

Motorists' Comprehension of Exit Lane Drop Signs and Markings

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A literature review and two motorist surveys designed to investigate current motorist comprehension of exit lane drop signs and markings are presented. In the first motorist survey study, motorists viewed computer-generated scenes of a freeway with markings and signs appropriate for an exit lane drop situation. The types of markings varied among different alternatives. Motorists were asked to indicate the anticipated movement of traffic in different lanes. The first study also contained questions on the participants' preferences of signs at different locations along an exit lane drop. The second survey was a mail-out survey to driving instructors who were asked to provide their interpretations of their students' comprehension of exit lane drop signs and markings. The results of the research indicate that motorists have a high level of understanding of the yellow EXIT ONLY panel; however, they have a poor understanding of the meaning of the white arrow next to a yellow EXIT ONLY panel. Motorists have equal comprehension of the meaning of a solid white line and double white lines extending from the gore, but they have lower comprehension of lane drop markings (short wide lines or short gaps).

Lanes are often eliminated from the roadway in an effort to make the highway function more efficiently. This phenomenon is known as a lane drop. There are three basic types of lane drops: lane splits, lane terminations, and exit lane drops. A lane split refers to the division of a multilane highway into two separate roadways so that the level of service provided to either roadway is approximately equal. A lane termination denotes the ending of a lane, usually by tapering it into the adjoining lane. The exit lane drop refers to the departure of one or more lanes from the freeway through lanes in the form of an exit. The exit lane drop is the focus of this paper.

Exit lane drops can cause confusion if the driver does not expect the lane to exit but instead to continue with the freeway main lanes. Without proper notification of the impending exit, drivers can find themselves performing erratic maneuvers to prevent exiting at undesirable locations. For motorists to travel successfully through an exit lane drop area, they need knowledge of the presence of the lane drop and its location in sufficient time to perform the desired maneuver. The National and Texas Manuals on Uniform Traffic Control Devices (MUTCD and TxMUTCD) contain information on signs and markings available to warn motorists of upcoming lane drops (1,2).

BACKGROUND

Exit only signs and pavement markings are two treatments used to communicate an exit lane drop to the motorist. Signs are a required condition by MUTCD, but pavement markings are optional. Exit

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only sign treatments include diagrammatic signs, the modified diagrammatic signs, the use of the black-on-yellow EXIT ONLY panel on conventional signs, and others. Pavement markings include larger lane striping [203 mm (8 in.) wide by 0.92 m (3 ft) long white stripes separated by 3.66-m (12-ft) gaps beginning approximately 0.81 km (0.5 mi) in advance of the theoretical gore point] and a solid white channelizing line [203 mm (8 in.) wide extending approximately 91.5 m (300 ft) upstream from the theoretical gore point].

The 1971 edition of MUTCD was the first edition to present information on the EXIT ONLY sign panel. It stated that the panel shall have a yellow background with black legend and may be used, but is not required, on the lower edge or lowest line of overhead gore, exit direction, or advance guide signs on roadways approaching an interchange where there is a reduction in the number of available lanes for through traffic (3). It was not until the 1978 edition of the national MUTCD that the EXIT ONLY panel became a requirement at all interchange lane drops (4).

Between 1970 and 1972, operational reviews of metropolitan freeways were conducted in California, and the need for a special treatment at exit lane drops was found. The striping was approved in 1975 by the California Traffic Control Devices Committee and included in its traffic manual. In a letter written in 1978 to the National Advisory Committee at FHWA, California recommended the special pavement markings for inclusion in the national MUTCD.

OBJECTIVES

The intent of this project was to determine how motorists interpret the meaning of sign and pavement marking alternatives they may or may not have experienced before. Specific objectives included the following:

- To determine driver interpretation and comprehension of existing pavement markings and signs currently used at exit lane drops,
- To determine driver interpretation of alternative pavement markings that could be used at exit lane drops, and
- To determine driver preferences of pavement markings and signs to be used at exit lane drops.

PREVIOUS RESEARCH ON EXIT LANE DROPS

Exit Only Signs

Black-on-Yellow Panels

A 1976 study by Lunenfeld and Alexander (5) evaluated the EXIT ONLY panel and other variations. The study recommended the use

of the EXIT ONLY panel when route continuity is maintained or, in conjunction with diagrammatic signs, at exits. Roberts and Klipple (6) reported in 1976 on an exit lane drop signing experiment that compared four different exit panel messages and one panel with directional arrows and no word messages. The experiment supported the conclusion that the MUST EXIT and EXIT ONLY panel messages were most helpful in correctly influencing driver expectations and that the difference between these signs is so small that either one is recommended for use; however, only one should be used in the interest of improving the accuracy of driver expectations.

Diagrammatic Signs

Several studies have investigated the use of diagrammatic signs versus conventional signs, especially at lane drops. Brainard et al. (7) in 1961 investigated the interpretability of diagrammatic signs, whether sign preferences existed, and whether these sign preferences are similar to typical diagrammatic signs found in Europe. The study concluded that pictorial signs were the most easily interpreted. MacDonald and Hoffmann (8) found that diagrammatic signs better communicate information to the driver in terms of initial perception time than do verbal signs. Another study, by Lunenfeld and Alexander (5), investigated the use of diagrammatic signs at lane drops with different geometric characteristics and recommended that diagrammatic signs be used at exits with route discontinuities.

A 1971 study by Roberts (9) investigated the effectiveness of diagrammatic signs at a single location in New Jersey and evaluated the use of these signs by conducting a before and after study. Roberts observed the occurrences of erratic maneuvers (stopping, crossing lane lines, or backing) in a 61-m (200-ft) zone ending at the gore to evaluate traffic characteristics before and after the installation of the signs. Roberts found that there were significantly fewer erratic maneuvers after the diagrammatic signs were installed. After six months, however, it was found that there was a significant increase in the number of erratic maneuvers. The increase was attributed to the two data sets being collected in unlike seasons.

A study of diagrammatic signs by Roberts and Klipple (10) investigated the effect of current signing and variations of current signing on driver expectancy violations, such as at lane drops. The study concluded that diagrammatic signs, with or without exit verbiage, influenced driver expectancy favorably.

Pavement Markings

The earliest study identified concerning pavement markings at exit and entrance ramps was conducted in 1966 by Roth and DeRose (11). This study investigated the effectiveness of a color coded system consisting of edgemarking, delineation, and signing. Pavement markings consisted of white lines for through traffic, blue for exit ramps, and yellow for entrance ramps. The study reported a significant reduction in erratic maneuvers around two exit and two entrance ramps as a result of the new pavement markings. The erratic maneuvers included two-lane lane changes (within the approximate 610-m (2000-ft) study sections), stopping, backing, and radical movements across the gore. In addition, driver interviews revealed that 85 to 90 percent of the drivers believed the system was beneficial.

Another study related to color coding of pavement markings was conducted in 1976 by Cornette (12). Cornette specifically tested 127-mm (5-in.) wide yellow edgeline and 0.61-m (2-ft) wide

yellow gore striping at various lane drop situations, including exit lane drops. In addition, Cornette tested the effectiveness of double amber reflectors on both sides of the roadway with decreased spacing approaching the gore area. Seven lane drop sites were chosen, including two single-lane exit lane drops. At both sites, the combination of amber delineators and yellow striping was most effective in reducing erratic movements and brake light applications, although this combination was not necessarily found effective in other lane drop situations.

In 1975, Pigman and Agent (13) investigated the effectiveness of raised pavement markers at lane drops. The study collected before and after data at five lane drop sites, including two exit lane drops. The raised pavement markers, although effective during day and night, were found to be much more effective in reducing erratic maneuvers during nighttime conditions.

In the late 1980s, Texas sponsored a study that investigated signing or pavement markings, or both, that could provide additional information to motorists regarding impending exit lane drops (14). The use of a series of short white dashes followed by a double white stripe before the gore area and a DO NOT CROSS DOUBLE WHITE LINES sign were selected for investigation. The pavement markings were installed at three sites in the Houston area. All erratic maneuvers between the mandatory exit lane and the adjacent through lane from the gore to a point between 152.5–213.5 m (500–700 ft) before the gore were recorded before and after the markings were installed. Comparisons were made on a matched 15-min interval basis. Because of geometric configurations at the sites, one location received the pavement markings and the sign treatment, and the remaining sites received variations on the pavement markings treatment only. One location showed improvement in operations during all peak periods, another location (Braeswood Exit) showed improvement in operations for peak periods except the p.m. period, and the last site had mixed results with some improvements in lane changes and some increases in lane changes. In the case of the last site, most of the deteriorating operations were attributed to the difficult geometrics of the site.

Approximately 1 year after the special markings were installed at the Braeswood Exit, additional lane change data were collected. The data from this effort were compared with the data in the preceding effort. The results showed a continual decrease in erratic lane changes over time. In addition, total and peak hour volumes were collected for all three study periods. The volumes showed a continual growth over time, demonstrating that even with increased volumes, the erratic lane changes decreased as a result of the pavement striping (15).

Other Studies

Geometric Considerations

Cornette (12) conducted a study in 1972 comparing the operational characteristics of four different types of lane drops (single lane exit with refuge area after the drop, single lane exit without refuge area, a lane termination, and a single-lane, lane split). Conflict surveys (erratic movements and brake light applications), spot speed measurements, and lane volume counts were collected at the four sites before and after various traffic control devices were implemented at the sites. Cornette found that the single lane exit without refuge area had the lowest conflict rates. In addition, the study concluded that lane drops associated with poor geometrics, such as high rates of curvature and sight distance restrictions, had higher conflict rates

than those with more optimal geometric features. As a result, it was concluded that traffic control devices are not as effective in reducing conflicts as are proper site geometrics. Goodwin and Goodwin (16), in 1972, and Goodwin (17) later in 1976 developed a set of principles on which lane drops should be designed, most of which are applicable to exit lane drops. Information needed to successfully and safely travel through an exit lane drop area included: (a) knowledge of the impending lane drop, (b) location of the lane drop, (c) choice of an appropriate maneuver, and (d) time to execute that maneuver.

Operational Effects

In 1971 Goodwin and Lawrence (18) conducted a study in which they determined from field data the effectiveness of existing freeway mainline lane drops with regard to traffic operations. For the exit lane drop, the results of data analysis showed that only 10 percent of the vehicles on the freeway were traveling in the exit only lane at the beginning of the test section (approximately 305 m (1000 ft) before the gore). Most of these vehicles not exiting performed the lane change well before the end of the lane. A few vehicles, however, did make their maneuvers in the last 15.3 m (50 ft) before the gore.

STUDY METHOD

Several options are available to the traffic engineer to communicate to motorists an approaching exit lane drop. Some of the options, such as the yellow panel on the green guide sign, have been used for several years. Other options, such as pavement markings, are reasonable ideas; however, they have not been used on a consistent basis. To test the effectiveness of several different types of pavement markings in the field would require a significant outlay of personnel effort and funds. A survey technique can obtain drivers' reactions to different types of pavement markings without the sizable monetary commitment. Two types of surveys were selected for this project: a survey of motorists at an automobile show and a mail-out survey of driving instructors.

MOTORIST SURVEY—AUTOMOBILE SHOW

Development of Survey

Initial efforts on developing the automobile show survey included several meetings of the research team to determine the survey's goals and to develop appropriate questions. Two goals for the questionnaire were to determine driver interpretation of alternative marking and sign techniques and, to determine driver preference of exit only signs.

The type of participant was also considered during the survey preparation efforts. Because these participants were attending a recreational event and were unpaid volunteers, simplicity and brevity were two qualities emphasized during the development of the questions. A survey length of 10 to 12 min was estimated to be the maximum time that a participant would be willing to contribute. Because this survey was testing alternative markings that may or may not be in current use, computer generated colored art work was used, instead of pictures of existing sites.

Once the survey questions were selected, the survey was pretested to ensure that the questions were understandable. More than 30 respondents representing different gender and age groups

were used to evaluate the questions. The pretest resulted in only minor changes.

Experimental Plan

To overcome any learning curve within the survey, the research team decided that the participants would be asked questions on only one type of marking. Four alternative versions of the questionnaire would be used during the survey period, with each alternative containing the same questions but with different pavement markings.

The four pavement marking alternatives selected for testing were

- I—typical white lane lines (3.05-m stripe with a 9.15-m gap) (10-ft stripe with a 30-ft gap),
- II—double white lines (each 101.6 mm wide, set 101.6 mm apart) (each 4 in. wide, set 4 in. apart),
- III—short lines and short spaces known as "lane drop markings" (203.2 mm wide, 0.92 m long, 3.66-m gaps) (8 in. wide, 3 ft long, 12-ft gaps), and
- IV—wide white line (203.2 to 304.8 mm wide) (8 to 12 in. wide).

The typical white lane lines (Alternative I) were tested to serve as a baseline for comparison. The questions for each of the four alternatives were assembled into a separate three-ring binder for use during the automobile show. A participant would be asked questions from only one of the four three-ring binders. The use of each three-ring binder would be rotated so that a similar number of participants would answer the questions for each alternative.

Several types of questions were asked within each alternative. For example, the initial questions dealt with driver actions when only the markings were visible, and later questions covered driver actions when both markings and signs with an EXIT ONLY panel were visible. Only the visual presented to the participant (i.e., the type of pavement markings) changed for each alternative; the questions remained the same. The questions dealt with the following conditions for each alternative:

- Questions 1 to 3 dealt with markings only,
- Questions 4 and 5 dealt with markings and the appropriate sign for a one lane, lane drop exit,
- Questions 6 and 7 dealt with markings and the appropriate sign for a two lane, lane drop exit with an option lane and an exit only lane,
- Questions 8 to 10 dealt with markings and the appropriate sign for a two lane, lane drop exit where the alternative markings were placed between one set of lanes (Lanes 2 and 3), and
- Questions 11 to 13 dealt with markings and the appropriate sign for a two lane exit only where the alternative markings were placed between two sets of lanes (Lanes 2 and 3 and Lanes 3 and 4).

The initial set of questions (Questions 1 to 3) was critical to the survey, because it relayed the driver's understanding of the pavement markings without additional visual clues of the approaching mandatory exit (see Figure 1). The next set of questions (Questions 4 and 5) used the same markings and added a green guide sign with a yellow EXIT ONLY panel.

In addition to investigating driver opinion on alternative pavement markings, the survey contained questions about driver preference for the different types and locations of exit only signs. The signs tested included

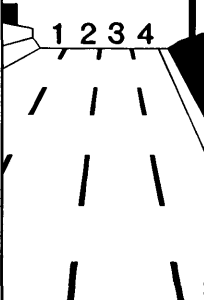
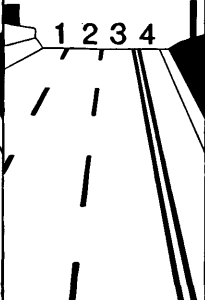
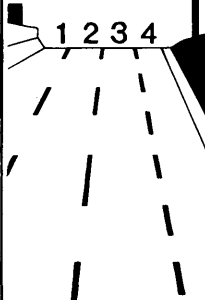
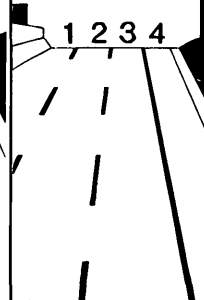
QUESTION LANE RESPONSE	Alternative I	Alternative II	Alternative III	Alternative IV
				
1 4 Must continue on freeway	2%	7%	8%	4%
1 4 Must exit	8%	73%	52%	72%
1 4 May either exit or continue	82%	13%	31%	19%
1 4 Not sure	8%	7%	9%	5%
2 3 Must continue on freeway	NA	67%	61%	55%
2 3 Must exit		3%	1%	3%
2 3 May either exit or continue		27%	37%	37%
2 3 Not sure		3%	1%	5%
3 L-4 must exit	NA	27%	42%	41%
3 L-3 may exit or continue		14%	35%	16%
3 May not cross marking		57%	9%	37%
3 Not sure		2%	14%	6%
Number of Respondents	132	148	124	124
Number of Responses for Question 3		175	153	157

FIGURE 1 Responses to markings only questions.

- The conventional green guide sign with a yellow EXIT ONLY panel (with a black down arrow on the panel or a white arrow on the green guide sign),

- A diagrammatic sign, and
- A green guide sign with a yellow EXIT ONLY panel and a black upward sloping arrow.

Conduct of Survey

The survey was conducted during the 1992 Houston Automobile Show. A total of 528 individuals participated, or an average of 130 per alternative. The participants in the survey were provided state and local maps and other literature from the Texas Department of Transportation in appreciation for their participation in the survey. No unusual conditions were experienced while administering the survey that would affect the survey results. Although the illustrations presented in this paper were modified to black and white for reproduction purposes, the actual drawings viewed by the participants were in color.

Findings

Demographics

The results from the demographic questions for the survey participants were compared with the distribution of licensed drivers in the United States (19). As in past automobile shows, most of the survey

participants (approximately 66 percent) were white males; males represent 52 percent of licensed drivers. More than 80 percent of the respondents were less than 40 years old, with roughly half of these respondents in the less than 25 years age group and the other half in the 25 to 39 year age group. Approximately 53 percent of licensed drivers were less than 40 years old. Because the survey participants were younger than the licensed driving population, the survey captured drivers with less driving experience. This condition is assumed not to have an adverse effect on the findings of the study. Most respondents had high school degrees or equivalent, with approximately one-third of the participants having college degrees.

Markings Only Questions

The objective for the initial set of questions was to determine the driver's interpretation of pavement markings without any other visual clues. Figure 1 shows a summary of the responses from the four alternatives. For Alternative I, 8 percent of the participants said that if they were driving in Lane 4, they must exit from the freeway. Responses from Alternative III revealed 52 percent of the participants stated they must exit if they are in Lane 4. The other two alternatives pertaining to the solid white line markings resulted in approximately 72 percent of the participants stating that they must exit if in Lane 4. The solid white lines, even without additional visual clues such as the approach to the exit or a yellow panel sign, indicated best to the motorists that they will be required to exit if they continue in the lane.

Question 3 of the survey was similar to Question 1 but presented in a different manner to obtain additional understanding of motorists' interpretation of the markings. Although the participants were informed that they could choose more than one response, most participants selected only one response, with the type of response varying among alternatives. For example, in Alternative II, respondents tended to focus on whether they could cross the markings, but in Alternative IV the participants chose almost equally the Lane 4 "must exit" and the "may not cross markings" answers. The response distribution for Alternative IV was expected. The pattern of responses in Alternative II may be a reflection of the Houston district's using two solid white lines on some freeway exit ramps merging with a frontage road in conjunction with the sign that says DO NOT CROSS DOUBLE WHITE LINES. The results of Question 3 in Alternative III indicated that participants interpreted the lane drop lines as permissive. A higher percentage of respondents for Alternative III than Alternatives II or IV indicated that the vehicles in Lane 4 may either exit or continue.

Comments received from participants were informative. Some participants indicated that they had never seen some of the types of markings being tested (i.e., the double white lines or the lane drop markings). Several participants stated that they wanted a sign to provide the information about whether to exit instead of just basing their decisions on the pavement markings. These comments served as a reminder of the need to provide a secondary source of information until drivers are familiar with the new markings.

One-Lane, Lane Drop Exit Questions

The objective for the one-lane, lane drop exit questions was to determine whether the combination of signs and markings improves

driver understanding of the approaching mandatory exit. Figure 2 illustrates the graphics as well as the findings from the survey. Driver comprehension of the markings increased noticeably with the addition of the EXIT ONLY sign. More than 91 percent of the respondents for each alternative indicated that Lane 4 must exit to Caster. For Alternative I, when no sign was used with the standard lane markings, 8 percent of the participants indicated that they must exit. When the sign was added, however, the must exit response increased to 92 percent.

Although the percentage of respondents choosing must exit to Caster for Lane 4 for the four alternatives was fairly consistent (91 to 98 percent), the percentage choosing "must continue" on freeway for Lane 3 was not as uniform. The lane drop markings alternative (Alternative III) had the lowest number of participants selecting the "must continue" option (60 percent). Most remaining participants selected the "may either exit or continue" selection. More than 80 percent of the participants of Alternative II selected the "must continue" option. This high percentage may be a reflection of the use of double solid white lines in some areas of Houston where some freeway exit ramps meet the frontage road.

Two-Lane Exit with an Option Lane and an Exit Only Lane Questions

The objective of these questions was to determine whether the combination of signs and markings improves driver understanding that the approaching exit is a two-lane exit with one optional exit lane and one exit only lane (see Figure 3). More than 90 percent of the participants recognized that Lane 4 must exit. Between 67 and 79 percent of the participants selected the "may exit or continue on the freeway" option for Lane 3, which is the correct answer. A sub-

QUESTION LANE RESPONSE	Alternative I	Alternative II	Alternative III	Alternative IV
	4 4 Must continue on freeway	2%	1%	2%
4 4 Must exit to Caster	92%	95%	91%	98%
4 4 May either exit or continue	6%	3%	5%	2%
4 4 Not sure	0%	1%	2%	0%
5 3 Must continue on freeway	NA	82%	60%	72%
5 3 Must exit to Caster		2%	2%	2%
5 3 May either exit or continue		15%	35%	23%
5 3 Not sure		1%	3%	3%
Number of Respondents	132	148	124	124

FIGURE 2 Responses to one-lane, lane drop exit questions.

QUESTION LANE RESPONSE	Alternative I	Alternative II	Alternative III	Alternative IV
6 4 Must continue on freeway	1%	5%	5%	5%
6 4 Must exit to Gradit	92%	90%	89%	91%
6 4 May either exit or continue	7%	5%	4%	4%
6 4 Not sure	0%	0%	2%	0%
7 3 Must continue on freeway	28%	30%	18%	21%
7 3 Must exit to Gradit	4%	3%	2%	2%
7 3 May either exit or continue	67%	66%	79%	76%
7 3 Not sure	1%	1%	1%	1%
Number of Respondents	132	148	124	124

FIGURE 3 Responses to two-lane exit with option lane and exit only lane question.

stantial portion of the respondents, between 17 and 30 percent, selected the "must continue on freeway" answer for Lane 3. This indicates that several participants did not interpret the white down arrow (that is, outside the yellow EXIT ONLY panel) to mean that the drivers in the third lane can exit or stay on the freeway. Few participants (less than 5 of the 130 participants per alternative) selected the "must exit" answer.

Two-Lane, Lane Drop Exit with Markings Between One Set of Lanes Questions

The objective of these questions was to determine whether the combination of signs and markings improves driver knowledge of an approaching two-lane mandatory exit. Over 94 percent of the participants correctly selected the "must exit" answer for Lane 4, but only 82 to 90 percent of the participants correctly selected the "must exit" answer for Lane 3 (see Figure 4). Between 80 and 91 percent correctly selected the "must continue" option for Lane 2. Alternative III (lane drop markings), elicited the highest number of incorrect answers, primarily the "may either exit or continue on the freeway" answer. Respondents interpreted the permissive nature of the broken lane lines as allowing them to change lanes.

Two-Lane, Lane Drop Exit with Markings Between Two Sets of Lanes Questions

The objective of these questions was to determine whether the change in marking alters driver knowledge of the approaching two-

lane mandatory exit. Figure 5 shows the results from the questions. The findings for this group of questions were similar to the previous group of questions. Between 93 and 99 percent (compared with 94 to 96 percent) of the participants correctly selected the "must exit" answer for Lane 4, and only 81 to 90 percent (compared with 82) of the participants correctly selected the "must exit" answer for Lane 3. Between 71 and 92 percent (compared with 81 to 91 percent) correctly selected the "must continue" answer for Lane 2. Alternative III (lane drop markings) again offered the highest number of incorrect answers, with those individuals selecting the "may either exit or continue" answer.

Several participants appeared surprised when viewing the graphics for Alternatives II to IV for this group of questions. They said that they had never seen a situation in which the markings are used between two sets of lanes. Several stated that Lane 3 should continue somewhere other than the direction of Lane 4 and that the sign is misleading because both lanes are going to Boulder. They thought that one lane should go to one destination and the other lane should go to another with this type of pavement marking.

Driver Preference Questions

Two objectives were selected for the driver preference questions. They were (a) to determine whether drivers understood the difference between an advanced guide sign and an exit direction sign and (b) to determine driver preference among different exit only signs. The participants were shown an exit only lane drop with three sign post locations. They were asked to indicate which of two signs they would prefer at each location (the choices were different for each sign location). The two primary findings were that diagrammatic

QUESTION LANE RESPONSE	Alternative I	Alternative II	Alternative III	Alternative IV
8 4 Must continue on freeway	0%	2%	2%	2%
8 4 Must exit to Lockett	94%	96%	94%	94%
8 4 May either exit or continue	5%	1%	4%	4%
8 4 Not sure	1%	1%	0%	0%
9 3 Must continue on freeway	4%	4%	3%	2%
9 3 Must exit to Lockett	84%	89%	83%	90%
9 3 May either exit or continue	11%	7%	14%	8%
9 3 Not sure	1%	0%	0%	0%
10 2 Must continue on freeway	87%	91%	80%	88%
10 2 Must exit to Lockett	3%	2%	2%	1%
10 2 May either exit or continue	9%	6%	18%	9%
10 2 Not sure	1%	1%	0%	2%
Number of Respondents	132	148	124	124

FIGURE 4 Responses to two-lane, lane drop exit with markings between one set of lanes questions.

signs were chosen most often for the first sign but less often for later use and that drivers prefer the down arrow for the first sign use.

Interpretation of Findings

The motorist survey indicated a high level of understanding of the exit only signs. Only the sign for the two lane exit with one lane mandatory and one lane optional had correct comprehension of less than 80 percent. The white down arrow next to the yellow EXIT ONLY panel was correctly interpreted by only between 66 and 79 percent of respondents, depending upon the type of markings shown on the figure (see Figure 5). Note that the visuals represented only a specific location along a freeway. Drivers can encounter other visual clues, such as the approaching geometrics and other signs, to aid them in their driving decisions. In those cases in which a driver failed to observe a preceding sign, or the driver entered the freeway after preceding signs, most drivers correctly selected the appropriate response.

A noticeable difference occurred between the lane drop markings (short lines and short gap treatment) and the solid lane line markings. Drivers correctly interpreted the broken line markings as permissive and the solid lines as a restrictive. For example, when only the markings (no signs) were shown, more than 70 percent of the respondents indicated that the right-hand lane must exit. Only 52 percent of the respondents selected the "must exit" choice for the special markings alternative (see Figure 1).

**DRIVING INSTRUCTOR SURVEY—
MAIL-OUT SURVEY**

The goal of the second survey was to obtain an indication of the comprehension of signs and pavement markings for freeway exit only lanes by inexperienced or new drivers. Driver instructors were requested to provide an assessment of their students' understanding of signs and pavement markings used at freeway exit only lanes. Of the 164 surveys mailed to driver instructors in large urban areas in Texas 44 were returned. Instructors indicated that their students had an above-average comprehension of current signing and pavement markings and a below-average comprehension of the difference between an up and a down arrow on an exit guide sign. In other questions instructors' responses revealed their belief that students had a good understanding of the meaning of the solid white line and a poor understanding of the meaning of the dashed white line (lane drop markings). When asked whether a diagrammatic sign better communicates that a lane must exit than the yellow EXIT ONLY panel, instructors responded overwhelmingly in favor of a diagrammatic sign. The survey indicated that the solid white line and the yellow EXIT ONLY panel are devices well understood by inexperienced drivers in Texas. This finding indicates the value of using pavement markings with signs to communicate information to motorists.

Instructors also made several suggestions for other traffic control devices at exit lane drops. Pavement treatments included pavement arrows, exit only signs, rough buttons lining the exit lane, and

QUESTION LANE RESPONSE	Alternative I	Alternative II	Alternative III	Alternative IV
11 4 Must continue on freeway		2%	2%	0%
11 4 Must exit to Boulder	NA	96%	93%	99%
11 4 May either exit or continue		1%	3%	4%
11 4 Not sure		1%	2%	1%
12 3 Must continue on freeway		5%	5%	2%
12 3 Must exit to Boulder	NA	86%	80%	91%
12 3 May either exit or continue		7%	14%	6%
12 3 Not sure		2%	1%	1%
13 2 Must continue on freeway		89%	72%	92%
13 2 Must exit to Boulder	NA	3%	2%	0%
13 2 May either exit or continue		8%	25%	6%
13 2 Not sure		0%	1%	2%
Number of Respondents	132	148	124	124

FIGURE 5 Responses to two-lane, lane drop exit with markings between two sets of lanes questions.

beginning the solid white line at the first exit only guide sign. Sign suggestions included using diagrammatic signs in conjunction with the yellow EXIT ONLY panel, changing the colors of the signs, and adding RIGHT LANE or LEFT LANE to the yellow panel.

SUMMARY AND CONCLUSIONS

This paper presented findings from a literature review and two surveys on motorist comprehension of exit lane drop signs and markings. Studies of the black on yellow panels conducted in the early 1970s supported the use of the panels. The panels were required at interchange lane drops beginning with the 1978 edition of MUTCD. Early and recent studies on diagrammatic signs also support their use at exit lane drops. The results from both surveys conducted during this research support the findings from the literature. Motorists have a high level of understanding of the yellow EXIT ONLY panel, but they do not understand the use of the white arrow next to a yellow EXIT ONLY panel (see Figure 3). More than a third of the participants incorrectly interpreted the meaning of the white arrows. Motorists preferred the use of diagrammatic signs as the first of several signs indicating an approaching lane drop and the use of the conventional black on yellow panel (instead of the diagrammatic sign) close to the exit lane drop.

Pavement markings for exit only lane drops were first included in MUTCD in 1984 at the suggestion of California transportation engineers. They had several years of positive experience with the

markings when they made the recommendation. Several of the previous research studies on pavement markings examined the use of markings at lane drops instead of exit only lane drops. A study in the late 1980s examined the effectiveness of markings at exit only lane drops. It found mixed results: at one location improvement in operations occurred during all peak periods, at the second location improvement occurred during the afternoon peak, and the third location had some decrease and some increase in lane changes during the times observed.

The motorist surveys conducted for this research indicated that drivers showed equal comprehension of the meaning of the solid extra wide white line and the double white lines. Participants' responses also indicated that they knew the broken line markings are permissive and the solid lines are restrictive. The participants did not demonstrate as high a level of understanding of the meaning of the broken lines as of the solid line. The use of a solid line before an exit only lane drop is more prevalent than the use of the broken line.

RECOMMENDATIONS FOR FUTURE RESEARCH

Although surveys can obtain drivers' reactions and opinions to different types of pavement markings, field studies can measure actual driver behavior in response to a change. Studies that measure driver behaviors, such as lane changes and erratic maneuvers, before a treatment is installed and after a treatment is installed would indi-

cate how drivers behave in response to a treatment. A control site study where two similar sites are identified and only one of the two sites receives a change in signs or markings could also be used. On the basis of findings from the surveys, testing the lane drop markings in the field would determine whether driver behavior is different with that type of marking than with standard white lane lines. Another area for research is the use of two sets of markings with a two lane exit (for example, see Figure 5). Several individuals during the automobile show commented that those markings would be appropriate when each lane is for a different destination.

Several studies, including this project, found that the meaning of the white arrow next to a yellow EXIT ONLY panel is not well understood by motorists. Research into alternative signs for two-lane exits with an option lane and an exit only lane would identify better techniques for communicating to motorists the downstream geometric exit configuration. The research could also examine whether different types of signs used at different locations would improve driver comprehension. For example, in this project, motorists indicated that they prefer the use of a diagrammatic sign as the first of several signs and the use of the EXIT ONLY panel close to the exit lane drop.

Additional research could also investigate the need for uniformity between signs and markings used for lane drops on freeways and on arterial streets (e.g., the use of the words EXIT ONLY on freeways and MUST EXIT on arterial streets). The research should include an appraisal of whether the status quo, although inconsistent, is better than modifying signs that have been used successfully for several decades.

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