Lane Line Markings in Advance of Lane-Reduction Transitions

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U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
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FOREWORD

The objective of the Transportation Pooled Fund Program's Traffic Control Device (TCD) Consortium is to assemble a consortium of regional, State, local entities, appropriate organizations, and the Federal Highway Administration (FHWA) to establish a systematic procedure to select, test, and evaluate existing and new TCDs that will support changes to the *Manual on Uniform Traffic Control Devices* (MUTCD) and interim approvals.

This report documents a FHWA project examining the comprehension of different lane-reduction markings. The goal of this study was to determine the effects of the different line-marking patterns in terms of merging behavior at lane-reduction transitions, driver understanding of the intended message conveyed at lane-reduction transitions, and perceived ranking of effectiveness.

This report is of interest to engineers, planners, and other researchers and practitioners who are concerned with the limits of road users' ability to comprehend and follow roadway lane-reduction transitions correctly.

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16. Abstract
Roadway lane-reduction transitions have long been reported to be problematic to drivers. Whether this problem is the result of a lack of understanding of lane-reduction signing or lane markings, a simple failure to comply with such markings, or other unidentified factors is unknown. This study, completed in 2016, explored driver comprehension of six different lane-reduction markings. The markings varied in terms of the incorporation and length of dotted and broken lines. In addition, half of the markings included a solid white line adjacent to the dotted/broken line. The supplemental solid white line resulted in improved understanding that the rightmost lane would end, earlier reported lane changes, and the highest preference ratings. Dotted lines also resulted in better understanding of an upcoming necessary lane change than did the longer, more traditional broken lane lines. This study contains recommendations and suggestions for lane-reduction marking changes to the *Manual on Uniform Traffic Control Devices*.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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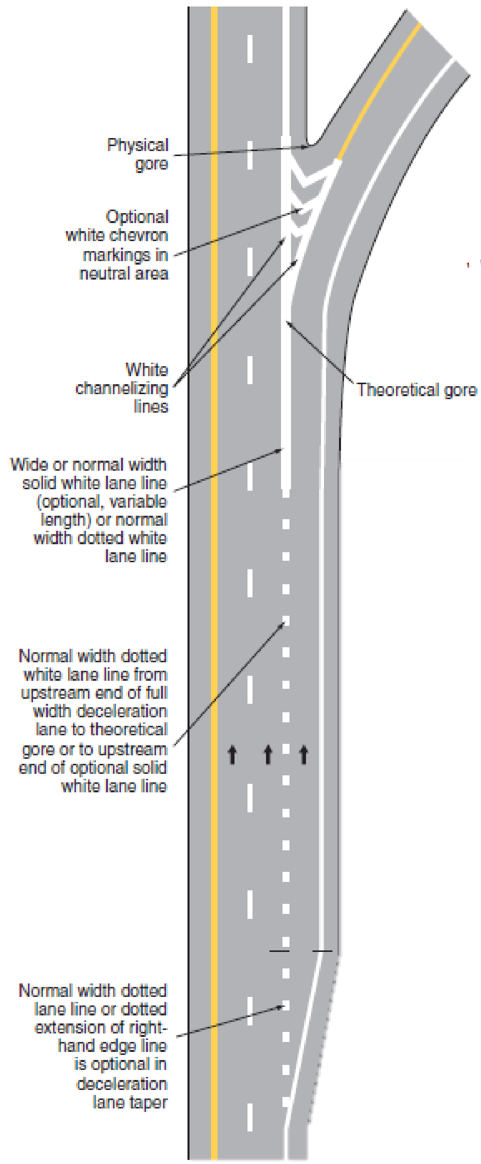
LIST OF ACRONYMS

FHWA	Federal Highway Administration
GLM	generalized linear model
MUTCD	*Manual on Uniform Traffic Control Devices for Streets and Highways*

CHAPTER 1. INTRODUCTION

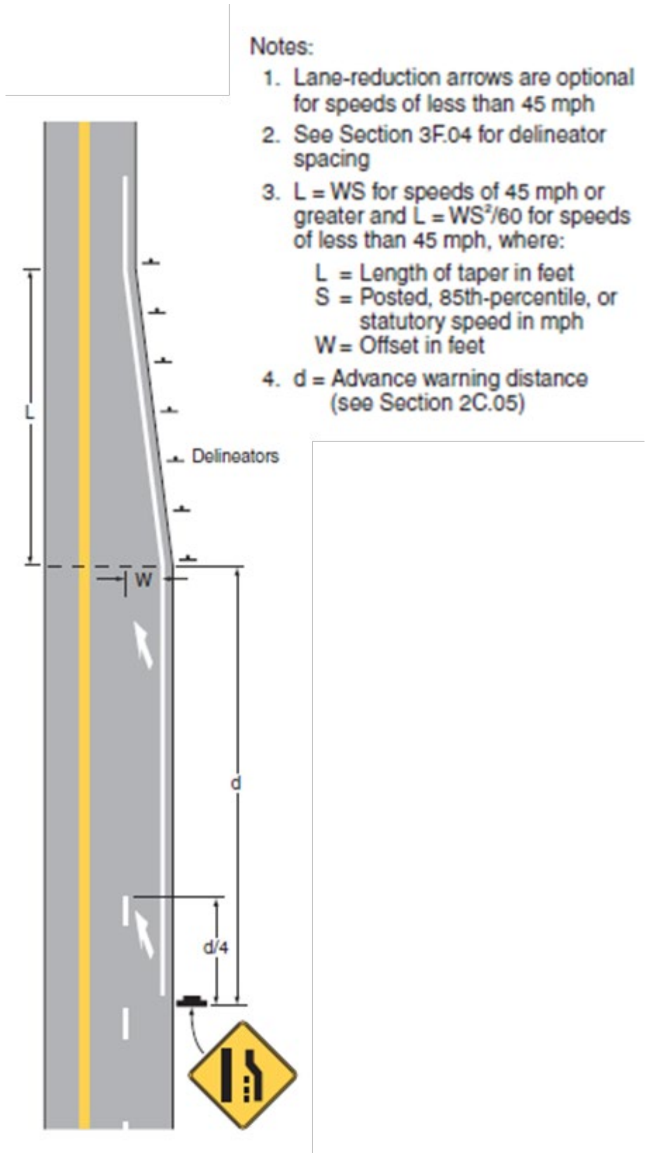
In the 2009 *Manual on Uniform Traffic Control Devices* (MUTCD), dotted lane lines (rather than broken lines) were adopted as the Federal Highway Administration (FHWA) standard for lanes that do not continue ahead beyond the next interchange or intersection (e.g., lane drops, auxiliary lanes, deceleration lanes, and acceleration lanes), both on freeways and on conventional roads (FHWA 2009). Figure 1 shows an example of dotted lane lines.



Source: FHWA.

Figure 1. Illustration. Dotted lane lines used at parallel deceleration lane for exit ramp (FHWA 2009).

Per Section 3B.09 of the MUTCD, lane-reduction transitions occur when the number of through lanes is reduced between interchanges or intersections. In such cases, where pavement markings are used, lane-reduction transition markings shall be used to guide traffic through the transition areas (FHWA 2009). An example of lane-reduction transition markings is shown in figure 2.



Source: FHWA.

Figure 2. Illustration. Lane-reduction transition markings (FHWA 2009).

Dotted lane lines (such as those seen in figure 1) also have been proposed by some engineers for use at lane-reduction transitions with the supposition that drivers approaching lane-reduction transitions could benefit from the advance warning and demonstrate safer merging behaviors with a dotted lane line versus the existing standard marking. Conversely, the lack of any lane line marking for three-fourths of the distance from the advance Lane Ends warning sign to the point where the taper begins (as the current lane-reduction transition standard calls for) may help to reinforce the need to merge early. There is also concern that the use of dotted lines at lane-reduction transitions may be confusing to motorists because lane-reduction transitions are significantly different from places where dotted lane lines are currently used. In other words, in a lane-reduction transition, all vehicles in the ending lane must merge into the adjacent lane, whereas in lane drops, vehicles that are unable to leave the lane have the ability to stay in the lane and proceed to exit or turn.

To the authors' knowledge, at the time this project began in 2014, no research studies had been produced that examined the effects of dotted-line markings for lane reductions; therefore, research was conducted to determine whether the use of a dotted lane line for some distance in advance of the lane-reduction is preferable to the longstanding marking pattern for a lane-reduction transition (i.e., discontinuation of the normal broken lane line a distance of $d/4$, or one-fourth of the "advance warning distance," beyond the Lane Ends warning sign) (figure 2).

OBJECTIVES

The researchers evaluated the existing standard lane-reduction lane line marking pattern as well as potential layouts of a dotted line for a lane-reduction transition. The goal of this project was to determine the effects of the different line-marking patterns on the following:

- Merging behavior (i.e., moving into the adjacent lane) at lane-reduction transitions.
- Driver understanding of the intended message conveyed at lane-reduction transitions (from both the terminating lane and the left-adjacent lane).
- Perceived rankings of effectiveness.

CHAPTER 2. METHOD

STIMULI

Design software was used to generate virtual roadways. This software package allowed the research team to generate environments using real roadway geographic information system (known as "GIS") data. The researchers were then able to manipulate the roadways as necessary (e.g., modify roadway lane line markings). After the roadway was built, a "fly through" was made, which created the illusion of moving through the environment from the drivers' perspective by using a computer animated simulation.

Markings

Researchers used five different roadways to present lane-reduction markings. The roadways had two lanes of traffic in each direction, and they transitioned to one lane of traffic in each direction. Design speed for all roads was 40 mph. Taper length was 320 ft. Given the design speed, the advanced warning sign (had it been present) would have been placed at 670 ft before the beginning of the taper (see table 2C-4 in the MUTCD) (FHWA 2009). Note that the lane marking relationship to the taper may vary with different road design speeds.

Six different lane-reduction markings were created (1A, 1B, 2A, 2B, 3A, 3B). Each was presented on five different roadways. In total, 30 different environments were created. Within each roadway, the only visual component that varied was the pavement markings—all other environmental aspects remained constant.

To explore exclusively the potential effect of the lane-reduction markings on driver understanding and behavior, neither elongated pavement arrows nor Lane Ends signs were included. It was suspected that the cues of these two items may overwhelm any potential differences in the lane line markings.

Marking Options

A 3 (broken versus dotted line) × 2 (solid white line) factorial design was used in lane-marking combinations.

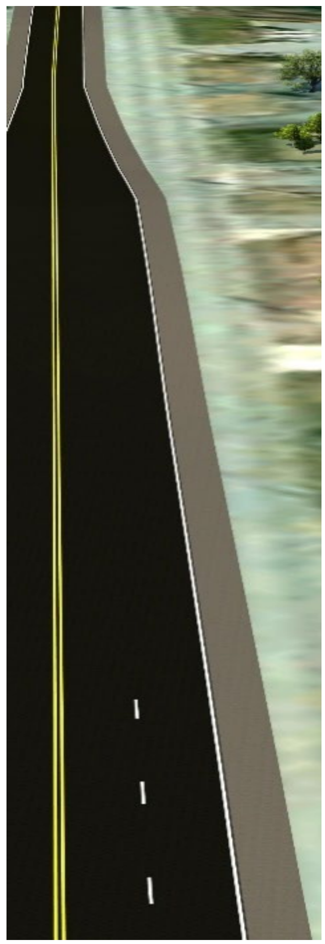
1. Broken line versus dotted line: There are three different broken/dotted line combinations (labeled numerically).

2. Solid white line: The presence or absence of a solid white line adjacent to the broken/dotted line (labeled with alphabetic characters).

The dotted-line marking does not comply with the 2009 MUTCD. Dotted lane lines are used to convey a lane drop rather than a lane reduction. The dotted lane line informs drivers that the lane they are in will exit the current traveled way. It does not indicate a merge into the current traveled way.

Additionally, the double white lane lines with the solid line on the left and the dashed line on the right are not addressed in the 2009 MUTCD. Applying the combination to roadways is not an MUTCD-compliant practice. When this report was created in 2016, this lane line configuration was undergoing the Request to Experiment process, which is the process used gain MUTCD approval.

Marking 1A was the existing, standard lane-reduction and lane line-marking pattern. Standard 6-inch-wide broken line pavement markings—each 10 ft in length and spaced 30 ft apart—were used in this study. Broken line pavement markings terminated 502.5 ft before the start of the taper (figure 3). The 2009 MUTCD states that markings should end at a distance of "advance warning distance"/4 beyond the Lane Ends warning sign.



Source: FHWA.

Figure 3. Illustration. Broken lines used in markings 1A and 1B.

Marking 1B was the same as marking 1A and included the addition of a solid white line to the left of the dotted/standard dashed lines. This line was meant to indicate that traffic in the continuing lane should not attempt to move into the ending right lane. The solid white line was 6 inches wide. It began at 1,005 ft before the start of the taper and terminated at 502.5 ft before the taper (i.e., the same location where the broken line terminated). The starting distance of the solid white line was selected to mirror the roadway distance between the end of the lane line markings and the beginning of the taper. In other words, the length of the solid line was 1.5 × “advanced warning distance” – “advanced warning distance”/4 in length.

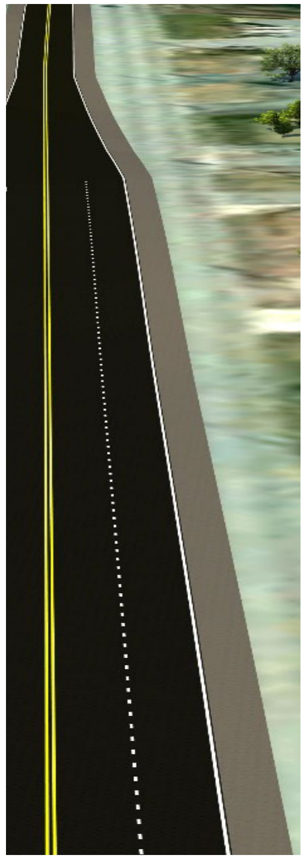
For marking 2A, the standard broken line changed to a dotted line at 1,005 ft (1.5 × “advanced warning distance”) before the beginning of the taper; the dotted line pavement markings terminated 502.5 ft before the start of the taper (“advanced warning distance”/4) (figure 4). The dotted lines were 6 inches wide; they were 2 ft in length and spaced 4 ft apart. Again, this marking is noncompliant with the MUTCD.

Source: FHWA

Figure 4. Illustration. Dotted lines used in markings 2A and 2B.

Marking 2B was the same as marking 2A but included the addition of a solid white line to the left of the dotted/standard dashed lines. This line was meant to indicate that traffic in the continuing lane should not attempt to move into the ending right lane. The solid white line was 6 inches wide. It began at 1,005 ft before the start of the taper and terminated at 502.5 ft before the taper (i.e., the same location where the dotted line terminated). The starting distance of the solid white line was selected to mirror the roadway distance between the end of the lane line markings and the beginning of the taper. In other words, the solid line was 1.5 × “advanced warning distance” – “advanced warning distance”/4 in length. Again, this marking is in the Request to Experiment process, but it is noncompliant with the MUTCD.

For marking 3A, the standard broken line changed to a dotted line at 670 ft ("advanced warning distance") before the beginning of the taper; the dotted line pavement markings terminated as the taper began (figure 5). The dotted lines were 6 inches wide; they were 2 ft in length and spaced 4 ft apart. Again, this marking is noncompliant with the MUTCD.



Source: FHWA

Figure 5. Illustration. Dotted lines used in markings 3A and 3B.

Marking 3B was the same as marking 3A but included the addition of a solid white line to the left of the dotted/standard dashed lines. This line was meant to indicate that traffic in the continuing lane should not attempt to move into the ending right lane. The solid white line was 6 inches wide. It began at 1,005 ft before the start of the taper and terminated as the taper began (i.e., the same location where the dotted line terminated). Again, this marking is in the Request to Experiment process, but it is noncompliant with the MUTCD.

Videos

Thirty videos (consisting of six different markings for five different roadways) concluded at the beginning of the roadway taper. An additional five videos (one for each of the five different roadways) were created in a neutral section, where the roadway did not taper (i.e., all travel lanes continue). These additional five videos were used as "control" or "catch" videos to ensure that participants were responding to the different stimuli presented. All videos simulated a driver's perspective traveling at 36 mph for 2,000 ft. Each video's duration was approximately 38 s. Videos were presented on a 60-inch LCD/LED 1080i television screen.

Stills

Aerial still shots were captured for all six pavement markings in a single environment. Stills included a 24-inch by 36-inch poster showing a longer approach as well as 18-inch by 24-inch zoomed-in images. Examples of two of the zoomed-in images can be seen in figure 6 and figure 7.

Source: FHWA.

Figure 6. Screenshot. Aerial view of marking 3A.

Source: FHWA

Figure 7. Screenshot. Aerial view of marking 3B.

EXPERIMENTAL TASKS

Task 1

The goal of task 1 was to determine if participants traveling in the rightmost lane (with lane reduction) were able to understand that their lane was going to end. Participants were shown videos from the driver's perspective in the far-right lane. After the video concluded, participants were asked two questions:

1. Are you allowed to continue to travel in the right lane? (yes or no)
2. If you continued to travel in this lane, what, if anything, would happen? (open answer)

Task 2

The goal of task 2 was to determine if participants traveling in the lane just to the left of the ending lane were able to understand that the right lane was going to end. Participants were shown videos from the driver's perspective in the left lane (the nonterminating lane that continued). After the video concluded, participants were asked two questions:

1. May you merge into the right lane? (yes or no)
2. What, if anything, might you expect the traffic in the right lane to do? (open answer)

Task 3

The goal of task 3 was to determine how quickly participants traveling in the rightmost lane (with lane reduction) were able to understand that their lane was going to end and would subsequently change lanes. Participants were shown videos from the driver's perspective in the far-right lane. Participants were told: "Imagine that you are driving down the roadway. While you are driving, you may need to change lanes to continue travel. As soon as you are confident that you need to change lanes, click the mouse."

Task 4

The goal of task 4 was to determine participants' preferences for the different lane markings. Participants were shown stills of all six of the markings and were encouraged to move around and to look as closely as desired at the markings. Participants were asked to answer the following questions:

1. There are several different ways in which roadway lane markings can be placed to indicate to drivers that the lane is about to end. Imagine that you are traveling northbound. Please rank the different pavement markings in terms of their effectiveness in indicating that the right lane is about to end.

2. In your opinion, what aspects of your highest ranked set of markings helps to make them more effective?

3. What, if anything, might you change in order to increase people's understanding of the lane ending road markings?

4. Which set of markings do you encounter most frequently in the areas that you drive?

5. Additional comments.

PARTICIPANTS

A total of 90 people (51 males) with ages ranging from 19 to 77 yr (mean [*M*] = 45.23 yr) participated. Each person was paid $40.

PROCEDURE

On arrival, participants were given a brief overview of the experiment, and each completed an informed consent document. Each participant was then assigned to task 1, task 2, or task 3. A brief, visual screening was performed to ensure a minimum of 20/40 acuity (the minimum to obtain a driver's license in most States). Next, participants were provided more specific instructions for their assigned tasks, were provided practice trials, and were given opportunities to ask any questions.

Participants were allowed to take breaks to stretch and to rest their eyes as needed. On completion of the assigned tasks, all participants completed task 4 (subjective preference of lane-reduction markings). In other words, all participants completed two tasks. Total participation time ranged from 30 to 50 min, depending on participant response speed.

CHAPTER 3. RESULTS

TASK 1

Again, the goal of task 1 was to determine if participants traveling in the rightmost lane understood that their lane would end and that they would need to move out of that lane.

A repeated-measures generalized linear model (GLM) (binomial response distribution, logit link function) was used to determine the influence of lane markings on participant response.
A response of "no" to the question, "Are you allowed to continue to travel in the right lane?" was considered correct.

Overall, the presence of the solid line to the left of the broken or dotted line (markings A versus markings B) did not affect responses, $\chi^2(1) = 2.94$, $p > 0.05$.

Overall, the variation of dotted or broken lines significantly affected participant responses, $\chi^2(2) = 16.94$, $p = 0.0002$.

Marking set 3 generated significantly more correct responses (must move out of the lane) than both marking set 2 ($p < 0.001$) and marking set 4 ($p = 0.003$). The responses to marking set 2 were similar to those responses to marking set 1 ($p > 0.05$).

The interaction between the addition of the solid white line and broken/dotted lines did not significantly affect participant response, $\chi^2(2) = 0.52$, $p > 0.05$.

In general, those participants who responded correctly demonstrated their understanding of the roadway markings in their responses to the question, "If you continued to travel in this lane, what, if anything, would happen?" Most participants indicated that the lane would end, that they would need to merge, or they otherwise responded with a similar answer.

Those participants who incorrectly responded to the yes-or-no question demonstrated their lack of understanding in their responses to the open-ended answers. Their comments were that nothing would happen, that they should continue straight, or they otherwise responded with a similar answer.

TASK 2

Again, the goal of task 2 was to determine if participants traveling in the lane just to the left of the ending lane were able to understand that the right lane was going to end and that they should expect traffic to move from the right lane into the left lane.

A repeated-measures GLM (binomial response distribution, logit link function) was used to determine the influence of lane markings on participant response. A response of "no" to the question, "May you merge into the right lane?" was considered correct.

Overall, the presence of the solid line to the left of the broken or dotted line (markings A versus markings B) significantly affected participant response, $\chi^2(1) = 34.46$, $p < 0.0001$. The presence of the solid white line (markings B) resulted in significantly more correct responses than the absence of the solid line (markings A).

When markings that included the broken line were compared to markings that included the dotted line, no significant effect on participant responses was found, $\chi^2(2) = 1.36$, $p > 0.05$. The interaction between the addition of the solid white line and broken/dotted lines did not significantly affect participant response, $\chi^2(2) = 4.12$, $p > 0.05$.

As in task 1, participants demonstrated their understanding of the lane markings when responding to the free response question, “What, if anything, might you expect the traffic in the right lane to do?” Those who answered the yes-or-no question correctly overwhelmingly responded with an indication that the traffic in the rightmost lane would be merging into the left lane. For example, responses included “merge into the left lane,” “switch lanes,” and “expect them to yield.” However, those who responded incorrectly to the yes-or-no question frequently failed to indicate that it was understood that the right lane would end. For example, responses included, “continue straight” and “nothing.”

TASK 3

The goal of task 3 was to determine how quickly participants traveling in the rightmost lane (with lane reduction) were able to understand that their lane was going to end and would subsequently change lanes.

A repeated measures GLM (normal response distribution) was used to determine the influence of lane markings on participant response time.

Overall, the presence of the solid line to the left of the broken or dotted line (markings A versus markings B) significantly affected participant response times, $\chi^2(1) = 42.20$, $p < 0.0001$. The presence of the solid white line (markings B) resulted in significantly faster responses ($M = 21.31$ s) compared to those responses with the absence of the solid line (markings A; $M = 23.64$ s).

Overall, the variation of dotted/broken lines significantly affected participant response times, $\chi^2(2) = 289.56$, $p < 0.0001$. Marking set 2 resulted in the fastest response times ($M = 19.29$ s), $p < 0.0001$. Marking set 1 ($M = 21.97$ s) resulted in significantly faster response times than marking set 3 ($M = 26.156$ s), $p < 0.0001$.

The interaction between the addition of the solid white line and broken/dotted lines significantly affected participant response times, $\chi^2(2) = 29.30$, $p < 0.0001$. Within marking set 1, the presence of the solid line (markings B) significantly reduced response time ($M = 19.44$ s) compared to the response times with the absence of the solid line (markings A; M =24.51 s), $p < 0.0001$.

Within marking set 2, the presence of the solid line (markings B) did not significantly affect response times ($M = 18.84$ s) compared to the response times with the absence of the solid line (markings A; M =19.74 s), $p > 0.05$. Within marking set 3, the presence of the solid line (markings B) did not significantly affect response times ($M = 25.65$ s) compared to response times with the absence of the solid line (markings A; $M = 24.51$ s), $p > 0.05$.

TASK 4

The goal of task 4 was to determine participants' preferences for the different lane markings. Participants were asked to rank the different pavement markings in terms of their perceived effectiveness in indicating that the right lane is about to end. Overwhelmingly, the markings with the solid white line (markings B) were ranked higher than those without the solid white line (markings A). Markings 3 were rated better than markings 2 and markings 1. Markings 2 were ranked higher than markings 1. Table 1 provides overall rank of each set of markings.

Table 1. Overall markings ranks in terms of perceived effectiveness.

Rank	Markings
1	3B
2	2B
3	1B
4	3A
5	2A
6	1A

Table 2 shows the Condorcet win/loss rates for each of the markings. Each cell depicts the proportion of time that the row markings would have been selected over the column markings had the two markings been directly compared. For example, markings 3B was selected as higher rated than markings 1A 87 percent of the time.

Table 2. Proportion of ranking win comparisons by markings.

Markings	1A	1B	2A	2B	3A	3B
1A	—	0.15	0.07	0.11	0.12	0.13
1B	0.85	—	0.55	0.24	0.55	0.28
2A	0.93	0.45	—	0.29	0.44	0.35
2B	0.89	0.76	0.71	—	0.66	0.49
3A	0.88	0.45	0.56	0.34	—	0.24
3B	0.87	0.72	0.65	0.51	0.76	—

—No data.

CHAPTER 4. DISCUSSION

The goal of this work was to assess drivers' understanding of both new and traditional lane-reduction roadway markings. Drivers participated in different tasks to determine the effects of the different lane marking patterns in terms of the following:

- Merging behavior (i.e., moving into the adjacent lane) at lane-reduction transitions.
- Driver understanding of the intended message conveyed at lane-reduction transitions (from both the terminating lane and the left-adjacent lane).
- Perceived rankings of effectiveness.

When participants were positioned in the rightmost lane that was ending and requiring traffic to merge, the addition of the solid white line did not affect the understanding that the lane would end and a lane change was required. However, marking set 3 (dotted line to the beginning of the taper) generated the most correct responses as indicated by the knowledge that the rightmost travel lane would end, and a lane change was required. Dotted lines are currently endorsed only when a lane drops, and there is concern that the use of dotted lines at lane-reduction transitions may be confusing to motorists, given lane-reduction transitions are significantly different from lane drops. However, no evidence of confusion was found in this study. Future work could explore how well drivers differentiate between land-reduction and lane-drop situations.

When participants were positioned in the left-adjacent lane to the terminating lane, the addition of the solid white line (markings B) helped drivers to understand that the right lane was going to end and that they should not attempt to move into that lane. Subsequently, open-ended questions confirmed a greater understanding that the traffic in the right lane would be expected to merge into the adjacent lane because of a lane reduction.

A group of participants was asked to indicate when they were confident that they would need to change lanes. The solid white line (markings B) significantly reduced participant response time by 2.33 s. At 40 mph, this reduction provides drivers an additional 136.87 ft to change lanes. In terms of dotted lines versus broken lines, marking set 2 generated the fastest response times, followed by marking set 1, and finally marking set 3. This finding may seem a bit challenging to interpret. Although not specifically tested as a variable, the location *where* the lane markings terminate influences *when* a driver is confident that the lane will end and when he or she will elect to change lanes. In other words, both marking set 2 and marking set 1 terminate lane markings at "advanced warning distance"/4, whereas marking set 3 continues markings until the beginning of the taper. Evidence from this study suggests that the termination of the markings acts as a cue to change lanes. However, an active driving study may help to confirm this finding.

These results taken together lead to several conclusions:

- The addition of a solid white line results in earlier lane changes, an understanding that drivers in an adjacent lane should not move into a lane that is about to terminate, and an understanding by drivers in an adjacent lane that they should expect merging traffic.

- Dotted lines (as opposed to broken lines) result in greater understanding that a lane is about to end.

- Drivers subjectively perceive the addition of the solid white line in lane-reduction markings to be helpful in indicating a lane reduction.

- Drivers subjectively perceive dotted lines to be more effective than the broken line alone.

RECOMMENDATIONS

Researchers have several recommendations based on the results of this laboratory study. These recommendations, however, would need to undergo the full MUTCD experimentation process before being implemented:

1. Add a solid white line to the left of broken/dotted lane markings in lane-reduction situations. This addition may help drivers to understand that a lane is ending. This addition is especially pertinent in situations in which drivers are:
    a. Frequently moving into a lane that is about to terminate.
    b. Not allowing other drivers to merge from a terminating lane.
    c. Taking too much time to begin merging out of a terminating lane.

2. Allow the usage of the dotted line in place of the broken line to indicate a lane-reduction. However, this study recommends that a more full-scale study (either via active driving simulation or real-world application) be performed to determine if marking set 2 or marking set 3 is more effective in the real world. Although marking set 3 generated more correct responses in terms of understanding that the right lane would end, marking set 2 generated faster response times. At this time, is it is unclear if one set of markings might cause more traffic problems (e.g., waiting to merge until the taper).

3. Future work should include the investigation of lane-reduction signage, delineation markers, and pavement arrows as they supplement lane-reduction pavement markings.

REFERENCES

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