5. It is estimated that, after one accounts for drivers who are unlikely to follow signposted routes, the potential savings in Great Britain are at least £180 million/year and could be £700 million/year if 86 percent of drivers continue to follow the direction signs.

6. The cost of modifying signs throughout Great Britain to conform to the idealized set is estimated to be at most £70 million at 1979 prices (in 1979, £1 = U.S. $2.12). This implies that, even if there are gross errors in the estimates, an investment in improving the accuracy and consistency of direction signs is likely to be one of the most worthwhile transportation investments that can be made at the present time in Great Britain. It should also be noted that the savings in fuel costs or accidents alone can more than justify the investment based on normally accepted rates of return.

QUESTIONS THAT REMAIN

There are obvious and perhaps important deficiencies in the work we have done. We have not studied important questions of policy. For example, the requirement that forces heavy lorries to use a bypass rather than drive through the center of a small town has been ignored in creating the idealized set of minimum-cost signs. Some of these questions will be answered in a new study that is just commencing and that will examine the practical problems associated with installing the idealized signs and the policy issues this raises.

On the other hand, the results that have been obtained are sufficient to raise questions about existing signing practices and policies, not only in Great Britain but also in other countries. We have no doubt that there are substantial savings to be made by improving the accuracy and consistency of information on direction signs. Achieving accuracy and consistency requires a review of existing standards (for example, what names and route numbers should appear on signs and to what extent). It also requires more discipline in determining the content of signs than is obtained from "back-of-the-envelope" designs, a phrase that we have all too frequently heard in discussions.

ACKNOWLEDGMENT

The results reported in this paper are taken from a research contract sponsored by the U.K. Department of Transport. The views expressed, however, are ours alone and do not necessarily represent those of the Department of Transport.

The SIGNPOST suite of programs discussed in the paper was developed by Wootton, Jeffreys, and Partners and has been purchased by the Department of Transport for use throughout the United Kingdom.

REFERENCES

1. Transport and Road Research 1976: Annual Report of the Transport and Road Research Laboratory. Her Majesty's Stationery Office, London, England, 1976.
2. C.C. Wright and H. Orrom. The Westminster Route Choice Survey: A New Technique for Traffic Studies. Traffic Engineering and Control, Aug.-Sept. 1976, p. 348.
3. Inter Urban Route Choice Study. Planning and Transport Research and Computation, Ltd., London, England, 1975.
4. V.E. Outram and E. Thompson. Driver Route Choice. In Transportation Models, Proc., Summer Annual Meeting, Planning and Transport Research and Computation, Ltd., London, England, Vol. P 153, 1977, pp. 114-121.
5. V.E. Outram and E. Thompson. Drivers' Perceived Cost in Route Choice. In Transportation Models, Proc., Summer Annual Meeting, Planning and Transport Research and Computation, Ltd., London, England, Vol. P 168, 1978, pp. 226-257.
6. Traffic Signs Manual. Her Majesty's Stationery Office, London, England.
7. Wootton, Jeffreys, and Partners. Effectiveness of Existing Signposts: Stage 2. Traffic Engineering Division, U.K. Department of Transport, Aug. 1979.
8. D.J. Jeffrey and N.B. Taylor. The Potential of Improved Route Guidance. In Highway Planning and Design, Proc., Summer Annual Meeting, Planning and Transport Research and Computation, Ltd., London, England, Vol. P 184, 1979, pp. 123-144.

Publication of this paper sponsored by Committee on User Information Systems.

Experimental Evaluation of Delineation Treatments for Special-Use Lanes

RICHARD F. PAIN AND BEVERLY G. KNAPP

Results of a laboratory evaluation of 18 buffer-zone treatments designed to delineate special-use lanes on highways and arterials are reported. A slide presentation using a paired-comparison technique and a questionnaire were administered to 40 drivers to determine whether various delineation designs had any inherent permissive or prohibitive meaning and effect for driver entry into a given lane. The impact of several design parameters on the prohibitiveness and permissiveness of the various designs was evident: Any design that had repeated openings was clearly more permissive than treatments that included a continuous line, the stroke width of lines appeared to be relatively ineffectual, and colored treatments were somewhat more prohibitive than white ones, though by relatively small amounts. Questionnaire data were collected to supplement the paired-comparison data, and a Spearman rank correlation coefficient of r_s = 0.93 indicated that the results of the two methods were highly complementary. Several design characteristics, including delineation width, effect of spacing or density of design symbols, and driver perception of where the vehicle can be stopped relative to the delineated special-use lane, require further definition and study.

The research reported in this paper is concerned with the experimental evaluation of delineation treatments that might be used to separate a concurrent-flow special-use lane from the general lanes of traffic. In recent years, in order to improve the speed and capacity characteristics of high-occupancy vehicles (HOVs), one (or more) general traffic lanes have been designated for the use of these vehicles either full time or only during peak travel hours (1). Since many of these lanes operate as special HOV lanes for one part of the day and then revert to more general use during the remainder, the delineation must be useful under both operating conditions.

Delineation schemes are, of course, usually secondary to information provided by posted signing (2). The focus of this research was to determine whether adequate directions for vehicle entry or nonentry can be conveyed to drivers by HOV delineation treatments alone, without signing. This allows system designers to establish what delineation can best be coupled with signing in presenting information about HOV operation to road users.

Table 1. Delineation designs tested.

Treatment No.	Type	Illustration
1	Conventional dash	
2	Wide dash	
3	Broken-solid combination (white)	
4	Double dash (white)	
5	Conventional dash and MUTCD diamond (15-ft line, 25-ft gap), diamond every 1000 or 500 ft	
6	Diamond with solid line (white)	
7	Design 5 with filled-in (solid) diamond	
8	Diamond with dash line (white)	
9	Diamond with connecting line (white)	
10	Diamonds only	
11	Diagonal crosshatch (left slant)	
12	Diagonal crosshatch (right slant)	
13	Design 2 in bright yellow-green	
14	Design 2 in light blue	
15	Design 7 in bright yellow-green	
16	Design 7 in light blue	
17	Design 9 in bright yellow-green	
18	Design 9 in light blue	

EXPERIMENTAL METHOD

Experts on the research staffs of BioTechnology, Inc., and the Institute for Research, State College, Pennsylvania, initially developed ideas on candidate delineation designs. The resulting ideas were critiqued from several perspectives--e.g., space and application requirements, potential meanings, and conflicts in driver expectancy with other signs, markings, or symbols. Fifteen markings survived this initial critique and were submitted to the Federal Highway Administration (FHWA) for review and comment. Based on suggestions from FHWA, 11 designs were finally chosen for experimental testing. Variations on several of these designs, such as color coding, brought the total number to 18 (see Table 1).

Figure 1. Sample stimulus pictures used in laboratory evaluation of delineation treatments.

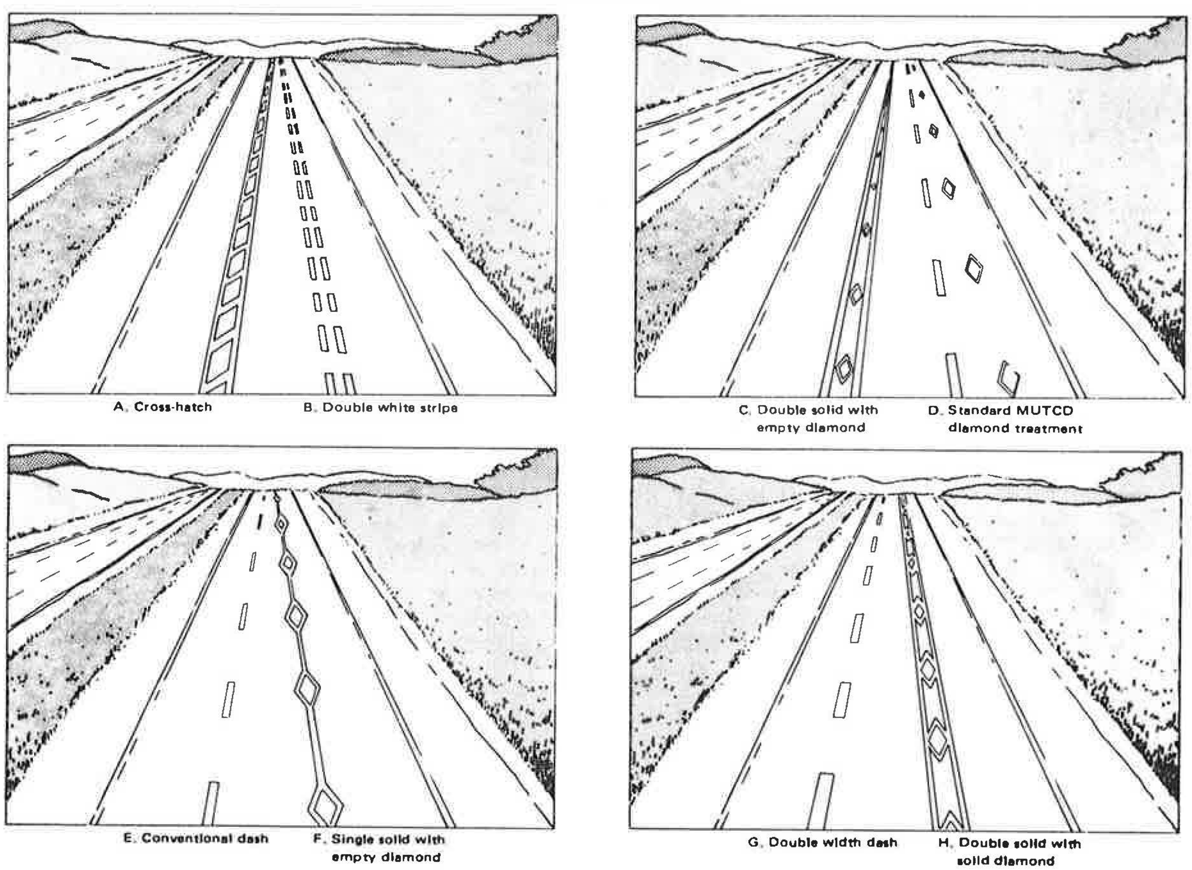

Table 2. Scale values obtained for delineation treatments.

Questionnaire Rank	Paired-Comparison Rank	Treatment No.	Paired-Comparison Scale Value[a]
2	1	1	1.3
			1.2
4	2	2	1.10
5	3	14	1.00
			0.9
1	4	13	0.8
			0.7
6.5	5	10	0.6
3	6.5	4	0.5
6.5	6.5	8	0.5
			0.4
			0.3
			0.2
			0.1
9	8	9	0.05
8	9	3	0
14	10	5	-0.1
10	11	17	-0.2
11	12	18	-0.3
			-0.4
12	13	6	-0.5
17	14	7	-0.6
13	15	16	-0.7
15	16	15	-0.8
16	17	12	-0.9
			-1.0
18	18	11	-1.1
			-1.2
			-1.3

Note: Spearman rank correlation $r_s = 0.93$.
[a]From most permissive to most prohibitive.

Each of the buffer-zone treatments was drawn on a clear acetate sheet. These sheets were laid on an artist's rendering of a three-lane freeway-type roadway. (The examples shown in Figure 1 are greatly reduced and, unlike the originals, are not in color.) Treatments were photographed in pairs so that every design was seen with every other design on a slide. Placement on the left or right side of the roadway picture was random. The resulting 35-mm slides were shown to groups of 10 subjects by means of a tachistoscope with 1-s presentation and a 5-s interstimulus interval. Since this was a study of inherent, not associative, meaning, no mention was made of special-use lanes.

In the first part of the experiment, the following instructions were given:

> Imagine that you are driving down the center lane of an ordinary three-lane highway (slide 1) when suddenly you see that something is blocking your way (slide 2). You must now make a choice, to go into the right lane or the left lane, in order to get by. For each of the following slides, please mark "right" or "left" to show which you think is the lane to take to get around the blockage. Don't be concerned with what is actually blocking your center lane; all we wish to know is which lane you feel you should take in each slide, right or left. There is no traffic behind you to worry about.

Subjects then indicated on a response sheet whether they would go around the truck (included in the stimulus picture) in the center lane by using either the left or the right lane. This is an applied use of the classical forced-choice paired-comparison technique described by Guilford (3), in which subjects must select one alternative over another in each stimulus presentation.

In addition to the paired-comparison experiment, each delineation treatment was shown alone, and subjects checked which of six driving behaviors was appropriate for that delineation or buffer-zone treatment. The following instructions were given here:

> Imagine you are still driving down the center lane as before. You notice a different stripe pattern on your right. Seeing this, please check all the statements that best describe the right lane to you.

The six statement choices provided and the percentage response to each for each delineation treatment are described later in this paper.

Forty subjects, aged 18 to 62, male and female, from the State College, Pennsylvania, area participated in the study. Each experimental session of 153 paried-comparison trials and 18 questionnaire trials lasted 30-40 min.

EXPERIMENTAL ANALYSES AND RESULTS

Paired-Comparison Data

Paired-comparison data were first summarized in a table of proportions, and then traditional scale values were calculated. Table 2 gives the scale and the position of each treatment. This procedure is described in detail by Guilford (3). Scale numbers are quite arbitrary--i.e., they could be transformed to all positive, all negative, times 100, etc.--but the distances between values are meaningful. For example, a standard dash line (scale value $\simeq$ 1.3) is twice as permissive as a line of diamonds (scale value $\simeq$ 0.6).

The impact of several design parameters, in relation to the prohibitiveness or permissiveness conveyed to subjects by the delineation treatments, can be seen in the scale in Table 2. First, any treatment that has repeated openings in the design--e.g., dashes or skips--is clearly more permissive than treatments that include a continuous or broken line. This appears to be a general design principle that is relatively unaffected by the specific pattern of symbology used.

An experiment on the I-95 priority lane in Miami provides supporting evidence for the laboratory findings (4). Over a 2.5-mile portion of that facility, a solid white lane line was used and then replaced with a standard dash. There were significantly greater weaving and higher rates of lane violation with the dash than with the solid line. This suggests that the differences found in the laboratory in subjects' reactions to dash and solid patterns will apply, at least to some degree, in an operational setting.

Width of line appears to have relatively little effect. The double-width dashes in treatments 3, 13, and 14 were less permissive than a standard dash but clearly less prohibitive than any other treatment. Whereas this one finding would usually not be considered conclusive, it is in complete agreement with the findings from the experiments with a priority bus-carpool lane on I-95 in Miami. In that project, 4-in and then 8-in skip lines were used to separate the general lanes from the priority lane over a 2.5-mile section of the roadway. For the three measures of effectiveness--weaving, lane-violation rate, and travel time--there were no differences between the two stripe-width conditions. Given the consistent laboratory and field results, further investigation of stroke width in buffer-zone design would not appear to be productive. These findings, however, do not fully explore the issue of

Table 3. Percentage response to questionnaire statements for each delineation treatment.

Treatment No.	Response (%) Pass and Travel Freely	Turns and Exits only	Repair or Emergency Lane	Special-Use Lane	Do Not Use	Don't Know
1	75	7	7	2	2	7
2	62	11	7	2	7	11
3	26	36	14	0	5	19
4	62	21	2.5	2.5	2.5	9.5
5	9.3	11.6	11.6	21	18.6	27.9
6	13.6	9.2	20.4	9.2	27.2	20.4
7	2	6	22	22	22	26
8	30.9	40.5	9.5	0	0	19.1
9	20	27.5	17.5	7.5	2.5	25
10	41.5	22	12.2	2.4	2.4	19.5
11	2.4	4.8	17.1	17.1	39	19.5
12	10	16	24	18	18	14
13	75	12.5	2.5	0	0	10
14	52	10.9	17.4	8.7	2.2	8.7
15	2.5	2.5	17.5	32.5	15	30
16	4.6	11.6	23.3	23.3	11.6	25.6
17	19	30.9	12	9.5	0	28.6
18	20.9	20.9	18.6	16.3	0	23.3

buffer-zone width, and further study of this will be required.

The impact of color was studied by including three buffer-zone treatments (treatments 2, 7, and 9) in different colors: white, light blue, and bright yellow-green. The relative positions of the colored designs on the scale in Table 2 show that (a) there is no consistent difference between light blue and bright yellow-green in meaning and (b) colored treatments were consistently more prohibitive than white treatments but by relatively small amounts. This suggests that color can be included in a buffer-zone design without drastically changing the prohibitiveness or permissiveness of a treatment.

Finally, the solid versus outline diamond design resulted in relatively small but consistent differences. The seven treatments in which diamond outlines were used were all more permissive in meaning than the three treatments in which solid diamonds were used. Since, however, this was not a completely factorial analysis and all treatment combinations (such as solid diamonds in a dash pattern) were not studied, this finding should be tested more extensively.

Questionnaire Data

In part 2 of the experiment, subjects were shown each delineation treatment and were instructed to choose which of the following questionnaire statements best describe the right lane:

1. I can enter the right lane for passing and travel as I wish.
2. I can enter the right lane for turns or exit ramps only.
3. I would enter the right lane for emergency repairs.
4. I should not use the right lane; it is reserved for special vehicles.
5. I should not use the right lane at all.
6. I have no idea whether I can enter the right lane or not.

The responses to the questionnaire were tabulated by treatment. Table 3 gives the resulting percentage response.

Since the six questionnaire alternatives for each treatment formed a loose scale or continuum, ranging from open or general use to assorted restrictions to "I cannot use the lane" and "I don't know", a weighted mean was calculated for each treatment. The number of the statement (1, 2, etc.) was multiplied by the frequency. These numbers were summed across responses for each treatment, and the total was divided by N to give a weighted mean. The lower the weighted mean, the more permissive was the meaning of the delineation treatment. Finally, the treatments were ranked from most to least permissive. These ranks appear next to the paired-comparison ranks in Table 2. A Spearman rank correlation of $r_s = 0.93$ indicates that the results from the two different measurement methods are highly complementary.

The questionnaire data supplement the paired-comparison data in several ways. Any treatment with a skip was seen as "restricted to special vehicles" or "not to be used" by very small percentages of the respondents. All treatments with a solid or continuous line or pattern elicited a higher rate of "restricted, I cannot use" responses; however, a relatively high percentage (12-25 percent) of respondents thought that the other side of the buffer zone could be used to stop for repairs. A much smaller percentage (2.5-17 percent) of respondents would stop on the other side of a dashed treatment. Further work on how drivers perceive where they can stop their vehicles is necessary before final buffer-zone design recommendations can be made.

Color had no strong impact on the perceived meaning of the designs. Blue tended to be associated slightly more with a reserved or special-vehicles-only meaning, and bright yellow-green with "can cross for turns and exit ramps". Based on the paired-comparison and questionnaire results, color appears to play a very secondary role in determining subjects' responses to buffer-zone designs.

Similarly, the paired-comparison finding regarding solid versus outline diamonds was supported by questionnaire results. Thus, a solid diamond appears to imply a more prohibitive meaning than an open diamond.

CONCLUSIONS AND RECOMMENDATIONS

As a result of the laboratory evaluation reported here, the following conclusions can be drawn:

1. The various delineation designs tested do vary in terms of prohibitiveness and permissiveness of meaning.

2. Dash or skip designs are more permissive in interpretation than continuous designs, regardless of the symbology used.

3. Solid (or filled) diamonds appear more prohibitive than diamond outlines.

4. Line stroke width appears to have little impact on subjects' reactions to buffer-zone designs.

5. Color tends to add a degree of prohibitiveness to design meaning but generally is a secondary determinant of subject response.

6. The paired-comparison forced-choice and questionnaire techniques provide different types of information about buffer-zone design, and the data are highly complementary, resulting in a Spearman rank correlation of $r_s = 0.93$.

7. Several design characteristics must be further defined before design recommendations can be advanced. Included are delineation-zone width, effect of spacing or density of symbol (rungs in crosshatch), and driver perception of where a vehicle can be stopped relative to the delineated zone.

8. Any design recommendations emanating from laboratory study should be evaluated in an operational setting.

ACKNOWLEDGMENT

The research reported in this paper was conducted by BioTechnology, Inc., under contract to the Federal Highway Administration. Alfred Klipple of the Traffic Systems Division, FHWA Office of Research, served as contract technical manager. The Institute for Research, State College, Pennsylvania, was subcontractor.

REFERENCES

1. J. H. DuPree and R. H. Pratt. A Study of Low-Cost Alternatives to Increase the Effectiveness of Existing Transportation Facilities: Results of Survey and Analysis of Twenty-One Low-Cost Techniques. R. H. Pratt Associates, Inc., Silver Spring, MD, Jan. 1973.
2. R. F. Pain and others. Signing and Delineation for Special-Usage Lanes. Federal Highway Administration, U.S. Department of Transportation, Interim Rept. FHWA-RD-78-205, Vol. 1, Dec. 1977.
3. J. P. Guilford. Psychometric Methods. McGraw-Hill, New York, 1954, Chapter 7.
4. K. G. Courage and others. Traffic Control of Carpools and Buses on Priority Lanes on Interstate 95 in Miami. Federal Highway Administration, U.S. Department of Transportation, Rept. FHWA-RD-77-148, Aug. 1977.

Publication of this paper sponsored by Committee on User Information Systems.

Study of Width and Density of Delineation Design Elements for Special-Use Lanes

BEVERLY G. KNAPP AND RICHARD F. PAIN

The results of a two-part study that investigated the effects of varying roadway delineation width and the density of design elements within the roadway line on driver lane-change behavior are reported. The width study consisted of a controlled field experiment in which drivers indicated their decisions on whether to cross 1-, 2-, and 3-ft delineation treatments laid on a closed section of roadway. In the second part of the study, a laboratory experiment, the number of elements in the line design was varied by overlaying various drawings onto a highway scene and showing these slides to subjects to elicit their lane-choice responses. The designs tested were generated from previous work related to delineation treatments for high-occupancy vehicle lanes, which often operate as special-use lanes during rush hours and then revert to general use during off-peak hours. Delineation markings must thus appear prohibitive at one time and permissive at another. Width of line was found to have relatively little effect on the prohibitive or permissive meaning of delineation treatments. Density of design elements, however, was found to be an important determinant of permissiveness or prohibitiveness in that the widely spaced elements invited lane crossover more than densely spaced ones. The study findings appear to be applicable not only to delineation designs for special-use lanes but also as general design parameters in the application of roadway markings.

In a paper elsewhere in this Record, various delineation marking designs for highways and arterials were evaluated in terms of their permissive or prohibitive effects on driver lane-change behavior. These marking designs were developed for potential application as delineators between concurrent-flow, high-occupancy-vehicle (HOV) lanes and general-use traffic lanes. The intent of the study was to determine the levels of prohibitive or permissive meaning conveyed by various delineation designs by using a paired-comparison process, since the final design chosen must operate in one mode during HOV lane operation and another mode during off-peak hours (i.e., must be prohibitive to some vehicles at certain times and not at other times). The delineation treatments tested are given in Table 1.

In general, the earlier study established that dashed "skip" designs permit or elicit vehicle crossovers while solid, connected lines prohibit them. It was also found that colored lines are somewhat more prohibitive in meaning than a white version of the same configuration. The results experimentally defined some basic design parameters.

This paper discusses the effects of two other parameters--width and density of design image--that were not resolved.

The data given in Table 2 indicate how the concept of "element density" emerged from the earlier paired-comparison data. Element density is the actual number of elements, either diamonds or crosshatch strokes, within any given line segment. This concept emerged from the results of the first experiments in the form of "clusters" of delineation treatments, according to varying degrees of what subjects perceive as a "wide, thick look" versus a "thin, sparse look." Treatments 1, 2, 4, 8, 10, 13,