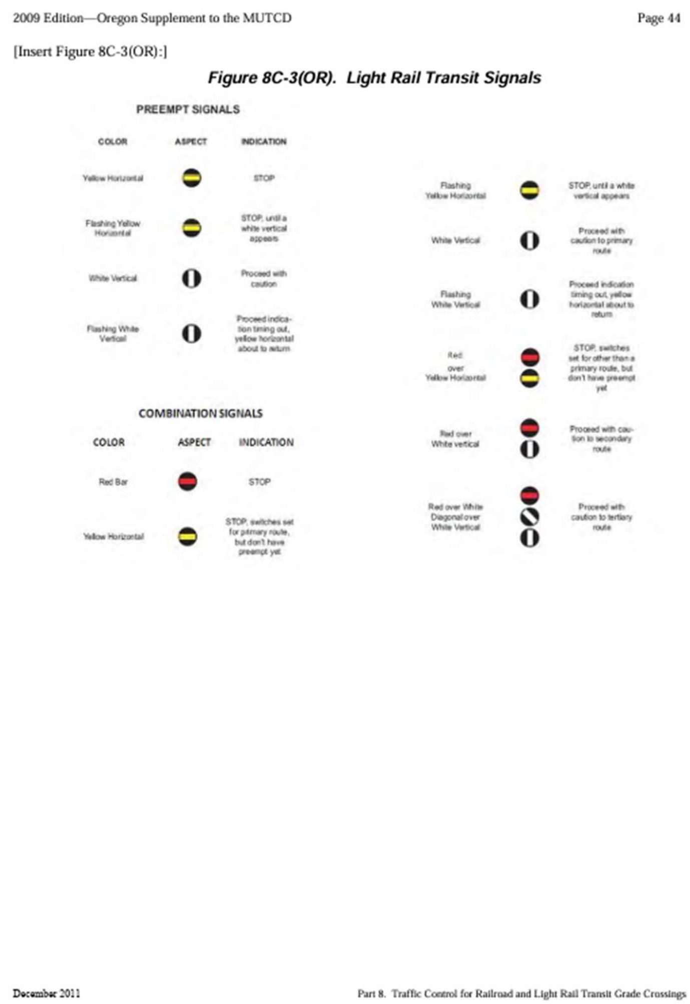
- The signal installation should consist of a three-lens signal face oriented vertically, conveying the STOP, PREPARE TO STOP and GO indications. Alternatively, the LRT signal may consist of a two-section head with the STOP and GO indications only. If a two-section head is used, the GO indication should also be used in a flashing mode for conveying the PREPARE TO STOP indication. A flashing STOP indication may be used to convey change to the GO indication
- The highway signaling convention with the STOP indication at the top and the GO indication at the bottom should be followed.
- The GO indication should be displayed as a vertical (proceed straight) or angled (turn) bar.
- The STOP indication should be displayed as a horizontal bar.
- The color for all LRT signal indications should be lunar white but may be incandescent white. Amber may be used for the PREPARE TO STOP and/or STOP indication. LED (Light-Emitting Diode) displays may be used.
- The size of the signal lenses that govern LRVs should be 12 inches.
- The primary LRT signal head should be located on the near side of the at-grade crossing or intersection.
- The LRT signal heads should be separated vertically and/or horizontally from the nearest traffic signal head or pedestrian signal head for the same approach by a minimum of 8 feet.

Nowhere in the research was there underlying findings that express for the stop indication to be a "shall be" white. In fact, it is stated as a "should" in the supporting work (the subsequent report made a recommendation). I am unaware of the research that furthers this finding for motorists, LRT/bus operators and all road users. While uniformity and consistency are important core principles of the MUTCD, even the FHWA in the Federal Register note the need for "flexibility" in the LRT signal displays related to assembly of indications. There are at least eight agencies that use "non-white" horizontal bars for stop. Most of these decisions have been made by transit operators to improve performance and safety – entered into with consideration of needs for motorists, weather impacts to visibility and best recognition for all users. Because these signals are specific to transit operators, their relationship to uniformity is different. They are only used by a group of road users that are professional drivers. Railroads have historically used red bar for stop indications. This all points to a need for defining research that establishes the best configuration for all road users. While the technical capabilities to conduct such research may not have existed in the 1990s, today various tools exist (simulators, eye tracking) that can explore the performance of transit signals (in addition to surveys and crash records) which can be used to guide the findings for proposing standard language.



The need for the LRT/Bus signal indication flexibility was part of the Oregon Supplement to the 2009 MUTCD in Figure 8C-3(OR), see below. In the Supplement for the 2023 MUTCD, ODOT has removed this text and figure. It is understood that the FHWA region administrator has provided direction that unless there is a standing statute in place (ORS) that a modification of a MUTCD "shall" condition would not be accepted. It is understood that no such language exists for LRT/transit signal display like that for the case of ORS 811.028 which requires drivers to stop for pedestrians. To obtain such ORS language would be 2026/2027 when the legislature returns, beyond the supplement deadline.

I would request to ODOT that, until research is conducted, the current Figure 8C-03 be retained. It has not been proven that this change to the 2023 MUTCD related to the "white bar" is safer for all road users than the prior language of 2009. Compliance does not establish the best practice – research does. A research problem statement has been developed by MBTA in Boston as they share this concern (draft attached).


2009 Edition—Oregon Supplement to the MUTCD Page 44

[Insert Figure 8C-3(OR):]

Figure 8C-3(OR). Light Rail Transit Signals

December 2011 Part 8. Traffic Control for Railroad and Light Rail Transit Grade Crossings

If the FHWA rejects this request, a second request would be to gain approval from FHWA for experimentation of red (colored) stop LRT/bus signal displays. This would be a collaborate experiment working with Portland (Tri-Met), Seattle (Sound Transit/King County Metro), San Francisco (SFMTA/Muni), Salt Lake City (TRAX), Houston (METRORail), Boston (MBTA), and others. It would build off the MBTA research statement, allowing the current signals to remain until the research is completed that establishes a finding as to the most effective stop transit signal indication.

Thank you for your consideration. Take care and be safe

Sincerely,

Randy McCourt

UMASS DRAFT WORK PLAN
EVALUATION OF TRANSIT SIGNAL DISPLAY OPTIONS

Start Date: September 1, 2025
End Date: August 31, 2027

Budget: $455,132. All task estimates also include 26% overhead

Task 1 Project Kickoff and Scope Refinement [09/01/25 – 09/30/25] – $1,722
The UMass team will revise the scope in response to suggestions from MBTA and others. They will also update the schedule of tasks and deliverables accordingly. The PI and co-PIs will also participate in the virtual meeting to discuss any proposed revisions.

Product: Final UMass scope of work, budget, and project schedule

The remaining tasks will be grouped into two Phases.

Phase I will focus on gathering existing information through a robust literature review, a detailed crash report analysis, a technical scan of existing implementations, and a survey of transit operators to understand existing guidelines and practices as they pertain to the implementation of optional transit signals in terms of both positioning and display as well their operational and safety impacts. In addition, this will allow for a comprehensive understanding of transit operator preferences regarding positioning and display of optional transit signals.

Phase 2 will focus on understanding driver behavior when encountering optional transit signals through both a field study and a driving simulator study. This will allow for a comprehensive assessment of the impact of various transit signal displays and mounting positions on driver behavior that will support the development of recommendations for the MUTCD.

Phase 1 – State of Practice

Task 2: Literature Review [10/01/25 – 11/30/25] - $13,291
UMass will lead the review of the literature related to transit signal displays using published material such as refereed journal publications and research reports. The team has extensive experience conducting review of published literature and for control devices. The literature will focus on documenting:

1. guidelines related to the implementation of optional transit signal heads:
    a. design (signal head shapes and colors)
    b. mounting position
    c. backplate color and shape (square v. rounded edges)
    d. use of supplemental sign,
2. the impact of the features on the operational and safety performance of optional transit signals.

3. preferences for specific transit signal displays, mounting positions, backplate colors and shapes, and supplemental signage, as expressed by transit operators and drivers and documented in the literature.

Emphasis will be placed on documenting differences between optional transit signals for light rail and transit buses. The team will utilize TRIS and other relevant databases and will have the support of the UMass Libraries, as needed, in accessing various publications. Some example publications to be reviewed include:

Table 1. Prior Studies of Transit Signal Displays

• TCRP 17, 1996 • TCRP 117, 2007 • TCRP Web-Only Document 53, 2011 • TCRP Web-Only Document 66, 2015 • TCRP Synthesis 149, 2020 • AASHTO Transit Guide • NACTO Transit Street Design Guide	• Traffic Control Applications for Bus Transit Survey, 2018, BRT/Bus Task Force NCUTCD • ITE Survey of Transit Signal Applications, 2024	• FHWA MUTCD Final Rule Making Federal Register, December 2020, pages 80967-80968 • FHWA MUTCD Supplemental Summary of Final Rule Dispositions, December 2020, pages 241-242

In addition, UMass will lead the outreach to transit agencies with the support of consultant Peter Koonce. More specifically, we will reach out to transit agencies that utilize optional transit signal displays (as documented in the 2024 ITE Survey) to inquire about:

a) the number and location of optional transit signals – including a summary inventory,
b) guidelines specific to the positioning of those signals, as well as the specific design of the signal heads,
c) any studies, surveys and research they have done regarding the performance of the optional transit signal displays, and
d) establishing a point of contact to acquire collision/crash data.

Consultant Peter Koonce will support this effort by identifying contacts with transit agencies as needed.

Product: A memo containing a summary of the reviewed publications (including those identified through the transit agency outreach) with a focus on the performance, safety, satisfaction and/or preference of various optional transit signal displays. This will include an annotated bibliography of research specifying what the research found related to transit signal displays. The memo will also include a description of the information collected via the transit agency outreach, namely, the number and location of optional transit signals used by the various transit agencies, guidelines related to the positioning and design of optional transit signal displays, as well as the safety and operational impacts of those on both transit operators and drivers. It is intended that this product will become an appendix to the final report. An inventory of all identified locations across the country will also be created.

Task 3: Technical Scan of Transit Signal Displays Applications [10/01/25 – 02/28/26] - $13,091

The UMass team will lead this Task by summarizing the viable alternative signal display options for both bus and light rail, as identified by the ITE survey of sites that use various transit signal displays in the United States as well as documentation, survey, data, interviews, and other input obtained from the transit agencies that the team reaches out to in Task 2. Additional outreach will take place as part of this effort through meetings with various standing committees related to transit such as:

- NACTO Transit,
- ITE Community/Transit Standing Committee,
- National Committee on Uniform Traffic Control Devices (NCUTCD), Signals Technical Committee,
- Transportation Research Board Public Transportation Group (AP000),
- AASHTO Council on Public Transit, and
- Other groups identified prior to the conclusion of this task.

Connections with those committees will be facilitated through the PIs' professional contacts as well as consultant Peter Koonce.

This task will prepare a summary of displays to frame up the unique transit signal displays being utilized presently. A summary will be prepared that highlights the following:

- "Stop" display application
- "Prepare to stop" display application
- "Go" display application
- Head assembly (2, 3, 4 aspects)
- Backplate color and shape

Additional elements will also be documented such as:

- Signal location - roadside (only on far side), overhead, etc.), signal indications (e.g., red bar, white triangle, etc.), type of sign(s) present and where located (e.g., on mast arm or roadside or in advance of crossing, mounting position, e.g., with respect to the other signals
- Construction date - Installation date for before-after analysis, which is the preferred technique for this research project, or verification that the installation preceded the crash data periods for cross section analysis
- Corridor information - Speed limit, presence of bus lanes, number and type of nearby intersections (access density), street network configuration, presence of on-street parking, bike lanes, sidewalk, buffer
- Crashes - Number of crashes, fatal and injury crashes, pedestrian crashes, and other types of crashes. Ability to articulate the role transit signals may have potentially been a factor in crashes
- Exposure - average daily traffic or peak hour volumes for motor vehicles (passenger cars and trucks), bicycles, and pedestrians
- Crossing Configuration - Number of legs, presence of skew, channelized turn lane, or other geometric feature of interest
- Land use - Presence (and type) of schools or parks, distance to school)

- Lighting - Is street lighting present (Yes/No)
- Roadway cross-section elements - Number, type, and width of lanes, median characteristics, on-street parking
- Roadway Facility Type - Urban Arterial, urban Collector, urban Local Street. Also, whether the approaches are two-way or one-way
- Nearby traffic control devices - Nearby signs (including supplemental TSP signs), signals, beacons, pavement markings and associated characteristics and placement.

An overview of other countries applications of transit signal displays will also be provided.

Product: A technical memo that explains the outreach process and data collection will be prepared. Tables and figures will be used to summarize various applications and site characteristics. Discussion will include assessment of the most common applications as well as unique applications of merit. Anecdotal performance of transit signal operation will also be documented. This will include identification of train signaling next to arterial streets as an example to identify if the use of red signals for these applications has been problematic to motorists. The memo will become an appendix to the final report. This Task will also deliver a list of contacts that can be utilized in Task 6 to request crash records.

Task 4: Agency Outreach Survey [12/01/25-01/31/26] -- $12,843
The UMass team will develop a survey to be shared with transit agencies across the country so that data (quantitative and anecdotal) related to the design and performance of various signal displays can be collected. The team will create a survey and will provide the MBTA with an opportunity for review and comment in advance of full-scale distribution. This outreach effort will be open to all but targeted to obtain information by at least 3-5 stakeholders (transit agencies and transportation/traffic engineering stakeholders that are familiar with transit signal displays) for each of the transit display types established in Task 3 with at least three years of operational experience with transit signal displays. An example of the types of questions that may be used include:

- What types of transit signal displays do you use (e.g., “stop”, “prepare to stop” and “go” displays, head assembly, backplate color and shape, mounting position and location, etc.)
- What do you consider as important when deciding what the transit signal head display would be? Is it consistent with the MUTCD? And if not, please explain.
- Can you give an example of why you have made this decision over another?
- Do you have unique bus/transit signal signing?
- Are your transit signal heads passive detection activated?
- In addition to transit signal heads, what types of supplemental treatments do you typically supplement them with (e.g., supplemental signage.).
- What are the operational characteristics of your system (transit only turns, queue jump lanes, bus lanes, etc.)
- Describe any benefits (both operations and safety) the region has experienced with transit signal priority/signal heads, including if there have been any issues associated with their operation and any countermeasures implemented to address those issues. Particularly focused upon the transit signal displays and their performance for both transit operators and motoring public.
- Have there been any crashes at transit signal display locations?

- Have you received any complaints from drivers and/or transit operators regarding the design, location, and operation of transit signals?
- Do you have any other comments regarding your region's use of transit signal display?
- Other questions as identified in Tasks 2 and 3 or from discussion with MBTA.

Consultant Peter Koonce will support the outreach component and participant recruitment for this survey and will provide expert input on the survey development. Recruitment will also be facilitated by the contacts obtained in Task 2.

Product: A technical memorandum summarizing the responses to the agency survey focusing on documenting their experience specific to transit signal displays, both from local agency and transit agency perspective. This will include their satisfaction and issues associated with their transit signal displays. The core findings will identify if preferences in operation exist and if there are experiences that document any preference (or desire for change).

Task 5: Transit Operator Survey [12/01/25-01/31/26] - $12,843

The UMass team will lead the development of a second transit operator survey targeting transit vehicle operators to understand their preferences and experiences with the various transit signal display options. This will include recruitment of MBTA and other agency operators where the red display is implemented as well as operators utilizing the white display. Example questions that could be included in the survey are:

- Which of the signal head designs allows drivers the higher recognition?
- What is the preference of transit operators?
- If changes were made to displays, in their opinion, what were the reasons for changes.
- Is comprehension affected by weather (e.g., fog, mist) or lighting conditions?
- Is comprehension affected by the presence of dedicated bus lanes or queue jumper lanes?
- Is comprehension affected by other characteristics of the operating environment?
- What is the information that need to be communicated to them for driving decisions and what is the best way for that information to be communicated? Do supplemental signs improve comprehension?
- Does the mounting location or backplate color/shape of the signal head matter? Is their impact a function of the size of the intersection, bus stop location, and presence of bus lanes or queue jumper lanes?
- Does uniformity with rail signaling or auto traffic signals matter for professional drivers?

Transit operators will also be asked to provide recommendations that would make their agency's current displays better from the drivers' perspective. Extraction of this information can be facilitated by questions on/visuals of alternate displays.

Consultant Peter Koonce will support the outreach component and participant recruitment for this survey and will provide expert input on the survey development. Recruitment will also be facilitated by the contacts obtained in Task 2.

Product: A technical memorandum summarizing the results of the outreach/survey with the intent to identify driver preferences that affect safety.

Task 6: Crash Records Safety Evaluation [01/01/26 – 02/28/26] - $26,031
The UMass team will lead Task 6 by contacting relevant stakeholders (identified in Task 2), obtaining crash data, analyzing crash reports and exploring narratives to create a database of transit/motor vehicle crashes at locations with transit signals. The objective of this task is to identify if any crashes have been associated with transit displays and why. The intent is to research crash records (up to ten years) for one site with 2009 MUTCD compliant signals (polar white), one site with 2023 MUTCD compliant signals (no triangle display), one site utilizing colored stop signal indications for transit and one additional site to be determined following Task 3 (for example a signalized queue jumper lane). The impact of signal mounting locations and supplemental signage will also be investigated along with other elements outlined in Task 3.

In cooperation with transit and local agencies, we will obtain crash and volume (both motor vehicle and transit headway) data associated with transit vehicles at signalized intersections controlled by transit signal indications. This task will also utilize TSP installation dates obtained in Task 3, so that the research team can parse out crashes that occurred before and after the installation of specific TSP signal heads to both determine the correlation of crashes with certain signal head designs by conducting a before and after the TSP installation crash analysis and exploring in detail the narratives of those crashes that have occurred after the installation of the TSP signal heads. The exploration of crash records and of the narratives will investigate if the cause of the crash was attributable to the transit signal display or other co-founding factors that are not relevant to the signal operations have contributed to the crash as well. Where crashes are documented, context and design of the location will be inventoried as available. These may include number of lanes, preferential lanes, intersection configuration, signal phasing, volumes by mode, headway, violation data, driver yielding, signal display configuration—particularly, the transit signal display position—context/land use/setting, site distance to signal displays, presence of other counter measures, for example, yellow reflective tape, and other elements as outlined and likely obtained in Task 3. During scoping, a determination will be made as to whether crash modification factors may be able to be computed comparing transit signal display configuration variations, which would be added to this task.

Product: A technical memorandum summarizing the crash data and comparisons between the various traffic signal control displays for transit. Specifically, if any crashes are attributed to a specific transit display – either transit operator or motorist – they will be identified and documented with details.

Phase 2 – Assessing Driver Behavior

Task 7: Empirical Observations of Driver and Transit Operator Behavior [03/01/26 – 06/30/26] – $85,210
This task will include a field study of 3-5 location with different optional transit signal displays that will be facilitated through the installation of cameras for at least 24 hours at each of the selected sites. Specific locations will be determined by the research team in collaboration with the MBTA and will include different states. We anticipate sites in at least Portland, OR and Boston, MA. An effort will be made to choose the sites while controlling for several other features, such as the number of lanes, car demand, type of bus infrastructure present at the

intersection, etc. The video recordings will be analyzed to obtain driver compliance with respect to the signal indications at the intersection, e.g., does the driver stop if a "stop" signal indication is on for vehicles and a "go" for transit vehicles? A statistical analysis of the collected data will allow us to obtain insights on bicyclist behavior at bike boxes and understand the impact of bike box design characteristics on that behavior.

Product: Video recordings and a technical memorandum summarizing the field experiment and its findings.

Task 8: Human Factors Testing of Design Images [06/01/26 – 08/31/26] - $24,401

This task includes a static evaluation survey, assessing motorist comprehension of optional transit displays. The UMass team will be responsible for the development of the survey, the recruitment and compensation of participants, and for summarizing the results.

This phase will utilize static images with human subjects, posing as drivers, to determine if transit signal displays are noticed and would affect their ability to safely travel through intersections. The images will include various combinations of traffic signal displays for motorists combined with alternative optional transit signal displays. The images will represent various operational scenarios (transit priority, queue jump, no transit call) and signal display designs ("stop", "prepare to stop" and "go" displays, head assembly, backplate color and shape, mounting position and location, etc.) Participants will be asked what they are supposed to do, if they experience any confusion from the traffic control device(s) and if they recognize transit signal displays (or if their operational decisions are affected or confused by them). The research team will seek answers to the following questions through this static evaluation to understand driver comprehension and preferences:

- Does the design ("stop", "prepare to stop" and "go" displays, head assembly, backplate color and shape, mounting position and location, etc.), of the transit signal affect driver behavior at the intersection?
- Is driver compliance enhanced when supplemental signage is provided?
- Does the presence of bus lanes and queue jumper lanes or the bus itself play a role in driver comprehension by improving their situational awareness?
- Is there a need for a pre-stop display of unique shape beneficial or does the flashing approach meet the need?

This will require a statistically significant number of subjects and test scenarios to explore various transit signal alternative scenarios. The results of this task will provide input in the specific scenarios that will be proposed in Task 9 and tested in Task 10.

Product: A technical memorandum summarizing the findings of the static evaluation with a focus on optional transit display elements that affect driver comprehension.

Task 9: Conceptual Development of Transit Signal Alternatives – [08/01/26 – 09/30/26] - $7,574

UMass will lead this task by providing a list of transit signal alternatives and experimental designs to be tested in driving simulation. The experimental design will be done with support from OSU. These will be presented to MBTA through a virtual meeting.

Product: Technical memorandum and project meeting (virtual).

Task 10: Simulation of Transit Signal Display [10/01/26 – 05/31/27] - $237,286

This Task includes the development of the driving simulation experiment as well as the analysis of collected data. OSU will lead the design of the driving scenarios for a passenger car driving simulator experiment, which includes the static and dynamic elements of the experiment, supported by UMass. These scenarios will be administered in the simulator labs at OSU and UMass. UMass and OSU will be responsible for obtaining Institutional Review Board approval for human subjects research, recruiting at least 30 usable participants, running the experiment, and downloading the simulator data at their respective locations. UMass will lead the analysis of the collected data to assess motorist comprehension and potential confusion when transit signal displays are present. A meeting will be planned with the National Committee on Uniform Traffic Control to present the proposed alternatives prior to them being tested.

Three operational scenarios using transit signal displays that have potential to establish if driver confusion using human subject in a driving simulator. The three scenarios will include a bus queue jump, median running bus/LRT and one additional scenario to be established during the previous Tasks. Optional transit signal displays to be tested will include variations in the signal display ("stop", "prepare to stop" and "go" display color and design, horizontal vs vertical bar) and will be positioned at the locations identified as the most effective for comprehension based on the findings of previous tasks. Additionally, using the same scenarios, driver comprehension in rain and fog conditions and in nighttime conditions will be tested at OSU and at UMass, respectively, to assess variations in driver comprehension under different environmental conditions. Cases to be tested include the transit indication being a "stop" display while motorists are provided a "go" display. A scenario where the bus has a queue jumper lane or bus lane and receives a "go" display first (while cars see a red light) will also be tested.

The objective of this phase will be to test motorist's behavior in the presence of alternative transit signal displays to determine confusion or distraction caused by the transit display. The simulation will consider all road users (transit, motorists, pedestrians, bicycles). Measures of effectiveness (MOE) of interest, will be comprehension of various combinations of the signal displays (auto and transit) as expressed by their compliance with them through proper stopping, unwarranted braking, sudden braking, moving through the intersection when the transit signal is green but the auto one is red, or, in post simulation surveys, driver perceptions of the transit signal display. In addition, eye tracking data will be collected and analyzed to understand driver scanning patterns and explore distraction or confusion as well as the of the signal positioning and overall design on those patterns and behaviors. Additional MOEs will be determined through the literature review (from similar studies) and will also be informed from the results of Task 8.

Product: (1) Meeting with NCUTCD to review proposed experimental design and driving simulation scenarios, and (2) a technical memorandum documenting the simulation approach and findings.

Task 11: Development of Findings Report [06/01/27 – 07/31/27] - $10,819

The UMass team will lead this task by preparing the final report that will be developed progressively while tasks are being completed and will include the following chapters:

- Executive summary (not to exceed 3 pages)
- Background (explaining the topic, issues and work plan)
- Existing Conditions of Transit Signal Displays (documenting current applications)
- Description of Alternative Transit Signal Displays
- Evaluation (a description of the evaluation of transit signal displays by phases 1-5)
- Findings, Recommendations and Conclusion (not to exceed 5 pages, including a recommended transit signal display for stop and prepare to stop)
- Appendix: Task technical memorandums

Prior to finalizing the final report draft the research team will present the research process and findings with professional communities so that their input can be incorporated in the draft final report.

Product: Powerpoint presentation for presentations with professional communities, Draft Findings Report, summary sheet (2-3 page tech brief), and summary PowerPoint presentation (not exceeding 20 slides).

Task 12: Proposed Changes to the MUTCD [07/01/27 – 08/31/27] - $10,021

The UMass team will lead this task by providing the summary, discussion of research findings, and proposed changes to MUTCD in the form of the NCUTCD proposal template. This will be provided to the Transit Multi-Committee Task Force for consideration and action prior to the January 2027 NCUTCD meeting.

Product: A draft proposal for changes to the MUTCD.

UMass Research Team

PI: Eleni Christofa (0.5 summer months), PhD, Professor, Civil & Environmental Engineering
Expertise: transit signal priority, user behavior and related safety outcomes; multiple driving simulator studies focused on micromobility
Responsibilities: Project management, communications with MBTA and Jacobs, supervision of all UMass tasks, students, deliverables.

Co-PI: Michael Knodler (0.09 summer months), PhD, Professor in Civil & Environmental Engineering, Director of the University of Massachusetts Transportation Center, co-Director of the UMass Human Performance Lab (driving simulator)

Expertise: transportation operations and safety; performed similar study on flashing yellow arrow before its inclusion in the MUTCD
Responsibilities: Supervision of the development of the experimental design and analysis of data.

Co-PI: Anuj Pradhan (0.5 summer months), PhD, Assistant Professor in Industrial Engineering, co-Director of the UMass Human Performance Lab
Expertise: Human factors expertise; etiology of crashes from a behavioral standpoint; experience with human factors research for young and novice drivers; has developed driver training and education material
Responsibilities: Supervision of simulator experiment development especially at it pertains to sensors for capturing driver behavior (e.g., eye tracker) and developing recommendations on driver training and education.

Co-PI Francis Tainter (10% effort), PhD, Assistant Research Professor
Expertise: Transportation operations and safety, traffic control devices. Extensive experience with driving simulator studies on the impact of control devices on motorist behavior and crash outcomes, e.g., flashing yellow arrow as well as on driver comprehension of control devices, e.g., Pedestrian Hybrid Beacon
Responsibilities: Supervision and troubleshooting simulator experiment development, participant recruitment, and managing data analysis.

Graduate Research Assistant 1 (20 hrs per week for 24 months): **Fay Kostopoulou, MS**
Expertise: Transit signal priority and the use of machine learning and statistical tools
Responsibilities: Literature review and analysis of collected data. She will also be responsible for the final report and any other deliverables to MBTA. Fay will supervise the development of the experimental design and the driving simulator experiments. As part of this she will work with OSU for the design of the alternative signal heads to be used in the experiments and while they are developing the simulator drives. She will also be responsible for analyzing the results of this study (using data collected both at OSU and UMass).

Graduate Research Assistant 2 (10 hrs per week for 12 months): **TBD**
Expertise: Crash data analysis, driving simulation
Responsibilities: Crash data collection via outreach to transit agencies and other relevant stakeholders, crash data analysis, including statistical analysis and extracting information from the narratives. They will also assist with the static evaluation and the development of the driving simulator scenarios.

Undergraduate Student Researchers (10 hrs per week for 8 weeks while running the simulator experiments): **TBD**
Responsibilities: Interacting with participants, collecting surveys from them, starting and ending the simulator experiment.

Subrecipients:
Oregon State University – PI: David Hurwitz ($165,000; charged overhead on only the first $25,000)

Expertise: transportation safety, human factors, traffic control devices; extensive experience in driving simulator experiments to assess user behavior
Responsibilities: The OSU team will support the field and driving simulation experimental design led by UMass. They will collect driver and transit operator behavioral data from selected intersections in Portland, OR. They will also lead the development of the static and dynamic elements of the experiment and the overall driving simulator scenarios. Finally, they will run an equivalent to UMass number of subjects at their driving simulator lab and analyze the driving simulator data.

Consultants:
Peter Koonce Consulting LLC ($10,000)
Expertise: traffic signal systems, traffic control devices, transportation safety, extensive experience in the evaluation of traffic control devices (some of which through NCHRP), participation in many relevant committees (e.g., NCUTCD, ITE, etc.).
Responsibilities: Peter Koonce Consulting LLC, will support the work of this project by providing expert input on the development of the surveys as well as assisting with the outreach to agencies and operators. In addition, they will play an instrumental role connecting the research team with NCUTCD. Lastly, they will provide expert input on the experimental design and recommendations that will result from the analysis of the collected data.

Other Costs:
Simulator Fee: $12,600 ($125/hour * 80 hours +0.26% overhead)
Student Tuition: $41,757 (no overhead)
Participant Costs: $1,600 (30 participants *$25/hour for driving simulator study + $500 for static evaluation; no overhead)

Summary

Task	Question	Dollars
1. Project Kickoff/Scope Refinement		$1,722
State of the Practice		
2. Literature Review		$13,291
3. Technical Scan of Traffic Signal Display Applications		$13,091
4. Agency Outreach		$12,843
5. Transit Operator Survey		$12,842
6. Crash Records Safety Evaluation		$26,031
Assessing Driver Behavior		
7. Empirical Observations of Driver and Transit Operator Behavior		$85,210
8. Human Factors Testing Design Images		$24,401
9. Conceptual Development of Transit Signal Alternatives		$7,574
10. Simulation of Transit Signal Displays		$237,286
11. Development of Findings Report		$10,819
12. Proposed Changes to the MUTCD		$10,021
TOTAL		**$455,132**

Questions;

Safety Parameters

- Separation from other signals?
- Position on approach?
- Limitation of visibility to other road users? (confusion issue + numerous TCD/signal displays – confounding drivers/other users)
- A supplemental sign (bus signal sign, lane use control signs w/ signals)?
- Unique treatments specific only for conditions where signal displays result in conflicts (LRT/bus display differs from similar vehicle display, otherwise transit and vehicle signals display same indication)? (turning vehicles across LRT/bus path, turning LRT/bus path across vehicles lanes, advance LRT/bus movement prior to similar vehicle movement (queue jump)