Designing for Consistency: Matching Applications to Scenarios in the Use of Traffic Signing

AUTHORS
Scott O. Kuznicki, P.E.
Bryan J. Katz, Ph.D., P.E., PTOE

SUBMITTAL DATE
Sunday, December 14th, 2014
Friday, January 30th, 2015
Friday, March 20th, 2015

SUBMITTED FOR THE
5th International Symposium on Highway Geometric Design
June 22nd-24th, 2015
Vancouver, British Columbia, Canada

AUTHOR INFORMATION
Scott O. Kuznicki, P.E. **CORRESPONDING AUTHOR**
Toxcel, *LLC*
4301 South Banyan Avenue
Sioux Falls, South Dakota 57110   USA
E-MAIL: sk@midwestroads.com
PHONE: 01-847-769-1098

Bryan J. Katz, Ph.D., P.E., PTOE
Toxcel, *LLC*
7140 Heritage Village Pl
Gainesville, Virginia 20155   USA

TRB-STYLE-CONFOMRING WORD COUNT

WORDS	4,997	4,997
TABLES	0	0
FIGURES	10	2,500
TOTAL		**7,497**

ABSTRACT

One elemental characteristic of an effective traffic control device (TCD) is its exclusive use under a specific set of circumstances. For example, right-hand curves are treated solely with signs that point to the right, never to the left. Scenario-based implementations, where the selection of a device is predicated on both the geometric conditions present and the message of the selected TCD, is essential for ensuring that the devices convey a clear and simple meaning and are readily understood and applied by road users.

Geometric design plays an important role in the application of TCDs within a system. TCD selection and implementation is dependent on the horizontal and vertical design criteria, roadside appurtenances, the type, location, and magnitude of transition elements such as lane reduction tapers, and even the width of lanes. In recent practice, two trends have emerged that threaten the "readability" of geometric design features and dilute the meaning and effectiveness of TCDs. On one hand, TCDs with a single meaning are being used across locations with differing geometric design characteristics. On the other hand, locations with identical or similar geometric design characteristics are being treated with TCDs that vary by location. Both of these misapplications of TCDs violate the key principle of driver expectancy. This paper identifies field cases of TCD misapplication, assesses the influence of geometric design in the selection of TCDs, and proposes model guidelines for geometric design processes and TCD implementation for practitioners who wish to achieve TCD consistency with geometric design.

BACKGROUND

As the transportation system in the United States continues to grow and develop, the need for skilled technical staff to evaluate, design, and install traffic control devices (TCDs) also increases. While the basic applications of many TCDs has not changed, complex roadway geometric design features and alternative intersection designs have necessitated new approaches to the design and installation of signs and pavement markings. One straightforward example is the “trap lane” (see page 10), once relegated to urban areas yet now ubiquitous, even on rural two-lane highways. Various methods of marking trap lanes exist in practice today and signing for trap lanes is inconsistent between jurisdictions and, in administrative regions without a traffic engineer on staff, often the signing and marking is nonexistent.

Diverging diamond interchanges, roundabouts, and new approaches to traffic calming, intersection channelization, and other measures designed to reduce speed or restrict access often necessitate the installation of traffic signing and pavement markings not specifically addressed in publications such as the *Manual on Uniform Traffic Control Devices* (*MUTCD*) *(1)* or the *Standard Highway Signs* catalog (*SHS*) *(2)*, both published by the Federal Highway Administration of the United States Department of Transportation. The companion to this paper, “Designing for Consistency: Matching Applications to Scenarios in the Use of Pavement Markings and Delineation” *(3)*, describes how the implementation of pavement markings can lead to inconsistent road user expectations, diluting the meaning and effect of traffic control devices. This paper addresses the effects of these inconsistencies as related to traffic signing.

INTRODUCTION

The intention of this paper is to present the concepts related to ad-hoc case studies, undertaken in this research, of inconsistent applications of TCDs. In general, the graphical presentation of these concepts, including numerous photographs and site sketches, is intended for the podium session in which the paper will be presented. This is done in an effort to preserve the readability of this document and to conserve the time and effort associated with assembling this document.

This paper is prepared in an effort to address the issue of awareness of geometric design and its relationship to TCD selection and placement. This awareness among traffic engineering practitioners and general transportation management personnel is certainly found to be lacking, as one must only look at a few case studies to recognize that inconsistent applications of TCDs exist and are likely to have a detrimental effect on traffic operations and safety. Beyond addressing the awareness of these trends, proposed changes to existing practice and a discussion of needed future research are provided, with the intention of starting a conversation.

This paper discusses addressing inconsistency by means of matching applications to scenarios in the deployment and design of traffic control devices, emphasizing the relationship of traffic signing and geometric design. Two forms of inconsistent application are typically observed in the field when traffic signing is considered. These inconsistencies can be thought of one-to-many relationships and many-to-one relationships.

In the first circumstance, the one-to-many relationship, a TCD with a single meaning is being used across locations with differing geometric design characteristics. This can be described as a *broadening usage*, that is, the application of a TCD beyond the specific case or specific set of related cases for which it was intended. An example of this broadening usage would be the placement of the DO

NOT ENTER sign in locations where some vehicles, but not all vehicles, are permitted to enter. On its face, this application may seem rather benign but it could potentially lead to an erosion of motorist respect for the DO NOT ENTER sign and perhaps the assumption that DO NOT ENTER signs are not to be uniformly obeyed as they do not always indicate that a wrong-way movement is about to occur.

In the second circumstance, the many-to-one relationship, locations with identical or similar geometric design characteristics are being treated with TCDs that vary by location. This can be described as *erratic usage*, that is, the application of TCDs with differing meanings in locations where one or a discrete set of TCDs should be consistently employed. An example of erratic usage is readily observable in the treatment of lane reductions, where there is a reduction in the number of lanes by means of a lane reduction taper.

The broadening usage and the erratic usage are both lead to inconsistent road user expectations. Some practitioners argue that prescribing specific use cases for TCDs and indicating clear designs in the *MUTCD* is some type of a "secret code" that only practitioners will know and that few will practice. This viewpoint fails to consider that consistently-applied TCD treatments, with narrow use cases and uniform applications, will lead to road users adapting to the treatments, recognizing the relationships, and reacting appropriately when presented with information in the form of TCD treatments.

DISCUSSION

While the *MUTCD* appears to specifically prescribe signing for various typical scenarios and the use of non-standard or non-conforming signing might seem unlikely, the variability of guide signing implementations alone indicates that training on the principles of sign design would be a valuable resource to practitioners with little exposure to the human factors aspect of sign design and the calculations used to determine the quantity, size, arrangement, and type of information that can be presented on a guide sign.

Legend Groups

In the process of designing a guide sign, the designer must take into account the external design inputs, such as marked routes, control destinations, and geometric design. Then, the designer must determine a legend arrangement that is logical in order and permits the grouping of legend components. Finally, designers must select the correct size group for the sizing of legend components, such that all components are sized uniformly. In this process, the selection of sizes for legend components is performed respective of the position with in a legend group and the relative importance of the legend element.

Guide Sign with Poor Legend Grouping *(4)* Design Concept with Legend Grouping

FIGURE 1 Legend Grouping Comparison for Guide Signing

The figure above, Figure 1, displays a field installation in Oklahoma and a proposed design that reduces the size of the sign while applying the concepts of legend grouping and size group selection and application. Careful observers will note that the route marker and roadway name are grouped together, then grouped with the cardinal direction, that unit being then grouped with the destination to form the guidance portion of the sign panel.

While it is certainly possible to argue that this specific example fits neither the broadening usage case nor the erratic usage case, it is evident that elements of both types of inconsistency exist here. Comparisons to be made with other signs administered by this agency reveal erratic applications of design principles and certainly indicate that certain elements of sign design are being misapplied in ways that dilute the meaning of legend elements and arrangements.

Understanding trends related to inconsistent guide sign design and implementation is critical precursor to addressing research, policy, training, and compliance issues. The design and layout of sign legend elements is one area where training and vocational exercises would prove helpful. The design of signs, of course, is an outcome of an examination of geometric design. Where that fails, signs are unlikely to be as effective in addressing safety and operational needs.

Option Lane Signing

Despite significant research efforts, the state of the practice for signing of option lanes remains fractured. While some agencies have chosen to adopt one of the practices outlined in the 2009 *MUTCD*, typically referred to as the "arrow-per-lane" concept (here referred to as the blended arrow concept), the state of the practice remains largely fractured.

Discrete Arrow Guide Sign
(Conventional Practice)

Blended Arrow Guide Signs *(5)*
("Arrow-per-Lane")

FIGURE 2 Examples of Guide Signs for Option Lane Signing

A U.S.-wide review of practices undertaken as part of this research identified five examples of practices and policy that serve as evidence of or contribute to TCD application inconsistency.

1. The 2009 *MUTCD* permits three different methods but did not correctly depict the original method of using one arrow per lane with the *discrete arrow* concept.
2. The practices depicted in *MUTCD* Figure 2E-11 and *MUTCD* Figure 2E-12 display inconsistent treatments of identical geometry, potentially encouraging erratic usage.
3. Agencies that were using multiple Down arrows for each lane have not ceased that practice, despite specific prohibition in the 2009 *MUTCD.*
4. The use of angled Down Arrows, one per lane, in the discrete arrow method was a practical means of indicating roadway curvature and is no longer permitted.
5. Down Arrow use historically indicated major or pull-through movements, while angled Type A and Type B arrows indicated exiting movements.

Distinct Uses of Guide Sign Arrows

Establishing a distinction between the various Guide Sign Arrows, as depicted in *MUTCD* Figure 2D-2, demands that the principles of good human factors design related to arrow shape and appearance. Additionally, this distinction is only preserved when sign design and fabrication are strictly controlled.

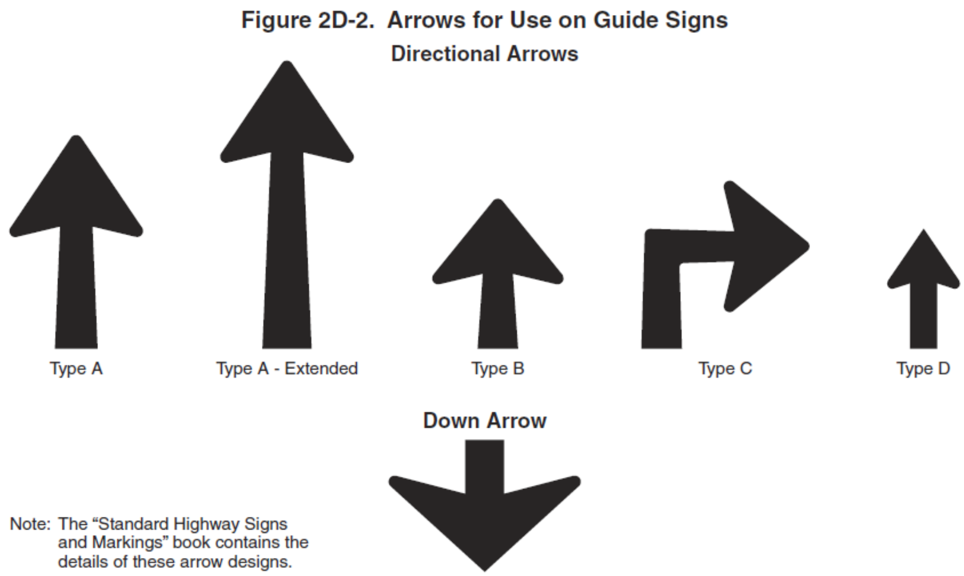


FIGURE 3 Arrows for Use on Guide Signs, *MUTCD* Figure 2D-2

When employing the Arrows for Use on Guide Signs, the Type A and Type B Arrows and Down Arrows, the following simple rules, identified in the synthesis of practice research for this paper, can be applied to the discrete arrow concept of signing lanes on motorways (defined here as multi-lane limited-access facilities with a non-traversable barrier median, including Interstate routes and other freeways in the United States and most toll facilities), including option lanes:

- A Down Arrow always indicates a lane that continues on along the mainline, even if that lane terminates downstream in a service interchange
- The degree of the angle of installation of a Down Arrow, when not 0° off the vertical, indicates the curvature of the mainline movement or primary movement(s) within an interchange, used only on signs placed at the decision point
- Down Arrows may be used on more than one sign at a junction if the additional movements are considered primary movements, such as at a major split of two marked routes of equal importance along a motorway corridor
- Angled Down Arrows are only applied in conjunction with overhead Exit Direction Signs
- The upward angle Type A or Type B arrow installation is indicative of the severity of the exiting movement
- Type A and Type B arrows never point down into a lane from an overhead sign
- Type A and Type B arrows are typically restricted to use on Exit Direction Signs at service interchanges

Consistent use of the arrows in the *MUTCD* would likely mitigate many of the problems currently being experienced with overhead guide sign installations on motorway-grade facilities.

Mixed Practices

The selection, orientation, and placement of guide sign arrows is only part of the design process. The design of guide signs using the discrete arrow method has not been a subject of any *MUTCD* content related to signs on motorway-grade facilities and this lack of information has led to fractured practice throughout the United States. On the whole, some 36 states use the discrete arrow design depicted in Figure 2, however, research preparing for this synthesis of practice revealed that many other states lacked the technical expertise and assistance to properly design and deploy discrete arrow guide signs. Given that the design of the blended arrow guide signs is that more complex, it is unlikely that legend arrangements and other key factors in effective guide sign design will be appropriately managed, unless extensive training is offered to convey the principles of guide sign design and the appropriate use of commercial software. Users have insufficient experience with commercial software and some packages lack the capabilities necessary to facilitate the efficient design of the blended arrow signs.

Figure 4 and Figure 5 illustrate the inconsistent application of discrete arrow guide signs. These misapplications cannot be judged inherent in the discrete arrow guide sign, as the misapplications concern a failure to match roadway geometry with the sign design. In Figure 4, white arrows on a green background are used on overhead Exit Direction Signs at interchanges with two differing geometric designs. The missing information related to the right-most lane, a lane that is always a mandatory movement lane in any ramp with two or more lanes, points to the weakness of this sign design and Figure 2E-12 in the 2009 *MUTCD.* Figure 5 displays two applications of the Exit Direction Sign displayed in *MUTCD* Figure 2E-11. As with Figure 4, this is a broadening use case, where a single TCD is used across multiple geometric design features. Only one of the four photographs depicts the correct use of the Exit Direction Sign from *MUTCD* Figure 2E-11, which itself depicts and incorrect use of the Exit Direction Sign.

FIGURE 4 Examples of Exit Direction Signs Based on *MUTCD* Figure 2E-12

The Exit Direction Sign on the left, below, matches the design in Figure 2E-11. It shows two "EXIT ONLY" lanes at the gore, although one of the lanes is an option lane. One principle to apply in this situation is that the arrow color and background colors should match on upstream (Advance Guide) and downstream (Exit Direction) signs. The Exit Direction sign on the right, below, correctly indicates that there are two exiting lanes at the gore and matches the upstream signing for that interchange.

One potential defense of the use of the signs in Figure 5 for option lanes has been that if the sign is placed far enough down the gore, both lanes are indeed exit only. This defense, however, does not consider that road users not concerned with the placement of the sign, but rather the upstream geometrics that they encounter; the sign must adequately display those so that the user's decision, made in advance of the gore, is informed by an appropriate indication of the intersection geometrics, not the selection of a foundation location for an overhead sign structure.

FIGURE 5 Examples of Exit Direction Signs Based on *MUTCD* Figure 2E-11

An examination of Figure 6 reveals that there are indeed four distinct cases of exiting lanes on motorway-grade facilities. Each of these cases must be treated differently with overhead signs, whether the discrete arrow or blended arrow methods. Further, the use of blended arrow signs typically requires a pull-through sign, which can make the difference between service interchanges and system interchanges indistinguishable. This difference is important because it assists users in the navigation task by helping them build a hierarchal mental map of the roadway transportation network. The clarity provided concerning exiting movements (as opposed to through movements) by means of upward-pointing arrows is an important input to the navigation and piloting tasks.

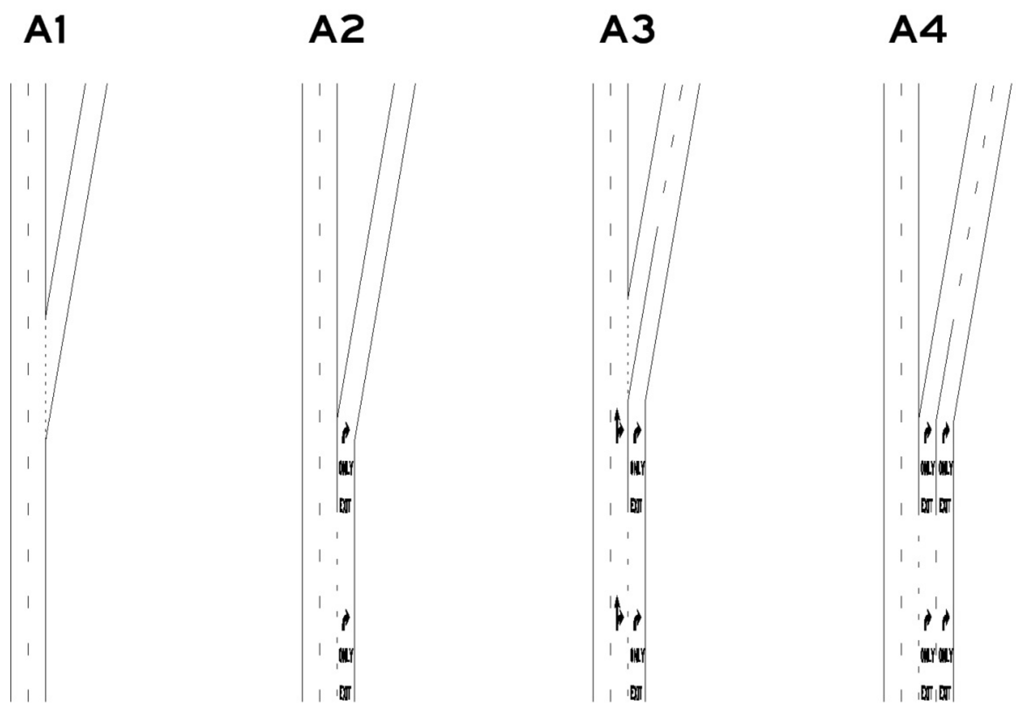


FIGURE 6 Configurations of Exiting Lanes

Arrows Used on "Arrow-per-Lane" Signs

Further, the use of the arrows on the so-called "arrow-per-lane" signs ("blended arrow" option lane signing) may not always clearly depict the geometric design nor necessarily provide for driver expectation. The use of the same curved modified Type D arrow for Advance Guide Signing and the Exit Direction Signs at the exit gore, even with the use of advance distance legend on the Advance Guide Signs, directly contradicts good practice in guide signing, where arrow selection depends on the advance placement distance and the degree of severity for the departing movement.

45° Type C Arrow Right-Sweep Type D Arrow

FIGURE 7 Arrows for Guide and Regulatory Signs

Lane-Use Control Signing

A particular case of erratic usage with respect to TCD location is the implementation of the RIGHT LANE MUST TURN RIGHT (R3-7) sign. This sign is often used in lieu of the R3-5R RIGHT TURN

ONLY sign that is permissible for use adjacent to a lane that must turn right. Proposed language for the 2009 *MUTCD* was to specify that the RIGHT LANE MUST TURN RIGHT sign be used only along continuing lanes that were converted downstream to right turn lanes, otherwise known as “trap lanes”. In the corresponding case for motorways and expressways and on principal arterials where an EXIT ONLY lane is present upstream of a ramp, the use of the RIGHT LANE MUST EXIT sign is specified.

Arterial Route / Turn Lane Case

There are three discrete cases where erratic usage of the RIGHT LANE MUST TURN RIGHT sign can violate driver expectancy.

In the first case, the sign is installed at or upstream of the beginning of the right turn lane taper for an exclusive right turn lane, in situations where there is no shoulder or a shoulder of limited width and the roadway consists of multiple lanes in the direction of travel. In these cases, as the sign is mounted immediately adjacent to the through lane, it may appear to apply to the right-most through lane itself. The solution here is to limit the use of all lane use control signs pertaining to only one lane or a limited group of lanes to locations where the lanes are fully developed.

In the second case, the sign is installed adjacent to a full-width shoulder at some location near or along the length of an exclusive right turn lane. During inclement weather, when pavement markings are obscured or in cases where pavement markings are not appropriately maintained, the sign would, as in the first case, appear to apply to the right-most through lane. In these cases, it is preferable to use the R3-5R lane use control sign at the location where the full width of the lane is available to roadway users. Additionally, on principal arterials and rural expressways with shoulders, the use of the BEGIN RIGHT TURN LANE sign or its long-standing variant, the RIGHT TURN LANE sign, at the upstream point of the right turn lane opening taper, clearly identifies the point at which the turn lane begins. In cases where queue spillback occurs and bypassing vehicles are likely to use the shoulder to access the right turn lane, an effective way to clearly mark the lane for enforcement purposes is to use the RIGHT TURN LANE sign and the R3-5R lane use control sign, in conjunction with a wide lane line and diagonal transverse markings along the length of the turn lane opening taper.

Finally, in the third case, the RIGHT LANE MUST TURN RIGHT sign is installed along an exclusive right turn lane in locations where horizontal or vertical curvature limits the user’s view of the pavement markings and roadway geometry, leading to confusing concerning the lane to which the sign applies. In these situations, use of the R3-8 lane use control sign, with all movements indicated on the sign, is preferable, as the number of lanes on the sign can be matched to the number of lanes on the upstream roadway.

Motorway and Expressway / Exiting Lane Case

In the case of EXIT ONLY lanes on high-speed roadways, the use of multiple versions of the RIGHT LANE MUST EXIT sign is observed. The Minnesota Department of Transportation has deployed the stacked legend on a vertical rectangle, which presents the text in a clear order and conserves roadside space, particularly in constrained urban environments.

Alternative designs, including the horizontal rectangle specified by the *MUTCD*, exhibit legend arrangements that may not be as clear as that of the vertical rectangle arrangement. The sign depicted in the bottom right-hand corner of Figure 8, a standard sign in Washington State, provides excessive emphasis on the text MUST EXIT without emphasizing the lane or road users to which the text applies.

In other locations, similar signs read “SINGLE OCCUPANT VEHICLES”, “ALL TRUCKS”, and “ALL TRAFFIC”. At speed and in congested conditions, the difference between shorter messages such as “ALL TRUCKS” and the message “RIGHT LANE” may be indistinguishable.

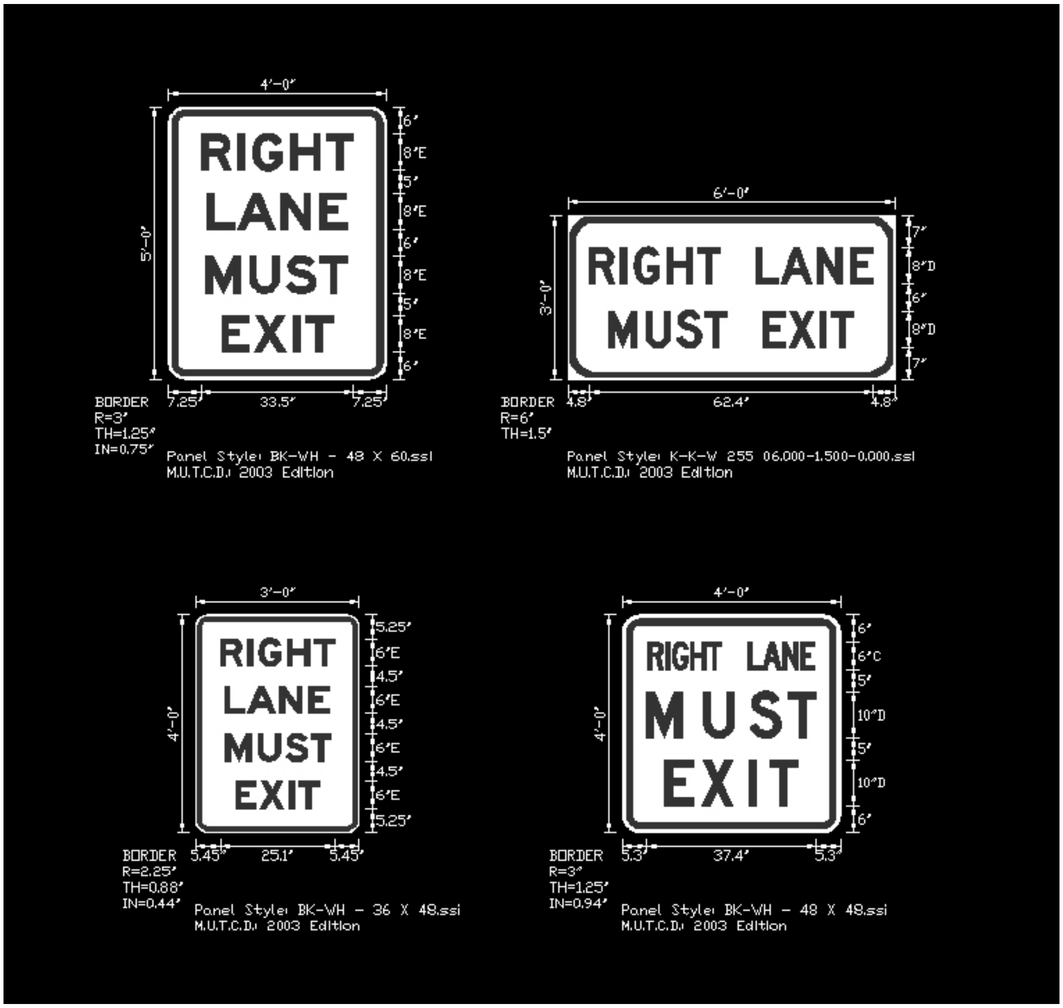


FIGURE 8 Various RIGHT LANE MUST EXIT Sign Panel Layouts

Signing of Island and Median Noses

The signing of median noses and island terminals downstream of painted median areas is a particular case of broadening usage of the KEEP RIGHT symbol sign (R4-7R). A median nose, at an intersection, for example, could be marked with the R4-7R sign or also with a yellow flexible delineator post. Safety performance is further enhanced with the presence of a yellow painted median nose and the installation of reflective pavement markers with yellow and red lenses on the right and left sides, respectively.

In cases where a painted median lies adjacent to the opposing left turn lane for some distance back from the intersection, terminating in a raised paved or landscaped median, it may be desirable to include some sign adjacent to the left-most travel lane and located at the beginning of the raised portion of the median. The R4-7R sign is inappropriate for this case, however, as it indicates that traffic is to pass to the right of a developed obstruction. In this case, the traffic is already traveling along a portion of roadway separated by a consistent-width median. A more appropriate installation would be the OM3-L object marker or the R4-7A KEEP RIGHT sign, which uses a Type D arrow rotated to 90° off the vertical. Neither of these signs indicates passage around a developing obstruction and would be more appropriate choices than broadening the use of the R4-7R sign.

Route Marking at Motorway Entrances

Marking entrances to motorways, particularly in urban areas, requires a careful evaluation of the use of the Advance Turn and Directional Arrow Auxiliary Signs (*MUTCD* Figure 2D-5).

In general, it is good practice to avoid marking ramps with upward pointing arrows unless the turning movement is a free-flow movement and can occur at a high speed. In some recent designs of single-point urban interchanges, the left turns were marked using the M6-2L Directional Arrow Auxiliary Sign, which encourages higher turning speeds and may give the impression that the movement is a ramp not subject to signalized control.

Various Warning Sign Applications

Additionally, it is clear from practice examinations and road safety audit work that many agencies lack the technical expertise necessary to appropriately implement safety countermeasures with warning signs and other delineation. The placement of warning signs is addressed in *MUTCD* Table 2C-4, but the engineering judgment of practitioners often prescribes the use of longer distances. For example, some practitioners have used a heuristic rule of increasing the posted speed limit by a factor of 10 and using the greater of that value or the Table 2C-4 value when determining the advance placement distance of warning signs not requiring high judgment.

Lane Reduction Signing

The signing of lane reductions, where a physical reduction in the number of lanes occurs by means of a lane reduction taper, is a topic of study providing numerous examples of erratic usage. Three different lane reduction warning signs exist in the *MUTCD* and there are roughly five more in ongoing use in the United States and Canada. If the erratic usage cases were limited to perhaps simply using a different lane reduction warning sign for a specific point in advance of the beginning of the taper, road user confusion would likely be more limited. However, each of these signs (excepting the MERGE sign with arrow) can be found in various locations upstream of any randomly selected lane reduction taper. Compounding the problem, when multiple installations of the W9-1 RIGHT LANE ENDS sign exist, upstream signs are not posted with a distance plaque indicating that one of the signs is posted in advance of the typical and expected location.

FIGURE 9 Lane Reduction Warning Signs

Warning Signs Used for Trap Lanes

One case of broadening usage for lane reduction warning signs relates to the R3-7R lane use control sign. Typically, a trap lane is signed using R3-7R lane use control signs in a sequence prior to the beginning of the solid white lane line. In some cases, however, agencies have elected to use lane reduction symbol signs instead of the lane use control signs. This leads road users to the mistaken impression that the lane is ending although it continues on as an auxiliary lane (defined by AASHTO) and is reserved for a mandatory turning movement. Even motorists intending to make a right turn, for example, will move out of the lane upon seeing the lane reduction warning signs. In some cases, it is apparent that the technical staff evaluating a compliance problem did not employ other appropriate countermeasures such as

- using the dotted lane line in advance of the solid lane line,
- providing enhanced conspicuity for the R3-7R and R3-5R signs,
- lengthening the transition zone, i.e. the distance in advance of the solid lane line that is typically marked with the dotted lane line and accompanied by the R3-7R signs, and providing additional R3-7R signs,
- providing distance plaques with the R3-7R signs, and/or
- providing advance guide signing, which typically obviates the need for excessive implementations of regulatory signing.

Occasionally, agencies that do not achieve the desired crash reduction result by turning to an inappropriate application of warning signs will fail to recognize the value of the countermeasures above and remove trap lanes, subsequently experiencing degradation in safety and operational performance.

Through Traffic Merge Left

Another misapplication of warning signs related lane reductions and lane use control is the use of the THRU TRAFFIC MERGE LEFT sign as a substitute for a lane reduction warning sign. The intended use of the THRU TRAFFIC MERGE LEFT sign is to indicate to traffic entering a motorway that the right-most lane on the facility is an auxiliary lane and that merging to the left, i.e. vacating the auxiliary lane, is required to enter a lane designated for through traffic. Use of this sign as a lane reduction warning sign could lead to road users failing to vacate the terminating lane, assuming that the right-most lane is an auxiliary lane continuing to a downstream interchange or intersection.

SUGGESTED FUTURE RESEARCH

This paper has presented examples of inconsistency in TCD applications. The broadening usage and erratic usage cases cited are indicative of practitioner inexperience and a lack of familiarity with human factors principles in design and operations. In some cases, it appears that expediency and TCD availability are valued over clarity and consistency. In other cases, it is apparent that spatial and temporal influences have brought about inconsistency in TCD applications. Careful study of these cases is necessary to determine how to best address the issue and tailor resources to specific problems.

Field and Laboratory Research Needs

Addressing the broadening usage and erratic usage cases would best be done by continuing and increasing the activities of NCHRP and other research program synthesis activities, particularly those related to identifying gaps in practice and practice applications that portend inconsistency within administrative regions and non-compliance with existing prevalent practices and/or the *MUTCD*.

As this synthesis research is carried out, it is likely that some studies will indicate the need to carry out additional data collection, human factors studies, and other activities typically undertaken as part of the research activities of the NCHRP and various pooled-fund study efforts. In many cases, research may indicate a preferred practice. Whether or not this is the end result of research activities, it is imperative that root cause analysis be employed to determine the reason for inconsistencies. Changes in policy, procedures, and work activities may address some issues. In some states, for example, the use of certain sign “cutting” software has resulted in traffic sign arrows that do not conform to the *Standard Highway Signs* manual published by the FHWA. State DOT-level policy memorandums and FHWA advisory circulars, similar to those used by the Federal Aviation Administration, could caution against certain practices and indicate corrective measures to ensure an improved level of consistency in in the design and fabrication of traffic signing. Such an approach would address all the vertical components of the contract delivery process, particularly subcontractors and contractors with limited experience and staff technical aptitude.

Technical Training

Providing for consistency in design activities, particularly within an agency, can be achieved by means of training activities and technical specialty certification programs led by technically-proficient expert designers. In the case of guide sign design in particular, the inexperience of practitioners without a human factors background or strong apprenticeship in traffic sign design could be partially mitigated with training programs. However, these training programs will be ineffective if led by contractors or personnel who are not first top-of-the field practitioners. In the opinion of the authors, training and technical certification programs are a key path toward correcting long-term deficiencies in the workforce development of technically-proficient staff, as many lack mentors and work experience with skilled designers, owing to industry-wide trends related to retirements of government agency employees.

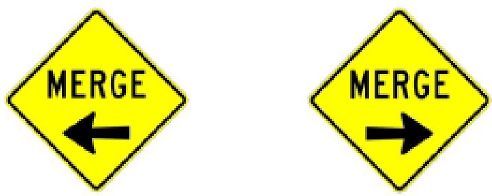
Users of the *MUTCD*

One means of reaching more practitioners with more practical knowledge is to combine the technical and regulatory information of the *MUTCD* with additional information related to TCD typical applications, field installations, and policy best practices. A potential means of distributing this information is the TCD “Fact Sheet”, a document which would provide information specific to a TCD, traffic control strategy, TCD system, or other discrete element. In referencing Figure 10, a user would also choose to examine a Typical Application diagram that addresses lane reduction transitions.

Manual on Uniform Traffic Control Devices
2016 Edition

Section 2C.42
Lane Reduction Warning Signs

W9-2 Lane Ends Hybrid Symbol Signs



W9-2L W9-2R

Information

The Lane Ends hybrid symbol sign is intended for use in advance of the lane reduction taper where a reduction in the number of lanes, either through lanes or auxiliary lanes, is accomplished by means of a lane reduction taper. The Lane Ends Hybrid Symbol sign is intended to be used downstream of and in conjunction with the RIGHT (LEFT) LANE ENDS sign (W9-1) or the Lane Reduction symbol sign (W4-2) where continuous lanes are ending. Alternatively, this sign may also be used alone in locations, such as short acceleration lanes, where the other advance warning signs cannot be provided.

The Lane Ends hybrid symbol sign is intended for placement just prior to the beginning of the lane reduction taper. Generally, the placement will be at the beginning of the lane reduction taper or in advance of the beginning of the lane reduction taper by a distance equal to no more than a multiple of 1.5 times the posted speed limit. Uniform placement between multiple locations in similar facility types is desirable.

Policy

Standard **The Lane Ends hybrid symbol sign shall not be used in advance of any other lane reduction advance warning sign.**

Guidance Use of the Lane Ends hybrid symbol sign should be standardized between locations of similar geometric and operational conditions.

Option The Lane Ends hybrid symbol sign may be installed in advance of the beginning of lane reduction tapers to warn motorists that the subject lane is ending and that a taper will begin at the location of or closely following the sign.

History

The Lane Ends Hybrid Symbol sign was developed for use in work zones by the Minnesota Department of Transportation. Use of the sign in permanent installations was tested in 2009 and its use expanded to several other states. This sign was first included in the 2016 Edition of the MUTCD.

Succession

This sign replaces the LANE ENDS MERGE LEFT (RIGHT) sign, which last appeared in the 2009 edition of the MUTCD.

References

W4-2 Lane Reduction Symbol Sign (Section 2C.42)
W9-1 RIGHT (LEFT) LANE ENDS Sign (Section 2C.42)
Pavement Markings for Transition Areas (Section 3B.08)
Typical Applications of Lane Reductions (Figure 2C-9)

FIGURE 10 "Fact Sheet" Sample (Typical Publication of Material from Database) *(6)*

This type of presentation of information is very similar to what one might find when presented with a “cut sheet” or product specifications guide. In fact, when mechanical engineers select bolts, bar, and chain for use in projects, they often refer to large catalogs containing basic information for an individual device or product. Key sections in the Fact Sheet are clearly displayed to ensure that information is easily accessible. These key sections are described in the companion to this paper and in detail in Kuznicki and Avery’s discussion on MUTCD implementation as a database-driven document *(7)*.

REFERENCES

[1] *Manual on Uniform Traffic Control Devices*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 2009.

[2] *Standard Highway Signs*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 2004.

[3] Kuznicki, S.O. and Katz, B.J. Designing for Consistency: Matching Applications to Scenarios in the Use of Pavement Markings and Delineation. Submitted for the 5th International Symposium on Highway Geometric Design. Vancouver, British Columbia, Canada, 2015.

[4] Photograph courtesy of Jeremy Lance, Mid-America Roads Facebook group, used with permission.

[5] Figure 2E-3. *Manual on Uniform Traffic Control Devices*.

[6] Kuznicki S.O. and Avery, R.P. Database-Driven Implementations for Future Editions of the Manual on Uniform Traffic Control Devices. TRB 14-0448, Proceedings of the 93rd Annual Meeting of the Transportation Research Board, 2014.

[7] Kuznicki S.O. and Avery, R.P. Database-Driven Implementations for Future Editions of the Manual on Uniform Traffic Control Devices. TRB 14-0448, Proceedings of the 93rd Annual Meeting of the Transportation Research Board, 2014.