Signing Treatments for Interchange Lane Drops

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Drivers often experience difficulty when freeway lanes are not continued beyond an interchange. Interchange lane drops represent situations that drivers do not expect and for which they are unprepared. The problem was studied to aid the driver's task by developing effective signing treatments. Devices in the Manual on Uniform Traffic Control Devices (MUTCD) were found to be not entirely satisfactory because of questions about their applicability, latitude in their application, and suitability for their intended purpose. Data from surveys, a state-of-the-art review, observations of as-built installations, and laboratory evaluations were used within the framework of a human factors analysis to assess MUTCD standards and recommend changes. Driver expectancy provided the basis for problem identification and solution development. Configurations were categorized by geometric and route attributes into eight types of exits and splits. Their concomitant expectancy violations were identified, and their effect on unfamiliar drivers was assessed. Each type violated the expectancy that all lanes will continue. Additional differing geometric and route expectancy violations precluded the use of a single signing treatment for all types. The black-on-yellow EXIT ONLY treatment was recommended for exit lane drops with route continuity. Diagrammatic treatments were recommended when the off-route was to the left of the through-route. Empirical evaluations demonstrated the effectiveness of the recommendations.

There are locations on freeways and expressways where traffic volumes do not warrant the continuation of a lane or lanes. One of the ways to discontinue a lane is in conjunction with an interchange. Interchange lane drops can lead to considerable driver difficulty. They occur on high-speed highways where drivers are often required to make simultaneous decisions under extreme time pressures. They present drivers with a set of unusual maneuvers that they do not expect and for which they are usually unprepared. They may be further complicated when routes as well as lanes are not carried beyond the interchange. Even without the discontinuation of a route, interchange lane drops represent serious problems in terms of safety and efficiency. Unlike the main-line lane drop, which forces the driver in a lane about to be terminated to merge with traffic in an adjacent lane, the terminated lane may cause the driver to take an undesired path or route. The consequences of interchange lane drops include accidents, turbulence caused by last-minute merges, erratic maneuvers at gores and on-ramps, and drivers getting lost or delayed.

Although there was agreement among highway engineers that interchange lane drops created problems, there was little consensus on how to characterize them and how the problems could be solved. Early evidence pointed to the usefulness of a black-on-yellow EXIT ONLY treatment (1). With its inclusion in the Manual on Uniform Traffic Control Devices (MUTCD) (2), the Office of Traffic Operations (OTO) of the Federal Highway Administration (FHWA) initiated a program to study its applicability and effectiveness. The primary objective was to evaluate all interchange lane drop signing standards and recommend MUTCD changes where applicable.

CATEGORIZATION

An initial problem analysis showed that a variety of geometric and route configurations were associated with interchange lane drops. The simplest case is that in which three lanes approach an interchange, two lanes go through, and one, usually the right lane, becomes the exit ramp. Exit lane drops are more complex when the left lane becomes the exit ramp. The situation is essentially similar to a major split. With splits, at least one (usually two or more) of the lanes is not continued through the interchange. Splits may be further complicated by an optional lane. Analysis showed that most interchange lane drops could be defined in terms of the following minimum characteristics:

1. Reduction in lanes;
2. Association with an interchange;
3. Right or left lane or lanes not continuing through the interchange; and
4. In some cases, through route not continuing through the interchange.

Eight basic types, shown in Figures 1 and 2, were categorized by using the scheme of Table 1. Although some

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interchange lane drops might not fit into the scheme, these four exit lane drops and four splits are representative of the majority of cases.

APPLICABILITY OF EXIT ONLY TREATMENT

OTO had promoted the EXIT ONLY panel for right exit lane drops before its inclusion in the MUTCD. Its adoption, however, still left several unresolved questions related to its applicability with variations in geometrics and route continuity. A preliminary survey of OTO personnel (37 in sample) was conducted to assess its applicability as judged by professionals and nonprofessionals. Those sampled were asked to indicate whether EXIT ONLY should be applied to each of six types of exits or splits. A X^2 goodness-of-fit test was used to test, at the 0.05 and 0.01 significance levels, whether the respondent's judgment of the applicability of the EXIT ONLY panel is dependent on the interaction between route and geometrics. The results are given in Table 2. Significant results were obtained in favor of EXIT ONLY at exit lane drops with route continuity (exit type 1) and in opposition when the through route is carried on the ramp (exit type 3). Split type 2 was the only split to yield significant results, with respondents opposing the use of the EXIT ONLY panel. The preliminary survey, a follow-up survey of redesigned treatments that yielded no significant results, and interviews with traffic highway engineers showed considerable disagreement concerning the use of the EXIT ONLY treatment and acceptable alternatives when it was not applicable. This resulted in a program expansion to consider other aspects of the program.

STATE-OF-THE-ART REVIEW

A literature review showed that relatively little research existed on interchange lane drops. One study looked at accident rates (3). It found that rates increased as a function of interchange versus main-line lane drop whether the drop was on the left or right and whether the geometrics could be seen. No conclusions were drawn regarding signing or marking treatments. A recent study in Kentucky studied traffic conflicts at sites with differing designs and information treatments (4). Whenever horizontal curves were minimized and vertical curves were either nonexistent or were sags, conflict rates were lowest. No single signing or marking treatment was significantly effective for all configurations. The conclusions of the Kentucky study were similar to those derived analytically elsewhere (5). Research on other traffic control devices is sparse. Some pavement treatments, including color coding (6) and raised pavement markings (7), were found to be effective. Although Michigan obtained a significant reduction of greater than 75 percent in erratic manuevers with the black-on-yellow EXIT ONLY panel (1), questions were raised about the suitability of the message. One jurisdiction in California conducted a questionnaire evaluation that showed ambiguity with EXIT ONLY and concluded that MUST EXIT was superior. This study was replicated by the FHWA (8) by using a variety of verbal messages. The FHWA study found all messages to be ambiguous and concluded that replacing EXIT ONLY with MUST EXIT was not warranted. Although literature is conflicting on verbal treatments, one study on diagrammatics (9) does provide definitive conclusions for several types of interchange lane drops. Although the study did not evaluate exit lane drops per se, its conclusions that diagrammatics are effective in situations where the off-route movement is to the left of the through-route movement are applicable to left lane drops and splits where the off-route movement is on the left leg.

State Survey

A survey of states (all states plus the District of Columbia and Puerto Rico) found that all types of interchange lane drops occur throughout the country and are distributed as follows:

Category	Number	Percent	Category	Number	Percent
Exit			Split		
1	48	93	1	25	48
2	26	50	2	21	40
3	33	64	3	34	66
4	17	33	4	30	58

Each state reported at least one of the types on its highway system. Exit type 1 was the most common, occurring in 92 percent of all jurisdictions, and split type 2 was least common, occurring in 40 percent of the jurisdictions. Seven urban states reported all types, and six rural states reported only one type.

Observation of Installations

Observations of interchange lane drops throughout the country found that drivers encounter differing signing treatments from state to state, from location to location within states, and from interchange to interchange at a specific location. This variability in treatment represents a source of driver confusion. Interchange lane drop signing that is nonstandard, inconsistently applied, or unique to a particular jurisdiction is potentially confusing. Consistent and standardized treatments are needed to aid the driver. Uniform traffic control devices consistently applied lead to self-learning, which enables drivers to link situations with information presentation, comprehend its meaning, and predict situations that will occur. Several examples of differing treatments are shown to illustrate the variability that a driver may encounter. The most typical treatment is to apply the black-on-yellow EXIT ONLY panel to the lowest line of the guide sign with the message bracketing a white or black down arrow as shown in Figure 3. Variations in arrow treatment, word message, and panel position are shown in Figures 4, 5, and 6. These represent only a small fraction of the kinds of signing found throughout the country. Reasons for this variability determined in discussions with operations personnel include local practice and MUTCD latitude.

MUTCD Analysis

The EXIT ONLY panel is the only treatment in the MUTCD specifically designed for interchange lane drops, although a conventional down arrow treatment applicable to one type of split is covered elsewhere. The EXIT ONLY treatment is not given emphasis or prominence and is included in a section on miscellaneous guide signs. Guidelines on applicability of the treatment are lacking, and there is latitude allowed in its use. EXIT ONLY is not a mandatory treatment. There is latitude in its application because it is not required on all guide signs in a given sequence. The only requirement on the subject governs the use of a down arrow with the panel when it is used at the advance guide sign location.

PROBLEM ANALYSIS

The surveys and state-of-art review activities served as the data base for an assessment of existing signing standards and as input to the problem analysis and solution development. Standards were not satisfactory because of latitude and questions of applicability and effectiveness. A driver-centered human factors analysis was performed to develop standards for each configuration because a single treatment was not possible. The analysis was based to a large extent on driver expec-

Figure 1. Types of exit lane drops.

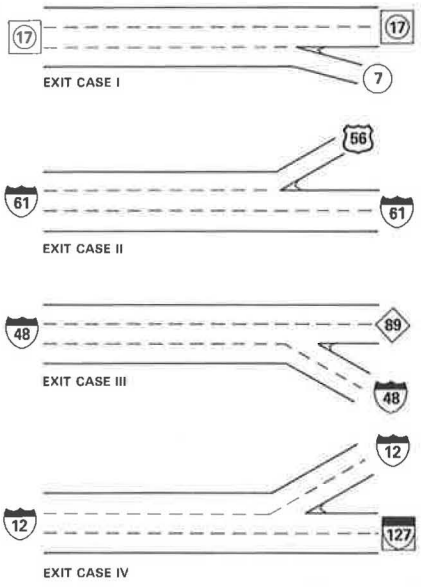


Figure 2. Types of splits.

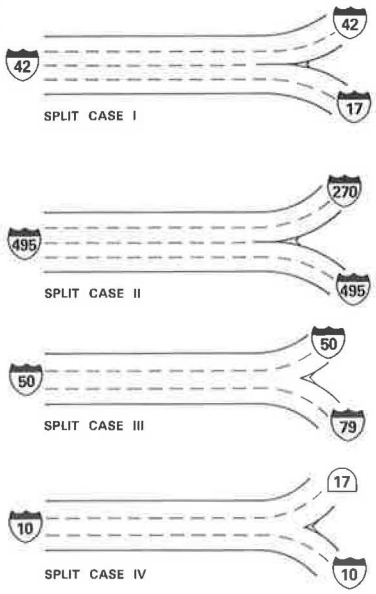


Table 1. Interchange lane drop categorization.

Type of Through Route	Geometric Design	Type of Exit	Type of Split
On main line	Right exit lane dropped	1	
	Left exit lane dropped	2	
On ramp	Right exit lane dropped	3	
	Left exit lane dropped	4	
On left leg	Split without optional lane		1
	Split with optional lane		3
On right leg	Split without optional lane		2
	Split with optional lane		4

Table 2. Mean responses of OTO personnel on applicability of EXIT ONLY treatment.

EXIT ONLY Panel	Exit Lane Drops		Splits			
	Type 1	Type 3	Type 1	Type 2	Type 3	Type 4
Should be applied	32.0[a]	11.3[b]	15.1	12.2[b]	14.5	14.7
Should not be applied	5.0[a]	25.7[b]	21.9	24.8[b]	22.5	22.3

Note: Number in sample was 37.
[a]Significant at 0.01 level. [b]Significant at 0.05 level.

Figure 3. Typical EXIT ONLY treatment.

Figure 4. Variation in arrow treatment.

Figure 5. Variation in message.

tancies and the effects of their violations. Recommendations for MUTCD standards have been made for all types and submitted for approval. It is beyond the scope of this paper to discuss all eight types. Exit types 1 and 2 are presented to illustrate methodology and treatments.

Figure 6. Variation in location.

Table 3. Interchange expectancies and concomitant violations upstream of interchange.

Characteristic	Expectancy	Typical Concomitant Violation
Design	Exit configuration	Split, directional
	Off-ramp on right	Left exit
	Movement to deceleration lane	Exit lane drop
	Single egress	Multilane, split
	All lanes continue	Exit lane drop, split
	Selected lane leads to choice	Optional lane
Route	Route and facility coincide	Through-route on ramp, off-route on main line
	Off-route to right of through-route	Left exit, split with off-route on left leg
	Choices identified	Route not signed, destinations not signed

Table 4. Interchange expectancies and concomitant violations at interchange.

Characteristic	Expectancy	Typical Concomitant Violation
Design	All movements on clearly defined path	Off-facility path unclear, through-facility path unclear
	All movements free from conflicts	Weaving sections
Route	Route and facility coincide	Through-route on ramp, off-route on main line
	Choices identified	Route not signed, destinations not signed
	Agreement between advance and exit direction signs	Disagreement

Expectancies

Expectancy relates to a driver's readiness to respond to common situations in predictable and successful ways. It affects the speed and accuracy of a driver's information handling, decision making, and response. Ordinary situations reinforce expectancies and help drivers respond rapidly and correctly. Unusual, unique, and uncommon situations violate driver expectancies. They may cause drivers to take longer to respond properly or cause them to respond poorly or commit errors (10).

Most freeway interchanges are sufficiently similar to cause drivers to develop a set of expectancies related to common geometric design and route characteristics. They are part of the deductive knowledge that drivers bring into the driving task. Common interchange expectancies and typical concomitant violations are given in Table 3 at locations upstream of the interchange where the interchange is not visible and where advance signing is either not present or not visible or, if visible, is ground mounted. Table 4 gives a summary of expectancies and typical concomitant violations in the vicinity of the interchange when its geometric design is visible.

Expectancy Violations

The driving task when one approaches and negotiates an interchange is usually complex and demanding even when expectancies are reinforced by usual geometric and route

Figure 7. Signing for exit type 1.

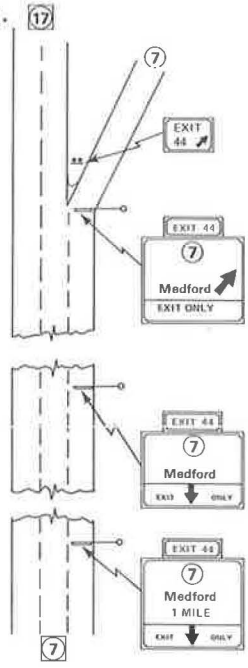


Table 5. Deductive expectancy violations.

Type of Exit	Description	Characteristic	Expectancy	Violation
1	Right exit lane drop, off-route on ramp	Design	Movement to deceleration lane to leave facility	Right lane becomes ramp
			All lanes continue beyond interchange	Right lane terminates at ramp
2	Left exit lane drop, off-route on ramp	Design	Off-ramp on right	Left off-ramp
			Movement to deceleration lane to leave facility	Left lane becomes ramp
			All lanes continue beyond interchange	Left lane terminates at ramp
		Route	Off-route to right of through-route	Off-route on left ramp

characteristics. The potential for overload, confusion, and driver error is greatly increased by configurations that violate expectancies. Effective signing aids the driver's task by warning him of unexpected situations and restructuring expectancies.

Expectancies that a driver holds before seeing interchange geometry or signing may be modified or restructured by their appearance. Design features provide information that the driver continually uses. Drivers generally believe what the roadway and its environment seem to be telling them when geometric design is consistent with their expectancies and have difficulty when their expectancies are violated. Signing should always match and augment design to be credible and effective. Exit lane drops with route discontinuity (exit types 3 and 4) and optional lane splits (split types 3 and 4) present credibility problems because signing can never fully match design. Exit types 1 and 2 also violate expectancies. However, properly designed signing treatments are both credible and effective for these cases because, after expectancies are restructured, they match the interchange geometrics.

Table 5 gives the expectancies violated by the geometric and route characteristics in exit types 1 and 2. These are the expectancy violations that the driver must be warned of at advance guide sign locations upstream of the interchange.

At these locations, when geometric and route characteristics are likely to be neither visible nor apparent, it is important to gain driver's attention, warn them of an unexpected situation, and restructure violated expectancies.

Affected Drivers

Interchange lane drops cause some drivers to perform unexpected and unusual maneuvers. Interchange lane drop signing treatments are intended for those drivers whose expectancies are violated. Drivers can be grouped into two broad categories: those who are familiar with the facility and routes and those who are unfamiliar with the facility and routes. The familiar group generally constitutes the majority of the traffic stream, particularly during peak periods. Unusual features of an interchange lane drop do not violate their expectancies. The unfamiliar group is the primary target group for interchange lane drop signing. The unfamiliar group includes local strangers who are somewhat familiar with the area and complete strangers who are driving the route for the first time. A recent study (11) shows that nearly all strangers have a trip plan prepared from available road maps. Drivers sampled by the study judged route choices as the most important information need. When approaching an interchange, strangers would not know geometric design but would have a trip plan and would want to (a) change routes to the off-route or (b) stay on the through-route.

Synthesis

All elements of the problem analysis were combined to identify expectancy violations that required restructuring and information needs that had to be satisfied for unfamiliar drivers. A synthesis was accomplished for each type of interchange lane drop as a function of lane position and trip plan. It was performed for advance locations and for the proximity of the interchange.

The synthesis for exit type 1 showed that, upstream of the interchange, the driver changing lanes is largely unaffected by the lane drop feature. He or she primarily needs route choice (destination, exit number) information. Because the driver expects the exit to be on the right, he or she will tend to be in the right lane and does not need to be told that the exit is on the right. The driver should be told, however, that the interchange geometrics will not require a change to a deceleration lane. This should be followed up at the interchange by information telling where the egress is from the facility. Through-route drivers are most affected by the terminated lane. If they are in the right lane, which they expect to continue, they must be warned that it will not continue. This should be accomplished upstream of the gore area to minimize chances of their being pulled off the route and the facility and to minimize turbulence brought about by last-minute lane changing. Similarly, through-route drivers in other lanes should be told to stay out of the right lane. This information should be repeated at the exit direction location to confirm information presented upstream.

The synthesis for exit type 2 showed that its associated geometric and route expectancy violations affect all unfamiliar drivers in all lanes. Drivers who want to change lanes need route choice information. They also need to know that the off-route is to the left of the through-route because they expect a right-hand exit. Drivers cutting across several lanes of traffic from right to left to take the exit are a consequence of not restructuring these expectancies. At both the advance guide sign and exit direction sign locations, drivers must be told that the left lane is the proper lane for changing routes. They also need to know that the interchange geometrics will not require a change to a deceleration lane. Through-route drivers must be warned that the left lane, the traditional through lane, is the exit lane so that they can leave it if they are in it and stay out of it if they are in the adjacent lane.

RECOMMENDED SIGNING TREATMENTS

Data developed by the program were used to develop a set of recommended treatments. These treatments were empirically evaluated by the FHWA and were found to be effective in restructuring driver expectancies. Recommended changes to the MUTCD are summarized for exit types 1 and 2.

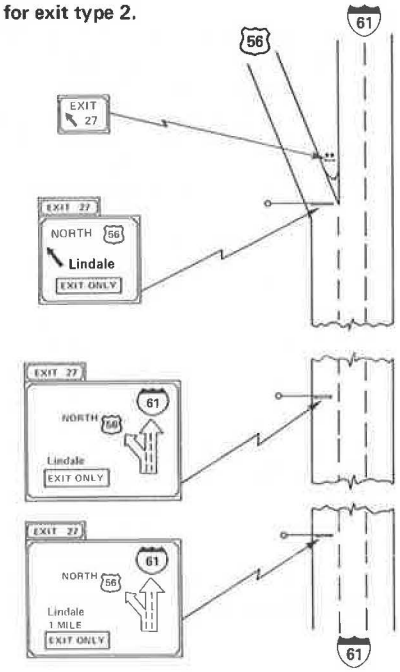
Exit Type 1

Because of the importance of proper signing, it was recommended that advance and exit direction signs be overhead mounted for all interchange lane drops. Analytical and empirical evidence shows the EXIT ONLY treatment to be effective for exit type 1 lane drops when applied consistently and uniformly. It was recommended that its use be made mandatory for all guide signs in the exit type 1 sequence.

Analysis of arrow style requirements shows that down arrows should be required for advance guide signs and upward sloping arrows should be required for overhead exit direction signs. The down arrow on advance guide signs serves to provide lane assignment, a primary information need for all drivers upstream of the gore. On overhead exit direction signs, an upward sloping arrow providing exiting drivers with "here it is" information is most important because lane assignment information has already been provided on the advance guide signs.

Analysis of distance information needs shows that, for the two advance guide signs case, the first advance guide sign is analogous to the first advance for a conventional exit; both off-route and through-route drivers need "where it is" information (displayed by distance information), and "what it is" information (displayed by EXIT ONLY). The second advance guide sign, which is the only advance guide sign in the single advance sign

Figure 8. Signing for exit type 2.



case, is usually located 0.8 km (0.5 mile) or less from the interchange. Safe and efficient operations require that all lane changes occur upstream of the gore. Because the EXIT ONLY panel, in the absence of distance information, implies immediacy, it will lead to desirable lane changing at an advance location for through-route drivers in the right lane and exiting drivers in the adjacent lanes. Distance information therefore should not be provided at this location because it may give drivers the impression that they can delay their decision. This could lead to undesirable lane changing in the vicinity of the gore. Recommended signing treatments for exit type 1 are shown in Figure 7.

Exit Type 2

The evidence showing the effectiveness of diagrammatics for configurations where the off-route is to the left of the through-route led to the recommendation that a diagrammatic treatment should be used as the standard for exit type 2 (9). Recommendations were in accordance with criteria for diagrammatics at left-hand exits: Diagrammatic treatment is used at the advance guide sign locations and conventional exit lane drop signing (as used in exit type 1) is used over the left lane on the overhead exit direction sign. Because the EXIT ONLY treatment was shown to have the attention-gaining characteristics required by the lane drop situation, its use without a down arrow was recommended along with the diagrammatics. Figure 8 shows the recommended signing.

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REFERENCES

1. Study of the Black-on-Yellow "EXIT ONLY" Freeway Signing. Traffic and Safety Division, Michigan Department of State Highways, May 1963.
2. Manual on Uniform Traffic Control Devices. Federal Highway Administration, 1971.
3. E. J. Tye. The Lane Drop Study (Relating Roadway Elements to Accidents). California Division of Highways, Sacramento, Rept. HPR 1(5), B-1-11, Oct. 1968.
4. D. Cornette. Operational Characteristics of Lane Drops. Kentucky Department of Highways, Frankfort, Rept. KYHPR-70-63, HPR-1(8), Part 2, Aug. 1972.
5. Freeway Lane Drops. NCHRP, Project 3-16, final rept.
6. W. J. Roth and F. DeRose, Jr. Interchange Ramp Color Delineation and Marking Study. HRB, Highway Research Record 105, 1966, pp. 113-125.
7. J. G. Pigman and K. R. Agent. Raised Pavement Markers as a Traffic Control Measure at Lane Drops. Kentucky Department of Transportation, Frankfort, Rept. KYP-73-48, HPR-1(9), Part 3, Feb. 1974.
8. E. Johnson. Lane Drop Signing—Yellow Panel Messages. Office of Traffic Operations, Federal Highway Administration, Aug. 9, 1972.
9. T. M. Mast and G. S. Kolsrud. Diagrammatic Guide Signs for Use on Controlled Access Highways. Federal Highway Administration, Rept. FHWA-RD-73-21, Dec. 1972.
10. G. J. Alexander and H. Lunenfeld. Satisfying Motorists' Need for Information. Traffic Engineering, Vol. 43, No. 1, Oct. 1972, pp. 46-70.
11. G. F. King and H. Lunenfeld. Urban Guidance: Perceived Needs and Problems. TRB, Transportation Research Record 503, 1974, pp. 25-37.