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Motorist Response to Guide Signing

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 3-21, conducted by BioTechnology, Inc., Falls Church, Va. Co-Principal Investigators on the project were Fred R. Hanscom and Wallace G. Berger

THE PROBLEM AND ITS SOLUTION

Much recent research has dealt with the characteristics of motorist response to various kinds of highway information systems. Assessment of the collective value of these studies has been hampered, however, by difficulties in comparing their results. Because these difficulties arise from a lack of validated measures of driver response, there are critical needs for development of suitable new measures and validation of both new measures and those that have been used in the past. Obtaining and using such a set of validated measures of effectiveness (MOEs) means that sign evaluation studies conducted by diverse organizations will have a common base and will be interpretable in widely acceptable terms. Even more important, signing standards will be more likely to be developed on the basis of definitive and generalizable research results.

This project was aimed, therefore, at conducting substantive research into the relationships among many measures of response to signs, and at defining the correlations between driver performance, attitudes, and information processing.

For practical reasons the scope of the project was limited to measures of motorist response to guide signing, specifically to signing encompassed by Sections 2E and 2F of the *Manual on Uniform Traffic Control Devices*. Furthermore, as the research results are most likely to have application within traffic engineering organizations, the project was oriented toward methods that can be implemented readily by the staffs of those agencies.

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The project did produce a methodology that will be readily implementable by traffic engineering staffs to judge the effectiveness of new guide signs. As the methodology requires only conventional equipment and procedures, the research results can be applied directly to practice and do not need to be combined with the results of other research in order to be useful. It must be noted, however, that while the measures of effectiveness will give precise indications of improved traffic performance, they may not be precise enough to evaluate the relative benefits of alternative signing improvements. It is also not clear whether the methods are generalizable beyond the traffic conditions studied (i.e., freeway guide signs) to other guide sign situations or to the design of regulatory or warning sign installations.

RESEARCH APPROACH

The present study has attempted to rectify some of the previous documented shortcomings by (1) selecting from the vast number of candidates those vehicle actions that are meaningful measures of guide sign effectiveness (MOEs) and (2) developing a set of vehicle action measures that are practical for use by operational traffic engineers. The report provides a description of each of these MOEs so that the traffic engineer can select those most appropriate to his problem and can, after collecting his data, better interpret the remedial effects resulting from his signing change. Additionally, the study also explored methods by which the traffic engineer can collect the required MOE data. The recommended methods are the ones that were found to be reliable procedures for collection of data, applicable to a variety of situations, and capable of obtaining the data with the required level of precision.

The project was conducted as a two-phase effort. Phase I primarily comprised a review and synthesis of literature to identify candidate MOEs and data collection methods. Phase II consisted of an empirical field evaluation of candidate MOEs and an assessment of the applicability of various methods to obtain MOE data.

The Phase I identification of potential MOEs and other sources of variance began with a systematic review of approximately 300 documents in the following three categories:

- Vehicle Action - refers to those candidate MOEs (e.g., vehicular speed, erratic maneuvers) used to characterize the static and dynamic orientation of a vehicle or stream of vehicles.
- Driver Information Processing - includes survey items that could be considered criteria to confirm the sign-related nature of a vehicle action (such as item detection, interpretation, preference, and information retention of a sign).
- Driver Predisposition - includes those sources of variance (such as biographical, risk taking, driver experience, preference, and comfort factors) capable of influencing a driver's response to guide signs.

The material classified as applied research was subjected to an intensive review process for the express purpose of gleaning from each article pertinent factors related to the types of measures used and their operational definition, the types of methods used, the situational content of the studies, and other characteristics. The review of the basic or theoretical literature was summarized in three papers, one for each of the measurement classes, given as Appendices A, B, and C of the project's interim report (1974); the bibliographies of these papers are included as an appendix of the final report.

Phase II of the project addressed the key issues of field evaluation of potential measures and assessment of the suitability of various methods to obtain those measures. The principal effort was a series of seven field experiments to develop and validate guide sign measures of effectiveness. Collectively, the field experiments comprised an evolutionary process of (1) an initial development of measures (both candidate MOEs and survey items) at one site, (2) testing the generalizability of the candidate MOEs across different driving populations, (3) testing generalizability of the candidate MOEs at interchanges differing in geometry, and (4) verifying the previous findings under differing sign conditions in a before-after field study.

FINDINGS

The principal findings are presented in the report in four parts. An overview first summarizes the sign-relatedness of each candidate measure, prior to a reporting of complete findings of the MOE evaluation. The second part presents a discussion of the driver factors and vehicle performances selected for evaluation in the field studies. A third part consists of the field study findings, including target behaviors (vehicle performances that are visually detectable by a human observer or time-lapse photography) and microflow vehicle performances (nonvisual traffic flow parameters) as related to driver-reported signing responses. These relations were used to develop the MOEs. The final part presents a number of methods found to be reliable for the collection of derived MOEs.

Overview of Signing MOE Evaluation

Tables 1 and 2 summarize the sign-relatedness of candidate MOEs for target behavior and microflow performance measures, respectively. Specific findings of the field studies established four checked target behaviors (shown in Table 1) as guide sign MOEs. Analysis of interview data, comparing responses of driver behavior, revealed group differences linking driver sign responses with each behavior as follows:

Gore Weave (and High-Risk Gore Weave):

- Greater sign information processing difficulty with all guide signs on interchange approach.
- Less certain of action response to all guide signs on approach.
- Less time available to read and respond to intermediate exit direction sign.
- Lower preference rating for intermediate exit direction sign.
- Less likely to detect at least one guide sign.

Driving Slowly:

- Greater information processing difficulty with at least one guide sign.
- Lower preference rating of gore-located exit direction sign.

Late Lane Change:

- Greater information processing difficulty with at least two guide signs.
- Less certain of action taken to gore-located exit direction sign and one advance sign.

Discriminant analysis was applied to distinguish between signing and other causal factors (e.g., biographical and attitude) for target behaviors. Biographical factors were often seen to outweigh signing factors in the determination of target behaviors exhibited by drivers. Results did indicate that sign responses could account for target behavior occurrences as follows: high-risk gore weaves (35 to 100 percent), gore weaves (25 to 64 percent), driving slowly (6 to 77 percent), and late lane changes (4 to 19 percent). This cited range of percentages represents the variability across three study interchanges of sign-relatedness for each observed behavior. These results were based on 1,109 field interviews of drivers who had performed the vehicle actions under study.

Certain findings of the microflow measure analysis (Table 2) served to reinforce target behavior findings. Correlations between survey responses and one microflow measure (precise exit weaving distance from the gore point) confirmed that gore weaves were more associated with sign detection and information processing difficulties than were late lane changes. A strong association was found between driver signing responses and vehicle speeds. Lower interchange approach speeds were linked with greater sign information difficulty. This tended to substantiate the target behavior, driving slowly, as a guide sign MOE. Moreover, the general increase in mean speeds that was observed with improved signing in the before-after study served to strengthen this finding. Another confirmation of the target behavior findings was that short headways were not indicative of sign response difficulties.

A number of studied vehicle actions were not shown to be suitable measures of driver guide sign response. Three target behaviors falling into this category were brakelight indications, following closely, and stopping (see Table 1). Conflicting directionalities of sign responses were observed among groups of drivers who exhibited brakelight indications. There was little evidence of any relationship between sign response and following closely. Despite the highly credible face value of stopping as a sign-related measure of driver confusion, small sample size availability and the lack of before-after sign change validation failed to produce evidence of its validity as an MOE. Available data indicated that stopping was more attributable to biographical driver characteristics (i.e., familiarity) than to sign responses. A number of microflow measures were also shown to be poor indications of driver sign responses. Certain speed-derivative measures showed either nonconclusive relationships with regard to sign responses or that observed differences were due to nonsigning factors.

Acceleration noise (minute speed changes resulting from the inability of the driver to maintain a constant speed) received special study. The primary finding was that increased variation in speed and acceleration resulted from personal conditions that affected driving. Generally weak relationships were found to exist between signing responses and selected speed derivatives, although sign detection did affect speed variance ($p \leq 0.05$). Rear-end accident potential, as derived from high relative closure speeds in combination with short headway distances, was not related to signing response.

Real-time information processing was examined using eight unfamiliar subjects in an instrumented vehicle study. The results could not be applied directly to validate target behavior causal findings of the MOE evaluation due to the small sample size and the fact that no subjects performed target behaviors. However, two compatible findings were noted. First, the relative importance of the intermediate exit direction sign was evidenced by increased eye search pattern activity in combination with higher questionnaire scores in response to that sign. Second, the fact that no test subject performed a target behavior is consistent with the higher information processing and sign preference survey scores found to characterize comparable driving behavior in the MOE evaluation.

Certain sign design implications emerged from the analysis. For example, drivers performing virtually all MOE behaviors had experienced difficulty in response to the intermediate exit direction sign. The more severe behaviors demonstrated increasingly greater driver information processing difficulty with this sign. Moreover, drivers not detecting the advance guide sign were also highly prone to experience difficulties with this sign. Significant improvement in over-all driving behavior was found in the before-after study when a conventional exit direction sign was replaced by a diagrammatic sign.

Applicable Data Gathering Methods

Lastly, the four target behaviors (gore weaves, high-risk gore weaves, late lane changes, driving slowly) found to comprise valid guide sign MOEs were applied in the development of a readily implementable sign evaluation method for use by operating traffic engineers. This methodology suggests collection methods shown to be sensitive to the MOEs, procedures for analyzing the field data, and guides for interpreting observed results in terms of potential benefits elicited by new guide signs.

Development of guide sign MOEs involved a reliability determination of several off-the-shelf methods of gathering the measures. Statistical reliabilities for each method were obtained by comparing its data with that of the Traffic Evaluator System. Recommendations for applicable methods also took into account the cost and general suitability of each method for use by a practicing traffic engineer. For the four measures found to be relevant, reliable, and sensitive for sign evaluation purposes, the following data collection methods may be used:

1. Gore weaves - Manual coding of vehicular weaves occurring in two directions (exit and through movements) over a gore approximately 600 ft (183 m) in length was found to be 98 percent reliable using 30-min coding periods with 10-min rest intervals between each, for the duration of a normal working day.

2. High-risk gore weaves - These maneuvers require tracing a vehicle's path within an interchange area; thus, time-lapse photography is recommended.

3. Late lane changes - Exit maneuvers in advance of the gore can be obtained using manual coding with equal accuracy as described for gore weaves, given that a compatible length of highway section is monitored. Yet, for lane changing maneuvers in advance of the gore, which require monitoring of longer sections of highway, manual coding was only 88 percent accurate. Therefore, the recommended method for gathering data on these maneuvers is to deploy a time-lapse camera in advance of the interchange and position it so as to permit lane changing to occur in the foreground of the field of view. The camera operator can then manually code gore weaving, providing ample coverage of all weaving maneuvers in the entire interchange approach.

4. Speed measurements - Stopwatch timing of vehicles between two inconspicuous roadway markings is an inexpensive, unobtrusive, and reasonably accurate method of gathering vehicle speeds. A currently available digital-display stopwatch (costing about $100) that displays time increments to the nearest 0.01 sec was found to gather speed data reliably with an accuracy of 1.1 mph for any given vehicle. Furthermore, sample means were obtainable with no significant error using this type of stopwatch.

Time-lapse photography was suitable for gathering vehicle speeds with 2-mph accuracy under certain filming conditions (e.g., depending on camera vantage point). By using film exposure rates of 8 and 12 frames per second and roadway marker spacings of 5 to 10 ft, obtained mean speeds were not significantly different from those gathered using the Traffic Evaluator System.

APPLICATION OF FINDINGS

Four candidate MOEs have been both evaluated and validated as direct measures of motorists' responses to guide signs, and reliable data collection methods have been determined for each. The application of these findings suggests a methodology by which operating traffic engineers can evaluate guide signs.

Sign Evaluation Approach

Operating traffic engineers are bound by numerous practical constraints in the conduct of signing studies. The sign evaluative procedure reported here specifically recognized the following constraints:

1. Data collection methods. Most traffic engineers do not have at their disposal sophisticated roadway instrumentation equipment capable of gathering highly detailed performance data on very large vehicle samples. Therefore, suggested methods are restricted to generally available off-the-shelf data collection equipment not requiring any developmental effort.

2. Observations limited to vehicles. Due to cost, operational constraints, and collection method limitations, traffic engineers generally restrict their data to measurable aspects of vehicular behavior. This restriction makes it impossible to collect several types of potentially useful data (e.g,. driver population definition, driver information needs). It is noteworthy that local versus nonlocal driver designation by license plate observation is often confounded in locations with highly transient populations and by the presence of the "local stranger." Therefore, suggested MOEs are comprised of readily observable and nonambiguous measures of vehicle behaviors.

3. Time, money, and manpower. These constraints limit the scope of traffic engineering study. Therefore, suggested procedures consist of minimum data collection time requirements to obtain the necessary sample size and low-cost, sensitive data collection methods requiring minimal field operation and data reduction effort.

Sign Study or Experiment?

The report points out the difference between a study (the examination of effects at the specific sign site) and an experiment, which entails the need for control sites and stronger design to ensure that observed changes in traffic behavior are indeed sign-related and generalizable. Procedures are suggested for experimental design, data collection, data analysis, and interpretation of results. Figure 1 conveniently summarizes not only the use of the validated MOEs in before-after investigations but also the range of expected outcome that may be derived from improvements in guide signing.

Table 1

Overview of Signing MOE (Target Behavior) Evaluation

MOE EVALUATION STEPS		TARGET BEHAVIOR: High Risk Gore Weave	Gore Weave	Drive Slowly	Late Lane Change	Brakelight Indication	Stop/ Backup	Follow Closely
Target vs. Nth Driver Differences	DETECTION			20	20	50		
	INTERPRETATION		67		20			
	PREFERENCE	50	67	60	20		33	50
	INFORMATION PROCESSING			80	60	50	67	
PERCENT SIGN-RELATED		33-100	25-54	6-77	4-19†	7-64	64††	
Validation	BEFORE-AFTER STUDY	✓	✓	✓	✓			
	KOLSRUD DATA BASE	✓	✓	✓	✓	N.A.	N.A.	

† Higher in absence of painted gore.
†† Generalizability unknown due to insuffient sample.

Note: For Kolsrud data base see Kolsrud, G. S., Diagrammatic guide signs for use on controlled-access highways. Vol. III - Traffic engineering evaluation of diagrammatic guide signs, Part 3 - Synthesis and Conclusions. Prepared by BioTechnology, Inc., for Federal Highway Administration, Washington, DC, December 1972.

Table 1 denotes the results of three valuations of each target behavior. First, survey response differences obtained between groups of drivers performing target behaviors and those performing none (Nth drivers) are depicted in the top portion of the table. Heavily shaded cells denote statistically significant differences in all of the experiments where a target behavior was studied; non-shaded cells indicate that no statistical differences were found. Lightly shaded cells signify mixed results, with the percentage of experiments where differences were observed indicated in the cell. Second, the percentage of each target group correctly identified, on the basis of signing responses, as performing the behavior using a discriminant analysis technique is listed next in the table. Finally, those target behaviors validated in the before-after study are indicated in the bottom portion of the table. Additionally, those target behaviors that were verified by the findings obtained in a pre-existing data base are also noted in the table.

Columns in the table represent target behaviors in approximate descending order of their sign-relatedness.

Table 2

Overview of Signing MOE (Microflow Performance) Evaluation.

	Microflow Vehicle Performance	Sign Response: β Detection	β Preference	β Info. Proc.	R^2	Validation
Basic Flow Characteristics	Exit Weave Distance from Gore Point	O		O	●	✓
	Merge Gap Acceptance Length	O			O	
	Mean Speed	O	O	⊠ O	O	✓
	Speed, 200′ from Gore Point	O		⊠ O	●	✓
	Speed, 800′ from Gore Point	O		⊠ O	●	✓
	Distance Driving Slowly	O			●	
	One Second Headway Violations	●			O	
	Two Second Headway Violations	O			●	
Flow Perturbance Factors	Point of Maximum Front Closure Speed	O		⊠	O	
	Point of Maximum Rear Closure	O		⊠	O	
	Point of Maximum Speed Change	O	O		●	✓
	Point of Maximum Acceleration Change	●		●	●	
	Size of Maximum Speed Change			O	O	✓
	Size of Maximum Acceleration Change		O	⊠ O	O	✓
	Acceleration Variance		O	O	O	✓
	Speed Variance		O	⊠	●	
Rear-end Accident Potentials	Maximum Front Accident Potential				O	
	Sum of Front Accident Potentials		O		O	
	Front Closure Speed				O	
	Maximum Rear Accident Potential	⊠ ●			O	
	Sum of Rear Accident Potentials	⊠ ●			●	

LEGEND:

●=Significant Correlation obtained at two sites.

O=Significant Correlation obtained at one site.

⊠= β ranked first among sign responses at two sites.

NOTES:

β indicates contribution of sign response toward the prediction of the microflow measure.

R^2 indicates relationship between sign responses.

Table 2 depicts findings obtained from correlation analyses between sign-related survey responses and 21 microflow performance measures that were found to be systematically related across sites to driver information processing of signs. The table shows the significance of correlations between on-road performance and each sign-related survey response (detection, preference, and information processing) as well as the overall correlation, R^2, with all three responses. Additionally, the sign-relatedness of certain performances was validated through showing a significant change between two conditions in a before-after study. These validated performance measures are indicated by a check in the right-hand column.

Guide Sign MOE:	High Risk Gore Weave	Gore Weave	Late Lane Change	Drive Slowly
Operational Definition:	A vehicle movement into deceleration lane across painted or physical gore, in addition to crossing at least one through traffic lane.	A vehicle movement into deceleration lane across painted or physical gore.	A vehicle movement into deceleration lane across painted gore extension line.	A vehicle speed ≤ one standard deviation below mean, 800 feet in advance of physical gore point.
Collection Method:	Time Lapse Photography	Manual Coding* or Time Lapse *Manual Coding is preferable if total weave area is 1000 feet or longer.	Time Lapse Photography	Manual Timing via Electronic Stopwatch
Collection Procedure:	Measure or count all occurrences continuously for one-half hour periods simultaneously at experimental and control sites at times-of-day and day-of-week to permit matching data in before and after conditions.			Slow and mean speed during alternate periods.
Analysis Procedure:	Pre-post design with control group: apply two by two factorial analysis of frequencies or proportions for each target behavior type and exit volume. Use X^2 (Chi-Squared) test for frequencies; Z-test for proportions.			
Expected Outcome:	Decrease of 35 to 100 percent.	Decrease of 25 to 54 percent.	Decrease of 4 to 19 percent.	Decrease of 6 to 77 percent.

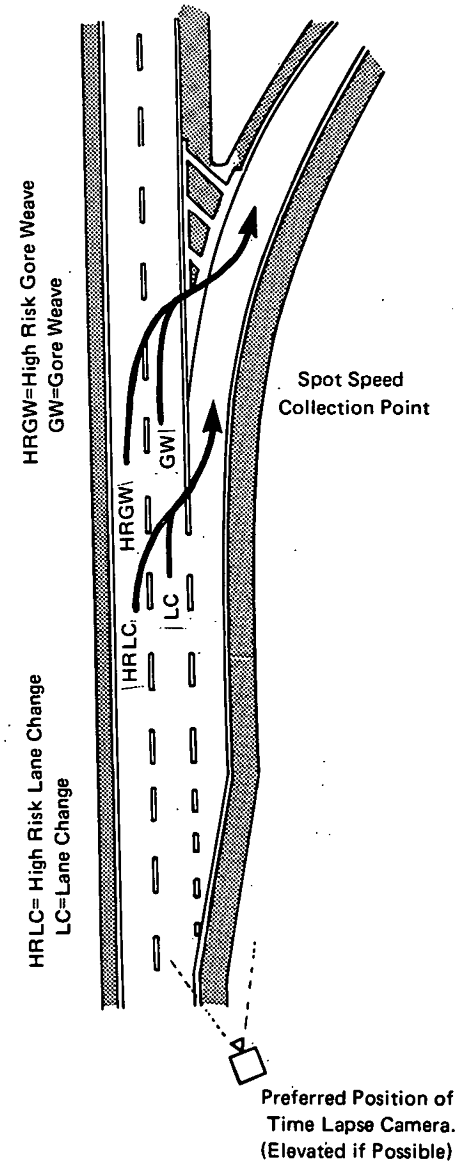

Figure 1. Application of Validated Guide Sign MOEs in Before-After Study or Experiment

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