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COLOR AND SHAPE CODING FOR FREEWAY ROUTE GUIDANCE

Vol. II. Final Report (Field Study Results)

March 1978

Final Report

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Prepared for

FEDERAL HIGHWAY ADMINISTRATION

Offices of Research & Development

Washington, D. C. 20590

Foreword

This report presents the results of laboratory and field tests of a unique color and shape coded guidance system which offers promise as a supplement to conventional guide signing at problem freeway interchanges. The effects of five color/shape coded systems on erratic maneuvers, lane placement and speed of vehicles traversing the test interchanges are discussed. Guidelines for system installation and use are reported.

The report concludes that the color/shape coding concept as applied to freeway route guidance results in sufficient benefit to merit further development and testing. The reported information will be of interest to researchers concerned with highway guide signing and routing information.

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Charles F. Scheffey
Director, Office of Research

NOTICE

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16. Abstract

The purpose of this research effort was to develop and field test a unique color and shape coding system which offered promise as a supplement to conventional guide signing on problem interchanges. Following a review of the technical literature, a series of laboratory studies was conducted to empirically identify the most appropriate color and shape combinations for symbol signs. The symbol signs were used in various ways in the design of five color/shape coded route guidance systems which were installed and subjected to field evaluation on problem interchanges.

With the exception of the initial system evaluated, all other systems resulted in operations and safety benefits as evidenced by a statistically significant reduction in erratic maneuvers and a significant improvement in other operational measures.

It was concluded that the color/shape coding concept as applied to freeway route guidance results in sufficient benefit to merit further development and testing of such systems.

This volume presents: a summary of the laboratory studies; a detailed description of the systems evaluated along with the results. Also included are guidelines for system design and implementation.

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I. INTRODUCTION AND BACKGROUND

This report documents an effort to develop and field test a unique color/shape coding system that offered promise as a supplement to conventional guide signs for freeway route guidance. The need for supplemental information for drivers is based upon observations and inputs from the traffic operations community which indicated that there are a number of freeway interchanges throughout the country that are difficult to sign via conventional means. The difficulty arises either because the interchange is unique and therefore violates driver expectancy or because the interchange is complex and results in information overload for the driver. In either case, the consequence is driver uncertainty which may be manifested in the commission of erratic maneuvers and increased turbulence in the traffic stream in the vicinity of interchanges, and a commensurate decrease in safety. Further, to the extent that the uncertainty results in inappropriate driver decisions regarding an exit, the "lost" driver represents an unnecessary increase in travel time and fuel consumption.

The assessment of color and shape codes as a promising means of supplementing conventional signs is based upon a great deal of past research which indicated that such codes are effective information carriers and that, once learned, the codes generally are processed rapidly under a variety of conditions.

Faced with the operational problem noted and the potential for a solution via application of color/shape coding, Mr. King Roberts and other staff members of the Office of Research and Development, Federal Highway Administration, conceived a system which through the provision of rapidly processable information (for both route guidance and path control) would facilitate the driver's task in traversing unusual or complex freeway interchanges. More specifically it was felt that coded information appearing on or added to existing sign panels, and/or on the roadway surface, could help the driver to more quickly and easily identify the lane he should occupy prior to and within the interchange to reach his desired exit.

The effectiveness of any such system is, of course, predicated upon the driver's ability to recognize or build an association between his desired destination (or route) and the color/shape symbol signs which are presented as a supplement to the conventional signing information. Once this association is made, the driver needs only to search for and follow the symbol signs, thereby reducing the information loading in the vicinity of the interchange. A further advantage of the symbol signs when they are used to supplement existing delineation in the vicinity of the exit gore and ramp is the provision of specific rather than general information regarding the exit and confirmatory information on the ramp.

It is important to note that the system developed and tested is intended to be used only on problem interchanges where conventional signing treatments have been shown to be or are expected to be inadequate due to unusual geometrics either in kind or complexity. That is, the system begins and ends within a problem interchange and there is no intention, at present, to utilize the system to aid the driver in long term route following.

The project was initiated with a review and synthesis of the academic and traffic research literature applicable to the development and use of the color/shape system. Given the nearly infinite variety of shapes which could be considered as candidates for inclusion in the system, it was necessary to utilize past research results to identify the shape characteristics which were most likely to be easily discriminable and result in rapid and accurate identification. Criteria such as complexity (e.g., critical detail and number of sides), angularity, and curvalinearity, perimeter-to-area ratio, size, and the like were derived from the academic literature and provided the basis for identification of the initial candidate set of shapes. The size of the candidate set of shapes was further reduced on the basis of reported performance of the various shapes in various perceptual and information processing tasks and also on the basis of judgments as to the frequency of exposure of the general public to the shape. This latter criteria is associated with the ability of subjects to attach a meaningful verbal label to the shape. While the literature did not provide definitive answers to all of the questions regarding selection of shapes, it did provide enough guideline information to reduce the number of candidate shapes to a workable set for inclusion in a series of laboratory evaluations designed to empirically evaluate the shapes.

The primary emphasis of the review of the literature related to color coding was upon the various ways in which color had been effectively used as a code rather than upon color perception and discrimination per se. The reason for this emphasis was a restriction upon the colors which could be used in the system. That is, the contract originally called for the use of the four colors identified in the Manual of Uniform Traffic Control Devices (MUTCD) as "unassigned" i.e., those not yet assigned a specific use by the National Joint Committee on Uniform Traffic Control Devices. However, since more than four colors were desirable for the system, the assigned colors in the MUTCD were also candidates for use. For those not familiar with the MUTCD, it should be noted that the "unassigned" colors are: coral, strong yellow-green, light blue, and purple. The colors currently assigned to a given use for conveying traffic control information are: red, yellow, orange, green, blue, black, white, and brown.

The synthesis of the color and shape literature is provided in Volume III, Appendix A of the report. Following the literature review, a series of three laboratory studies were conducted. Because the range of colors to be used were restricted to those which were identified in the MUTCD as "unassigned", the initial laboratory efforts were aimed at identification of the most appropriate shapes to be used in the system. These studies were followed by a symbol sign format evaluation and an outdoor laboratory study designed to identify the best color/shape combinations. A summary of the laboratory studies is provided in this volume of the report and the detailed procedures and results for each study are provided in Volume III, Appendix B.

Following the completion of the laboratory studies, a series of field evaluations were conducted. The purpose of the field evaluations were twofold: to empirically determine the extent to which the color/shape coding system was conceptually sound in serving its intended purpose and to establish a set of guidelines for further development and/or implementation of the system should the concept/system produce favorable results. Along with this orientation was an awareness of and practical appreciation for the role which complexity and cost play in the acceptance of innovative systems. Thus, the field studies began with the simplest and most easily implementable system which promised a reasonable probability of meeting the informational needs of users. Each system variation evaluated in the field involved the addition of various information elements to the basic treatment. The field evaluations were designed as before/after comparisons, with the "before" condition at each site being the existing conventional guide signs. Given the contractual limits on the period of performance it was not possible to provide a long term empirical validation of the concept since this would have required acclimation periods between the "before" and "after" phases of sufficient duration to rule out all novelty effects. However, it should be noted that the system was developed for use only on problem interchanges and since the primary beneficiaries of the system are unfamiliar drivers, the system would capitalize to some extent on novelty effects. Thus it was expected that the lack of long acclimation periods would have no substantive effect on the primary measures of effectiveness.

The detailed results of the field evaluations and the guidelines for design and implementation are provided in this volume of the report.

II. LABORATORY STUDIES

The purpose of the laboratory studies was to provide an empirical basis for choosing the color/shape (C/S) symbols to be used in the subsequent development of the system to be field tested. Since the conceptual objective of the C/S system was to provide supplemental guidance information at problem interchanges on a spot basis rather than for long term route guidance involving the entire highway network, a large number of different symbols was not required. Based upon the assumption that even the most complex interchange (or even two adjacent problem interchanges) would not require more than eight route choices, the objective of the laboratory studies was to identify two sets of four symbols which would be best suited to the system. Since the colors were restricted to those currently identified in the Manual of Uniform Traffic Control Devices as "unassigned", the first two studies were designed to identify the most appropriate shapes. The third study was designed to investigate the role of background and direction of contrast as related to visual target (symbol) location. A fourth study involved the evaluation of alternative symbol sign formats and the fifth study, conducted in an outdoor environment, was designed to assess the best color/shape combinations to be used in the field tests.

This section provides a brief discussion of the purpose, methods, and general findings of each of the laboratory studies. The detailed documentation of the studies is presented in Volume III, Appendix B.

Study I. Nameability and Confusability of Shapes

Two of the most important selection criteria for the shape of the C/S symbols which are to be used on the roadway are the interrelated attributes of high nameability and low confusability.

The nameability criterion is important for two reasons. First the system effectiveness can be expected to be enhanced if communications between a "navigator" and driver are as unambiguous as possible. The navigator, as defined here, could be another occupant of the vehicle providing real-time verbal information or could be someone providing prior verbal directions regarding landmarks and other appropriate features, including the color and shape guidance system. Second, there was evidence in the psychological literature which indicated that having a specific verbal label (name) to serve as a mediator between the sensory experience of a shape and its later recognition might facilitate that recognition, especially when relatively long term memory was required. Four aspects of nameability were judged to be most important: (1) ability to produce a name for the shape; (2) concensus regarding the name for a given shape; (3) lacking complete concensus; the smallest possible set of names for a given shape (e.g., "barbell" and "dumb bell" as names for a given shape where one name or the other is used by virtually all subjects), and (4) low usage of the concensus name for a given shape when presented with other shapes.

The confusability criterion also had several aspects. One was low verbal confusability which was included among the important aspects of nameability (i.e., number four above). A second aspect, low perceptual confusability, was important for two reasons: (1) the small amount of time normally available for recognizing and acting on highway guidance information, and (2) the proposed use of the color and shape guidance system in locations where the information load on the driver was already high.

The number of different shapes which could have been used as the starting candidate set was, obviously, nearly infinite. From a large number of shapes, the project staff selected a set of 30 (see Figure 1) with the selection being based upon several considerations: (a) the performance of the symbols as reported in previous relevant research studies; (b) conformance of shape characteristics to relevant guidelines related to "perceptual goodness"; and (c) judgments as to the frequency of the general publics' exposure to the shape.

The study was conducted in three phases. Phase One was designed to provide data regarding the number of names for each shape, degree of concensus among subjects regarding the name for each shape, and the use of the same name for different shapes. Phase two was designed to provide preliminary data about the perceptual confusability of the 30 shapes and to aid in the selection of shapes to be used in subsequent studies. Phase Three was designed to provide data about the confusability of shapes when subjects attempted to match shapes to remote verbal labels.

One result of the study was a ranking of the shapes with respect to nameability. A second result was the identification of the shapes which were most likely to be verbally confused. The final output of the study was a rationale for selecting groups of shapes which could be used together as sets in marking alternative routes in the same interchange. This rationale was provided by a cluster analysis of the subjective judgments of which shapes were "like", i.e., likely to be confused with or mistaken for one another and those which were "unlike", i.e., least likely to be confused with or mistaken for one another. While the cluster analyses did not yield clusters as distinctive as one would have hoped for, they did permit the identification of four sets of four shapes wherein the members of each set were from different clusters of like shapes and therefore subjectively not likely to be confused with one another. These four sets were identified as candidates for use in the color/shape route guidance system; hence, they were labeled candidate sets.

Four additional sets of four shapes were identified from the cluster analyses as control sets. In contrast to the candidate sets, control sets were made up of shapes from the same "like" clusters or "neighboring" like clusters so that they were subjectively likely to be difficult to discriminate, i.e., more apt to be confused one with another.

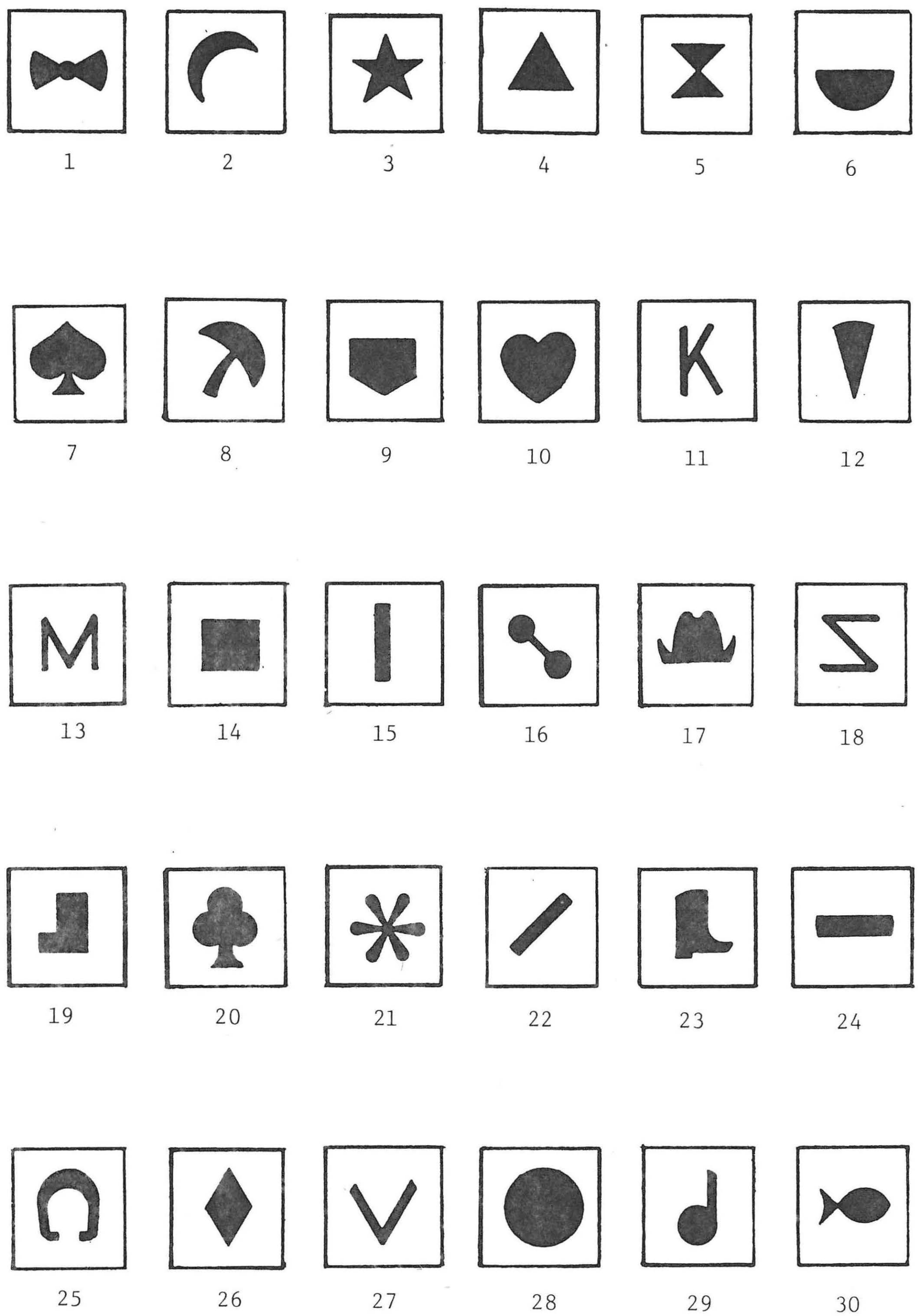


Figure 1. The 30 Shapes used in Study I

Study II. Speed and Accuracy of Location of Target Shapes

The purpose of Study II was to attempt to validate the candidate sets of Study I in a controlled performance situation which simulated important dimensions of the automobile driver viewing situation. Just as in Study I, where subjects were asked to judge where confusions would occur under "glance" viewing conditions, Study II subjects were given a short duration (1/2 second) presentation of the target shape in a context formed by either candidate or control shapes. While, indeed, the highway driver may have more than a half second to locate, recognize, and read guidance information, the use of symbols requiring minimal processing time is obviously advantageous. Time not devoted to searching for, locating, recognizing, and reading route guidance information can be applied to attending to vehicle control and other traffic. Of course, it is equally important that the driver process the guidance information accurately. Hence, both response latency and accuracy measures were taken. To simulate the spatial uncertainty of route guidance information, shapes designated as "target" shapes occurred randomly in one of the four quadrants of a projected image. In addition, target (and non-target) shapes were located randomly at one of nine locations within each quadrant. While these features of the design do not simulate all aspects of the "real" situation, they do increase the likelihood that the laboratory results will be relevant to the subsequent field test situation.

In summary, then, it was predicted, on the basis of Study I results, that the sixteen shapes would be located and responded to more quickly and accurately when presented in the context of their candidate sets than in the context of the control sets. Stated another way, it was expected that trials involving the presentation of candidate sets would, on the average, result in faster and more accurate target location than trials, involving control sets. In the event that this expectation was not borne out, the results of this second study would provide further and alternative criteria for selecting candidate shapes and, possibly, candidate sets of shapes. In the case of conflicting results, priority would have to be given to the perceptual performance data of this study rather than to the judgmental data of Study I.

While there were some conflicts between the accuracy and response latency ranking, the results provided a reasonably unambiguous basis for choosing shapes for which the responses were both accurate and rapid. Further, there was reasonable agreement between the combined criteria of this study and the results of the nameability data, i.e., none of the shapes indicated by the locational accuracy/latency measures had to be rejected because of poor nameability.

Study III. The Role of Background Shape and Direction of Contrast as Cues to Visual Target Locations

The third experiment was designed to evaluate the effects of two visually coded variables on the location and recognition of shape coded signs. The supplemental coding dimensions tested were direction of contrast (light figure on a dark background or vice versa) and background shape (circle versus square). It was assumed that the route symbol signs would frequently be presented together, i.e., with two or more at the same location, and that the effectiveness of the system would be enhanced by any additional design features which would reduce the time required to locate and recognize the relevant symbol. Of course, this is one of the benefits expected from the color coding of the symbols. However, it was expected that both direction of contrast and background shape could serve as additional coding dimensions. Thus, a specific route symbol might be unique, not only with respect to the shape code, but also as the only shape appearing as a dark figure on a light circular background. Other shape codes used at the same interchange might appear as light on dark or on rectangular-shaped backgrounds. In any case, the information in these two variables would be redundant with the shape code, but nonetheless, either or both variables were expected to enhance speed and accuracy in locating and recognizing the target shapes.

The results of this study showed that, under the conditions of the experimental test, neither background shape nor direction of contrast, or the combination of the two variables improved either speed or accuracy of target location. It appears that the subjects could not or did not attend to the relevant information which these cues provide.

Study IV. Sign Format Evaluations

Since the results of Study III did not provide definitive information regarding direction of contrast, the decision regarding symbol vs. background (direction of contrast and reflectivity) had to be made on another basis. Further, it was necessary to make other sign format decisions including: the use of high intensity vs. engineering grade sheeting and the use or non-use of reflective borders on the background and on symbols. These format decisions were made on the basis of the pooled subjective judgments of seven staff members. A paired comparison technique was used, where each pair judged was varied on a single dimension. Symbol sign "component" plates were fabricated such that various combinations of reflective intensity could be quickly assembled. For example, symbol borders, background, and background border plates were fabricated with high intensity and engineering grade reflective sheeting and with a non-reflective material. These components could be sandwiched and temporarily clamped together to produce any combination desired. Each of the component sets was made in a bright color (yellow) and a dark color (blue) from 3-M reflective sheeting or a matching non-reflective paint in order to permit evaluation of symbol to background relationship of light on dark or dark on light.

The sign pairs were placed ten feet apart and the staff members serving as subjects made judgments first from 300 ft (91 m) and then from 200 ft (61 m). Since some earlier work with reflective materials showed that a "star" shape tended to result in fuzzy edge gradients under some conditions, it was chosen as the symbol, i.e. to represent a "worst case" condition. The subjects had no information regarding the components which were combined for any given trial and were simply asked to judge which symbol sign provided the best symbol definition. The order of presentation was randomly assigned for the two sets of distance trials, as was the lateral position of the two signs.

The concensus of judgments resulted in the choice of a high intensity symbol on a dark non-reflective background, with a high intensity background border.

Study V. Color/Shape Interactions

The results of the first three studies identified eight shapes which were generally recognizable, nameable, and discriminable with a high degree of accuracy under short exposure viewing conditions. Further, four "unassigned" colors were developed for use on reflective sheeting. These four "unassigned" colors and four of the "assigned" colors were used for this experiment. The terms "assigned" and "unassigned" refer to the Manual of Uniform Traffic Control Devices (MUTCD) and the assignment of meaning to colors therein.

Unlike the previous studies, this study was conducted outdoors on an unopened section of highway, using symbol signs fabricated from 3-M high intensity sheeting, on which the appropriate "unassigned" colors had been silk screened. The "assigned" colors were fabricated from off-the-shelf 3-M high intensity sheeting. The study was conducted at night, under headlight illumination conditions since it was necessary to ensure that the reflective materials did not result in color confusion, or symbol misidentification due to edge gradient problems.

The experimental task was based upon the identifiability of colors and shapes, where each of the eight symbols was paired with each of the colors. Because of the time constraints on subject availability, assigned and unassigned colors were separated into two blocks, treated as a between subjects variable and analyzed as separate experiments. Upon presentation of a single symbol per trial, the subjects were required to write both the color name and the shape name on a response sheet.

Since the purpose of the study was to identify color/shape interactions such that colors could be paired with shapes in a manner which facilitates proper identification, responses were dichotomized as either correct (color and shape both properly identified) or incorrect (either color and/or shape improperly identified).

The results of the study showed that while the color and shape main effects were clear, the results of the interaction were not. For this reason, the process of pairing shapes with colors for the purposes of choosing the symbols to be field tested was based in large part upon the cell means in the two dimensional color/shape treatment matrix.

Thus each color was assigned to the shape with which it performed best insofar as possible. That this was not possible in every case is based on the fact that the "matching" procedure was limited by ties and the necessity to assign shapes to only one color. The symbols chosen as candidates for field evaluation were:

Coral	Heart
Strong Yellow-Green . . .	Barbell
Light Blue	Horseshoe
Purple	Halfmoon
Orange	Quartermoon
Yellow	Musical Note

III. FIELD EVALUATIONS

The field evaluation phase, as is true of any project having a practical application as its major goal, was the central activity of this research. The approach employed in these evaluations was selected to facilitate the accomplishment of two important purposes: first, to empirically determine the efficacy of the color/shape coding concept in providing route guidance information for drivers negotiating unusual or complex interchanges. The second purpose served by the evaluation was to provide feedback from the field application in a form that would be useful in the progressive development of both the system itself and the generalized guidelines for implementation at a wide variety of complex interchanges. In short, the field evaluation provided data to assess the effectiveness of the color/shape concept and a basis for the ancillary observations and judgments needed to enhance the effect and permit generalization to situations other than those specifically evaluated.

The general plan of the evaluation involved a three phase, five test sequence of evaluations, with modifications of the system being made between each of the evaluation exercises. Table 1 provides a verbal description of the various C/S system components as used in the various evaluations. In general the modifications involved increases in system complexity based upon both observed driver performance and field related judgments by the project staff. In other words, the initial field evaluation utilized what was judged to be the minimum system. Based upon observations during the data collection phase system elements were added and existing elements repositioned or otherwise changed. Observations during the second field evaluation then formed the basis for the system configuration to be employed in the succeeding phase. With regard to the major components of the system, i.e., the gore delineation, ramp delineation, guide signs, and introductory signing components, it should be noted that the data are not properly interpretable on the basis of these individual components. That is, the components were not systematically varied within or across the field tests because existing site characteristics and existing guide sign locations in most cases dictated the configuration of the individual components, i.e. spacing and position of ramp and gore delineation and the position of the symbols. The observation based judgments, validated via system effectiveness data from the succeeding evaluation represent a much more practical and effective means of accomplishing the second major purpose of the field evaluation.

One other general observation regarding the evaluation scheme involves the deliberate tradeoff between system development goals and direct assessment of long term (i.e., novelty free) system effectiveness. The rationale for using relatively short adaptation or acclimation periods, while recognizing the eventual need for research on this specific question prior to widespread system deployment, is based upon the fact that the system is primarily aimed at drivers unfamiliar with

Table 1. Color/Shape System Configurations

			TREATMENTS					
SYSTEM	PHASE	SITE	INTRODUCTORY SIGNS	GUIDE SIGNS	"FOLLOW" AND "TO" PLATES	GORE	RAMP DELINEATION	PAVEMENT SYMBOLS
A	I	York, PA. I-83	None	24" Symbol signs - Peripheral tabs	None	12" Symbol sign - Post mounted	12" Symbol sign - one shoulder only	None
B	I	York, PA. I-83	Route Marker format - Post mounted	24" Symbol signs - Peripheral tabs	Introductory signs and two Guide Signs	24" Symbol sign - Post mounted	12" Symbol signs - both shoulders Exit/one shoulder through	None
C	II	Phila., PA. I-83	None	24" Symbol signs - Top tabs only	All Guide Signs	12" Symbol sign - Post mounted	12" Symbol signs - both shoulders	None
D	III	Phila., PA. I-76	Upstream Overhead and Ground mount route/ symbol association signs	36" Symbol signs - Sign face mounted	None	36" Symbol sign with Arrow Plate - Post mounted	Lead 24" subsequent 12" Symbol signs -- both shoulders	None
E	III	Phila., PA. I-76	Upstream Overhead and Ground mount route/ symbol association signs	36" Symbol signs - Sign face mounted	None	36" Symbol sign with Arrow Plate - Post mounted	Lead 24" subsequent 12" Symbol signs -- both shoulders	9' X 3' On 200' centers through treated site

the specific interchange; drivers for whom novelty is a component of system effectiveness. The effect either positive or negative for drivers familiar with the site is expected to be minimal after only a few exposures to the system.

The Phase I field evaluations were conducted at a site on I-83 near York, Pennsylvania. The problem on this site was one of route continuity, where the exit movement was a two-lane tangent ramp and the through movement (I-83 North) involved a rather severe curve to the right. Thus the driver's expectations of through versus exit maneuvers are violated by a geometry where the through movement appears as the ramp and vice versa, thereby resulting in problems for unfamiliar drivers. The initial Color/Shape (C/S) system used on the site (System A) was the "baseline" system in that it was the least complex and the easiest to implement. System A consisted simply of the peripheral "tabbing" of C/S symbol signs on the existing guide signs, and the use of post-mounted C/S symbol signs for gore and ramp delineation. The second system evaluated at this site (System B) involved the addition of informational elements (i.e. "FOLLOW" and "TO" tabs) to two of the symbol tabs and the placement of two upstream informational signs which provided the driver with the association between the symbols and routes. Some minor changes in the ramp and gore post-mounted symbols were also made. A full description of each of the C/S systems is provided in the following sections.

Based upon the positive results of the evaluation of System B, it was decided to evaluate what was essentially the same system on a different type of site, i.e. a site which was more urban and involved a different interchange configuration. This Phase II evaluation was conducted on I-76 in Philadelphia, Pennsylvania. The site consisted of a three lane freeway which diverged into three two-lane movements. The C/S system used in this field test (System C) involved the use of "FOLLOW" and "TO" tabs on all of the symbol signs. However, since the existing guide signs on this site were such that the association between the symbols and routes could be clearly identified through the use of "FOLLOW" and "TO" tabs, the upstream associational or introductory signs used in the System B configuration were not used.

The Phase III field evaluations which consisted of two C/S system evaluations were also conducted on the I-76 Philadelphia site. Since the Phase II evaluation showed positive system effects it was felt that an additional series of tests was merited, using a system configuration which was designed specifically for the site rather than one which was adapted to the site. In the case of the Phase III evaluations, the C/S symbol signs were integrated with the existing guide sign information rather than tabbed on the periphery of the existing signs. Further, a set of upstream introductory signs was designed and installed. The difference between the two systems (System D and E) as evaluated in the Phase III studies was that System E involved the addition of the pavement symbols to the System D configuration.

Since the Phase II evaluation on this site had been conducted during October and November, during a time when relatively fewer unfamiliar drivers would be using the site, it was decided to conduct the Phase III evaluation on the same site, but during the peak of the summer vacation period. Since I-76 is a major route to New Jersey shore resorts, it was felt that the existence of an increased number of unfamiliar drivers would constitute a better system evaluation. Further, it should be noted that in view of the fact that final recommendations regarding the C/S system would derive largely from the Phase III evaluations, the coding of erratic maneuvers was modified to provide more conservative tests of the systems and to better assess the potential safety benefits of the systems. While this data coding change reduced the overall erratic maneuver rates well below the rates observed during the Phase II evaluations, it was felt that the more conservative evaluation was appropriate at this stage.

The remainder of this section provides a description of the field sites, identifies the specifics of the C/S systems evaluated, and presents the empirical results of the field evaluations.

PHASE I EVALUATION

Site Description

The site of the Phase I field evaluations is on I-83 North near York, Pennsylvania, at the exit to York designated as Exit 5/South George Street. The geometry is an atypical configuration consisting of a left (tangent) exit and right curving through movement, as well as a major diverge, where two 12 ft (3.7 m) mainline lanes diverge to two 2-lane movements. As shown in Figure 2, Exit 5 is a tangent two lane continuation of the mainline. This site is a classic example of a route continuity problem based on both site geometry and extant signing in the gore area. In addition to the exit geometics appearing to be a continuation of the through movement, the potential confusion to drivers unfamiliar with this site is further influenced by two exit gore area signs: (1) a right shoulder, post mounted "BUSINESS LOOP 83" shield, and (2) a 55 mph (88 kph) speed limit sign. Both of these signs are visible from a minimum of 1000 ft (304 m) upstream of the exit gore. The impact of these signs is that they both imply a continuation of the mainline. That is, the exit speed limit is the same as the mainline speed limit, and although the Business 83 shield is green and white, it is still likely to be confused with the I-83 shield because of its similar size, shape, and message. In addition, there is a mainline right shoulder, post-mounted curve advisory plate with a 40 mph (64 kph) speed reduction tab located 455 ft (139 m) upstream of the exit gore. This signing adds to the driver confusion in that drivers may assume that the curve and speed reduction are associated with a right exit which is the typical, and expected configuration.

For purposes of both operations evaluation (data collection) and signing treatment it was necessary to study, in addition to the exit area, a much larger highway segment including all the relevant upstream signing. Interstate 83 is a 4-lane freeway with a median guardrial. Approximately 450 ft (137 m) upstream of the exit gore the two 12 ft (3.7 m) mainline lanes begin to diverge: lane 2 to a tangent, two-lane exit, and lane 1 to a right curve through movement. As noted, the posted exit speed is 55 mph (88 kph) and the speed limit for I-83 is an unposted 55 mph (88 kph) except that the mainline speed limit is reduced to 40 mph (64 kph) through the curve.

Guide signing for the site begins approximately 3500 ft (1067 m) upstream of the exit gore on the first of a series of three sign bridges. The positioning and legends of these signs can be found in Figure 3. As shown, Sign #4 assigns the right lane to I-83 North traffic and sign #5 assigns the left lane to Exit 5 traffic; lane assignment is made via down-pointing directional arrows. Sign #6, a right shoulder mount structure located approximately 2850 ft (869 m) upstream of the exit gore, provides additional distance information (i.e. "5 - S. GEORGE ST. 1/2") for exiting drivers, however, the lane assignment (lane 2) is not reinforced. The right lane assignment for I-83 North is reinforced by sign #7 (again with a down-pointing arrow), located on an overpass structure approximately 2800 ft (853 m) upstream of the exit gore.

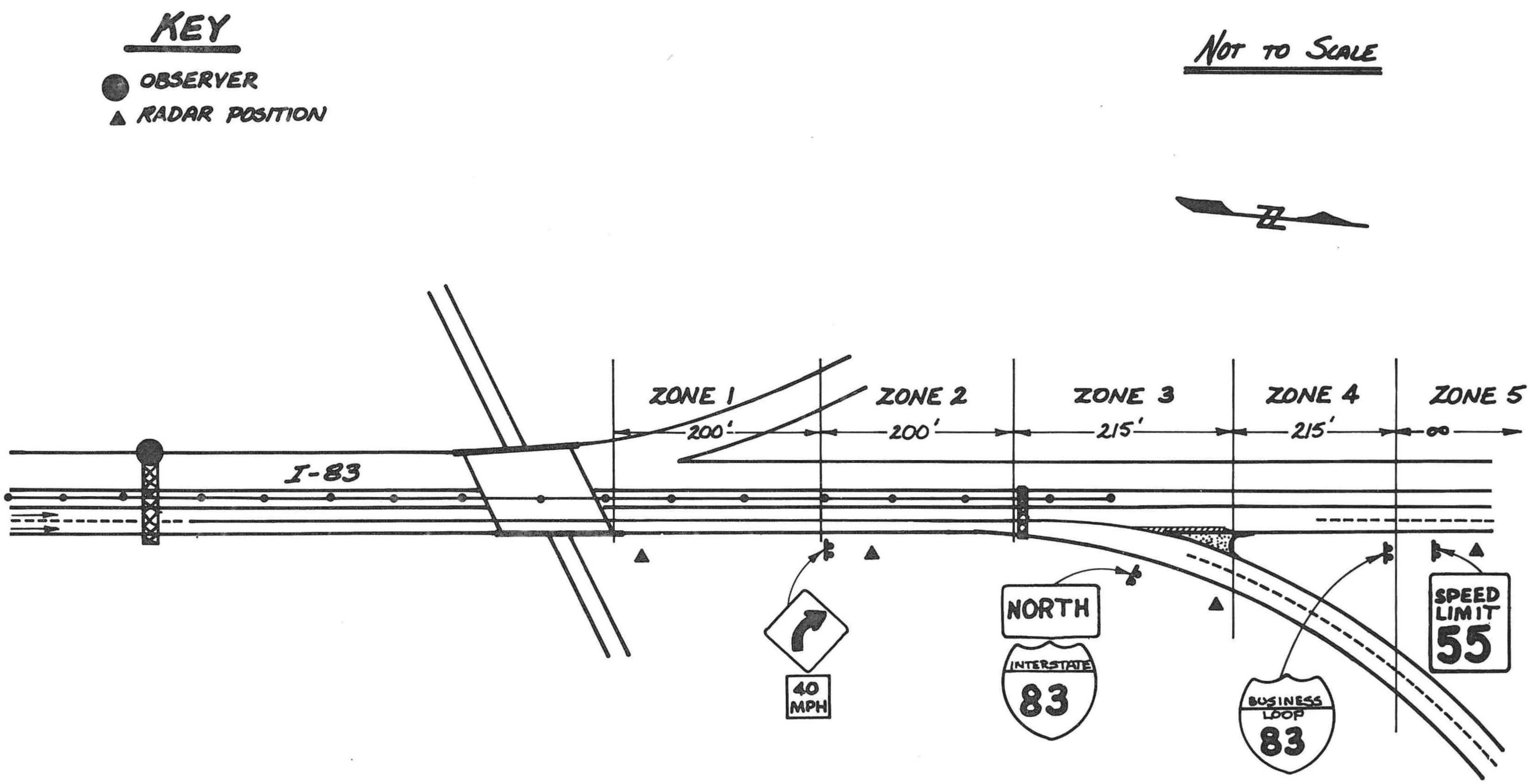


Figure 2. I-83 York Site Schematic

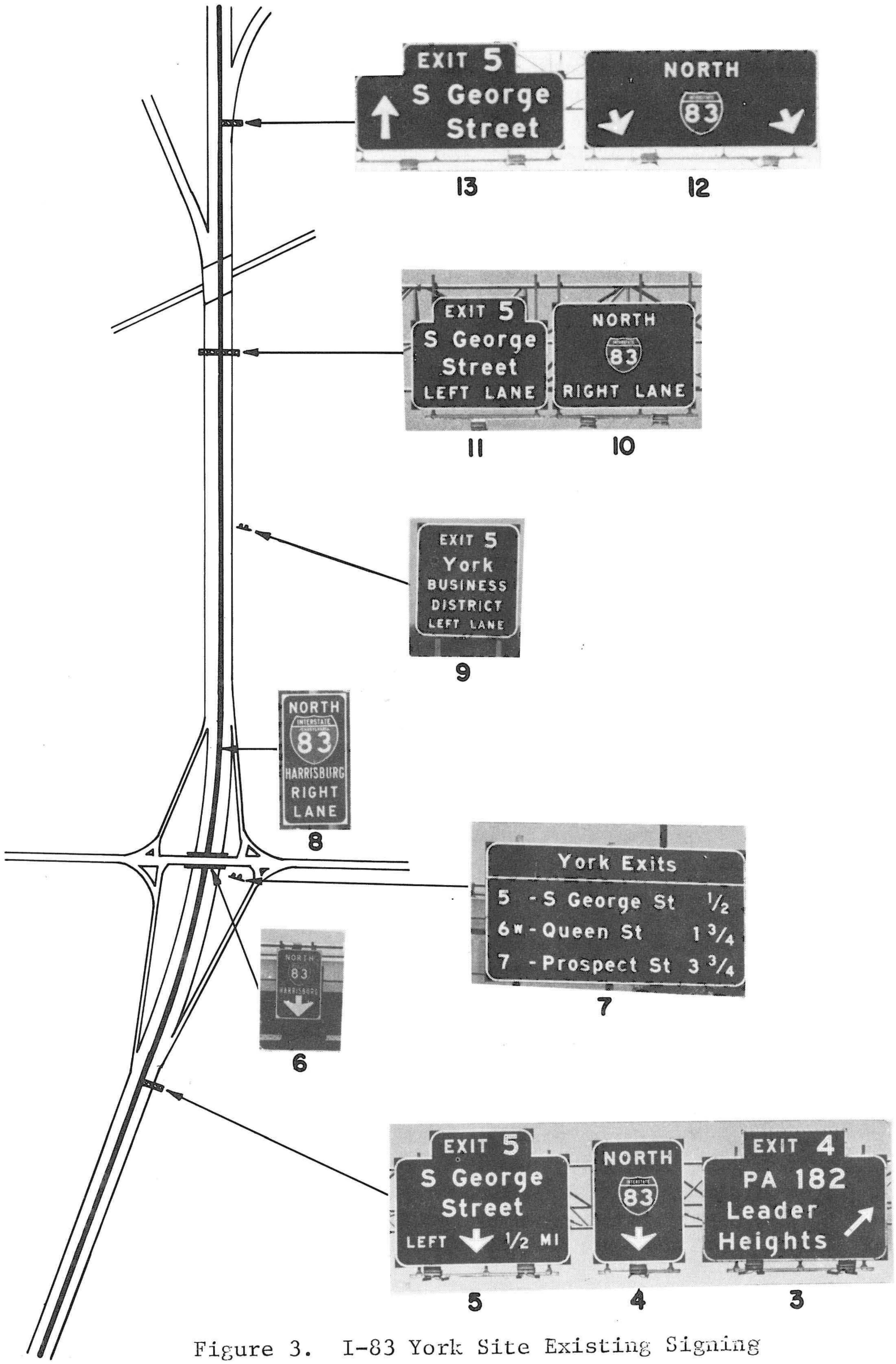


Figure 3. I-83 York Site Existing Signing

Sign #8 is post-mounted in the median (left side) of I-83, approximately 2500 ft (762 m) upstream of the exit gore. The message, again, is a lane assignment for I-83 North, with the message being verbal (i.e., "RIGHT LANE"). A right shoulder mounted sign, sign #9, located approximately 1600 ft (488 m) upstream of the exit gore, assigns the left lane to the Exit 5 movement to the York business district; again, this assignment is presented verbally. Sign #10 and #11 are mounted on the second sign bridge of the site located approximately 1400 ft (427 m) upstream of the exit gore. Although placement of these signs is directly over the appropriate lane of travel; the lane assignment is made verbally rather than by arrows. The final sign bridge of the site includes signs #12 and #13. These signs are essentially gore area (i.e. final decision point) signing since the sign bridge is located only 200 ft (61 m) upstream of the exit physical gore. Although the message content is consistent with all the previous upstream signing, the lane assignment/directional information indicated by arrows is different yet appropriate for exit (gore area) signing.

The mainline ADT (one way) over all the days of data collection was 12,000 with an average volume of 838 vph during data collection periods. The average car/truck mix was 91% and 9% respectively. The percentage of drivers who exited during data collection periods ranged from a low of 7% of the mainline traffic to a high of 72%, with an approximate 40% exit and 60% through split occurring during commuter peaks and at those times when local drivers would be expected through the interchange (i.e. morning shoppers, lunch-time traffic). Speed data for this site is reported in the results and conclusions section to follow.

Signing Treatment

There were two phases of signing treatments on this site: System A, which was a minimal "baseline" treatment (see Figure 4) which involved peripheral tabbing of the symbol signs, and System B, which was the same as System A but with the addition of route/symbol association signs (see Figure 5). Both systems were specifically designed for and adapted to this particular site, taking into consideration such things as existing signing, site geometry, sight distance, symbol/message associations, etc. Therefore, there is uniformity in the size of the color/shape symbol signs which were used, but there are differences in the placement of the symbol signs relative to the guide sign information. The differences in placement resulted from physical restrictions as to where the symbol sign could be attached. For example, guide signs which are illuminated from the bottom preclude a bottom attachment of the symbol signs because of the lighting structure. Also, where several guide signs are mounted side-by-side, only the outside or top edges of the outside signs can accommodate the symbol signs.

System A involved the peripheral tabbing of all the existing guide signs and route markers with color/shape symbol signs as well as the addition of post-mounted gore area and ramp symbol sign delineators.

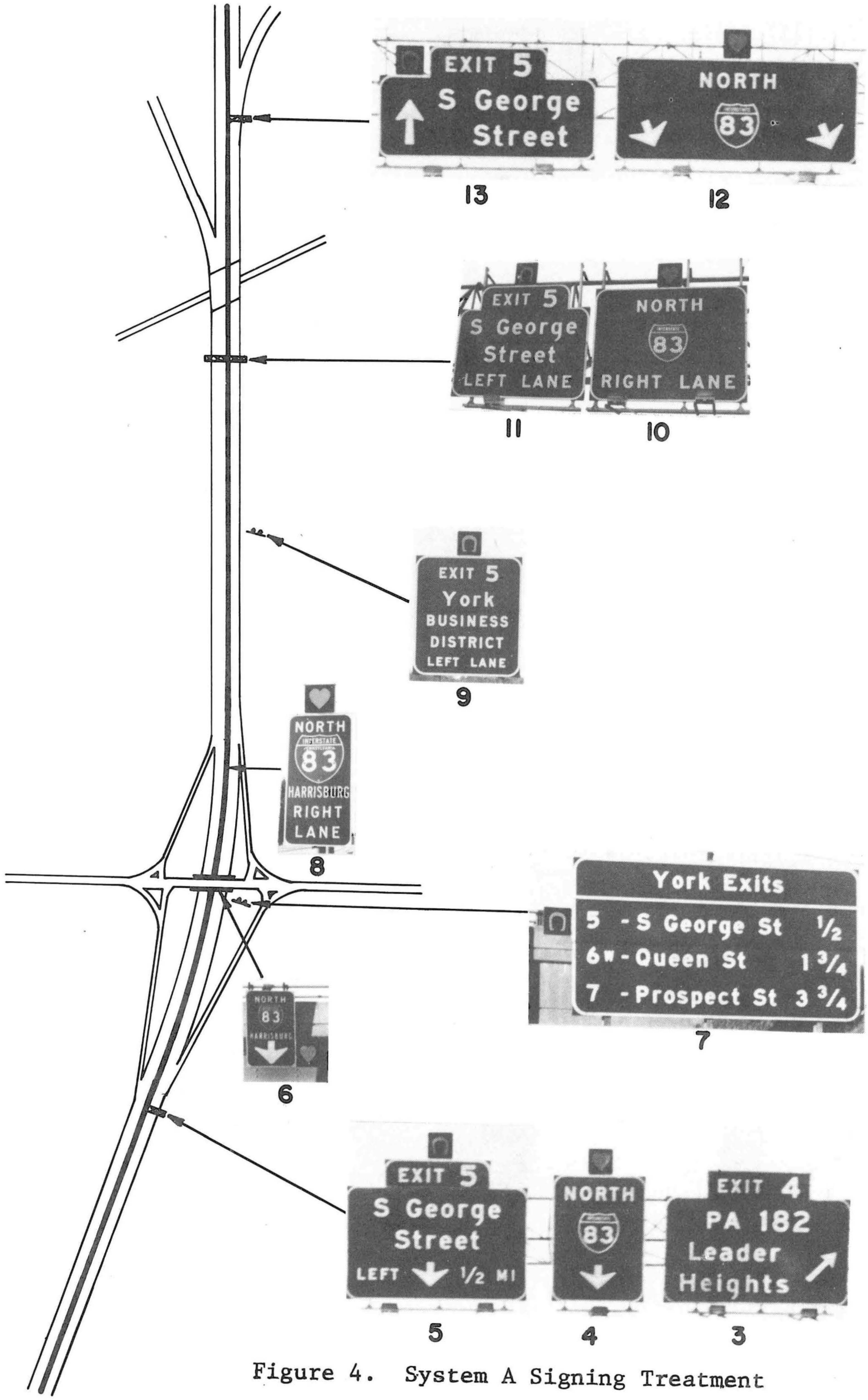


Figure 4. System A Signing Treatment

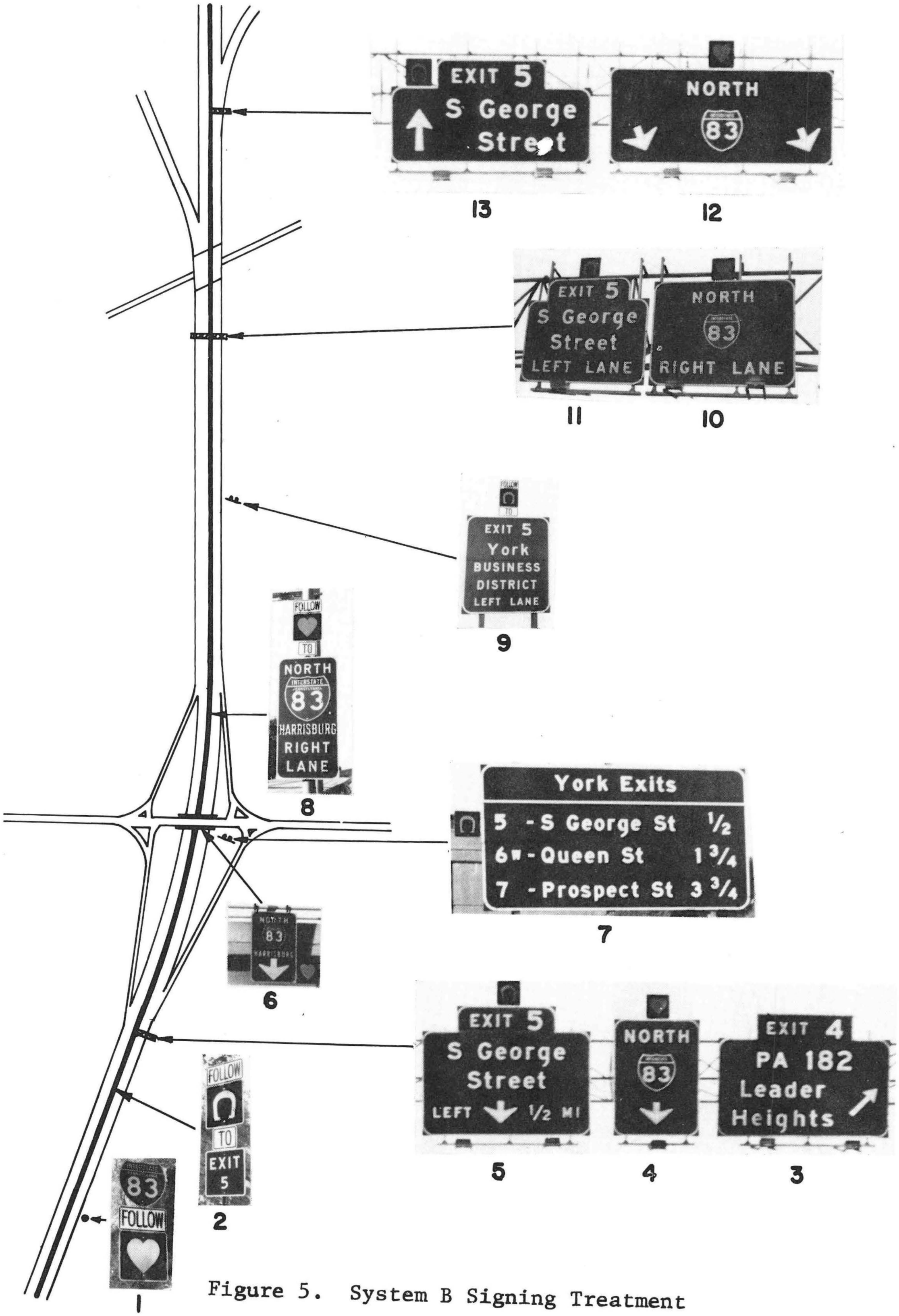


Figure 5. System B Signing Treatment

The dimensions of the color/shape symbol signs used for tabbing the guide signs and route markers were 24 x 24 inches, and the delineator symbol signs were 12 x 12 inches. Originally, based on their 1-2 ranking in the laboratory studies, the symbol signs targeted for use on this site were a coral heart for I-83 North, and a strong yellow-green barbell for Exit 5. However, the fact that York, Pa. is the home of one of the largest barbell manufacturers in the world resulted in the decision to substitute the #3 rank ordered symbol, a light-blue horseshoe, for the Exit 5 movement in order to guard against the possibility of drivers making a spurious association of the symbol sign barbell with the York Barbell Co.

Figures 4 and 5 illustrate the guide signs and route markers which were treated and the actual placement of the color/shape symbol sign tabs on these signs. In order to present a uniform and predictable system, the guide signs were top-tabbed wherever possible (Signs #4, #5, #8, #9, #10, #11, and #12). There were two primary reasons for the choice of top-tabbing: (1) the luminaires of the sign bridges were bottom-mounted, thus rendering bottom tabbing impossible (not to mention violating MUTCD minimum height requirements), and (2) side-tabbing of the overhead signs was undesirable because it would have been necessary to tab the Exit 5 signs on the left and the I-83 North signs on the right (based on space available), thus imposing a needless, complex information search/association task on drivers.

The two signs which were side-tabbed (Signs #6 and #7) were so treated for different reasons. Sign #6 was side-tabbed because this was the only possible way to insure that the association of the light-blue horseshoe with the Exit 5 message would be made, since sign #6 contains additional information concerning two other, unrelated exits. Sign #7 was side-tabbed for purely practical reasons; bottom-tabbing violated MUTCD minimum height standards, and top-tabbing increased the chance of vandalism because of the resultant accessibility of the symbol sign from the pedestrian walkway of the overpass structure. The final guide sign that was treated, sign #13, was top-tabbed, but not centered. The symbol sign was placed directly above an upward-pointing directional arrow of the guide sign in order to increase the probability that the desired association would be made. This was the only guide sign where the arrow/symbol sign association was possible. There were two route markers treated; one for I-83 North and one for Business Loop 83 (Exit 5); both are right shoulder post-mounted, bottom tabbed, and located in the vicinity of the exit gore.

The delineator spacing and placement for System A was different for each movement. Because the exit is tangent to the mainline and sight distance is therefore essentially unlimited, a 200 ft (61 m) spacing between delineators was chosen for this movement; five delineators were used beginning 300 ft (91 m) downstream of the exit gore and continuing downstream on 200 ft (61 m) centers and were right shoulder mounted. Since the through movement involved a sharp curve, with sight distance for the right shoulder virtually nonexistent, it was decided to install the symbol sign (coral heart) delineators as left shoulder mounts on 100 ft (30 m) centers beginning approximately 200 ft (61 m) downstream of the exit gore. This configuration enabled through drivers to view a minimum of two delineators at any given point beginning at the diverge and continuing through the curve. The preceding configurations were designed to maximize the target value and upstream visibility of the delineator symbol signs for each movement, thus enhancing their primary function of confirmation signing.

System B, as shown in Figure 5, was the same as System A except for the following three additions and/or modifications. The first addition was that of two upstream route/symbol association signs. The first sign (#1) was right shoulder, post-mounted approximately 1000 ft (305 m) upstream of the first sign bridge that was treated. This sign was actually a composite of three separate signs. In descending order they were: a 24 x 24 inch I-83 shield, a 24 x 12 inch "FOLLOW" plate, and a 24 x 24 inch coral heart symbol sign. As presented, the message reads: "I-83 FOLLOW THE CORAL HEART". It should be noted that a variant configuration was considered, which involved the addition of a "TO" plate. The message of this configuration would have read "FOLLOW THE CORAL HEART <u>TO</u> I-83". However, this design, although consistent with the following description of sign #2, was not in compliance with the MUTCD specifications for the use of the "TO" message and was therefore not used. Sign #2 was located approximately 400 ft (122 m) downstream of sign #1 and was (left) post-mounted in the median. The message unit of this sign was comprised of four signs/plates; in descending order they were: a 24 x 12 inch "FOLLOW" plate, a 24 x 24 inch light-blue horseshoe symbol sign, a 12 x 12 inch "TO" plate, and a 24 x 24 inch white on green "EXIT 5" sign.

The distance interval between signs #1 and #2 was based on two primary considerations. The first was site geometry (i.e. available space for signing) and the second was sign information processing time/distance available to drivers. The 400 ft (122 m) distance between system introductory signs allows for approximately 5 seconds of processing time assuming stream speed is 55 mph (88 kph) or less, and the 600 ft (183 m) between the last introductory sign and the first sign bridge treated (i.e. the first presentation of the system) affords drivers slightly over 7 seconds of processing time, again, assuming 55 mph (88 kph) stream speed. Both time intervals are adequate for the information processing/association task with which drivers are confronted.

The second addition to System A was that of "FOLLOW" and "TO" plates (in the same format as sign #2) to the previously treated signs #8 and #9. This was done to reinforce the association presented in signs #1 and #2. The only difference and/or nonstandard application involved in this treatment concerned sign #8. In order to mirror the information presented in its counterpart (sign #2), it would have been desirable to only use the "FOLLOW" plate. However, since the color/shape symbol sign system was added to <u>existing</u> signing, the use of just the "FOLLOW" tab would have resulted in a complete reversal of the previous message; that is, "CORAL HEART FOLLOW I-83". The trade-off of message integrity/uniformity or standard application (as per MUTCD) was decided in favor of message integrity.

The third and final addition involved the installation of a lead delineator for the through movement (I-83 North), and the installation of delineators on the left shoulder (median) of the exit in addition to those on the right.

The lead delineator for I-83 North was placed 100 ft (30 m) upstream of the first delineator of System A, and a 24 x 24 inch symbol sign was used. The intent of this treatment was to increase target value and upstream visibility of the gore symbol signs for this movement. Also, by locating the lead delineator closer to the gore (final driver decision point) the additional information would allow drivers to make their directional decision earlier and with more confidence.

The addition of left shoulder mounted delineators for the exit was done for the same reasons given for the modification of the through movement; increased target value, visibility, and confirmation. Three symbol signs were involved here: a 24 x 24 inch post-mounted symbol sign was placed 200 ft (61 m) downstream of the exit gore, and two 12 x 12 inch delineators were installed downstream on 200 ft (61 m) centers.

The left shoulder (median) was treated for reasons related to site geometry and existing signing. Since the exit is tangent to the mainline, visibility of the median is essentially unlimited. Also, there was no existing signing in the median which could detract from or obscure the color/shape delineators as was the case on the right shoulder. Hence, with the increased and earlier visibility of the median-mount delineators, drivers were afforded the opportunity to make earlier and more confident directional decisions.

<u>Data Collection and Reduction</u>

Two preliminary observation trips were made to this site for the purpose of ascertaining specific site operational problems, the potential for data collection (observation vantage points, visibility, etc.), and possible data collection technique. During these trips various combinations of personnel, positions, equipment, and techniques were tried and evaluated. The combinations ranged from an automated collection system (film, recording counters, radar) to a completely manual collection system (observers, manual counters, and stop watches). The resultant data collection system was a composite of both manual and automated techniques as follows.

It was decided to utilize two observers for the collection of erratic maneuvers, volumes, speeds, and traffic composition. One observer (Observer 1) was charged with collecting volumes, speeds, and traffic composition (truck counts), and the other observer (Observer 2) was responsible for the recording of erratic maneuvers (EM's), and monitoring two recording counters and two CB radios. Figure 6 presents the actual data collection schedule which was designed to provide for simultaneous collection of the various types of data so that valid comparisons and conclusions could be made; each observer functioned independently yet in a coordinated effort.

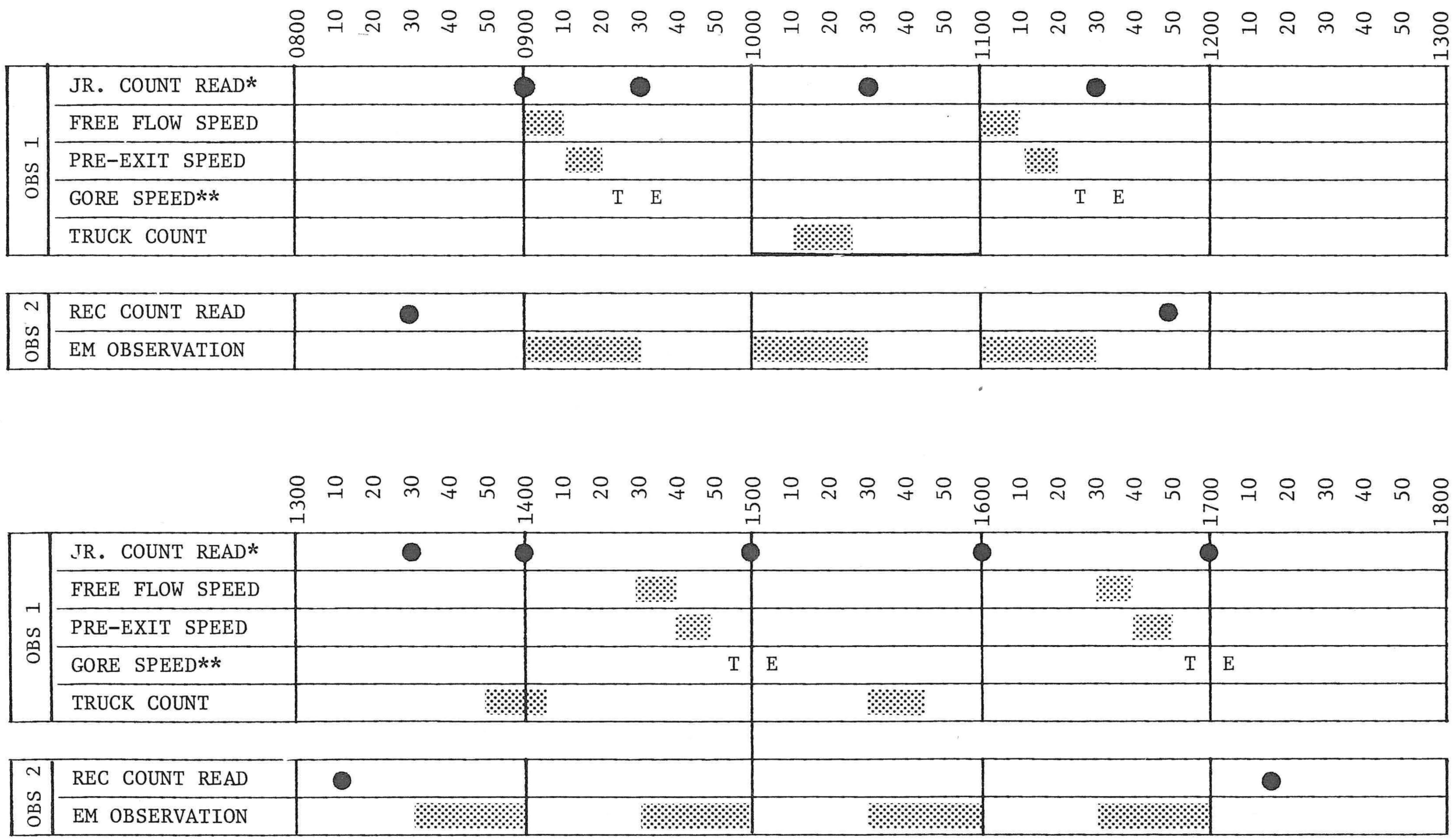
Observer 1 recorded volumes for both the exit and through movements via Streeter-Amet "jr" counters which were located downstream of the gore for each movement; these counters were read in accordance with the schedule shown in Figure 6. Traffic composition (truck count) was recorded manually at the gore for the two movements. A summation of these counts yields the mainline traffic (site entry) composition.

Using a Decatur Rangemaster 715 remote antenna radar unit, Observer 1 recorded speeds at four locations for single or lead vehicles. Free flow (FF) mainline speeds were obtained from an unobtrusive roadside position approximately 1200 ft (366 m) upstream of the exit gore. Pre-exit (PE) speeds were recorded at a point approximately 400 ft (122 m) upstream of the exit gore. Gore speeds were recorded for both movements (exit and through) at points approximately 500 ft (152 m) downstream of the physical gore. In all cases, Observer 1 was hidden and/or camouflaged in order to avoid detection. In addition, the radar antenna was camouflaged to appear as if it was a piece of trash (frequently a brown paper bag was used) and placed at or near the roadside.

The sampling plan for speed data collection was rather simple. Observer 1 took either a 10 minute sample or 50 vehicles per location. In order to have communication between the two observers, Observer 1 was equipped with a walkie-talkie and constantly monitored CB channel 5; the channel also monitored by Observer 2.

The primary function of Observer 2 was the manual recording of erratic maneuvers. This was accomplished from a rather unique vantage point; that is, from atop a sign bridge 1200 ft (366 m) upstream of the exit gore. A triangular shaped plywood platform was placed in the topmost superstructure on the southbound side of the aforementioned sign bridge structure. The underside of the platform was painted silver-grey so as to blend in with the superstructure, and Observer 2, stationed on the platform, was attired in light blue-grey clothing. This vantage point provided a clear field of view of the entire site as well as facilitating unobtrusive observation.

For purposes of data collection, the site was divided into five zones defined by existing landmarks (pavement seams, trees, signs, etc.) as shown in Figure 2. Observer 2 recorded EM's on data collection forms that were designed to correspond with the noted zone divisions. The design of the data collection form and the coding system used, along with the relatively low site volumes, allowed Observer 2 to maintain a "heads-up" posture and thereby capture approximately 90% of the EM's which occurred. The capture percentage was determined during the pre-data collection activities.



*Gore speed T = Through Movement, E = Exit
**JR = Streeter-Amet "Jr." Counter

Figure 6. Phase I Daily Data Collection Schedule

There were nine different EM's recorded by Observer 2: late exit lane change (LEC), late through lane change (LTC), gore crossing, swerve, braking, stopping, backing, slow driving, and revolves. In addition, each EM recorded received an additional code of "only", "first", and "subsequent" which was designed to describe the frequency and relationship to other EM's committed by an individual driver. The operational definitions of each erratic maneuver which is not selfexplanatory may be found in the Results and Conclusions Section (pages 27-38) under the discussion of each maneuver.

Two Streeter-Amet recording counters (tape print) were deployed in order to obtain continuous counts; one was located 200 ft (61 m) upstream of the data collection sign bridge, and one was located on an entrance ramp across from sign #8 (Figure 3). Observer 2 monitored both recording counters (as per Figure 6) to insure proper functioning. The final task of Observer 2 was the continuous monitoring of two CB radios; one turned to channel 5 to allow constant communication potential between the two observers, and one tuned to channel 19 to ascertain the success of the camouflage/concealment efforts of the observers.

Data reduction was rather straightforward. The EM data were tabulated and summarized; the speed data were summarized via calculation of means and standard deviations; and the volume data were corrected for truck volume. However, because the three periods of data collection occurred within a relatively short time span (approximately 3 months), none of the data reduction was undertaken until all the data was collected. This was done to avoid the possibility of introducing any form of bias or "self-fulfilling prophecy" between data collection cycles, i.e. to avoid any "expectations" of the EM observer based on the results of previous data sets.

The Phase I data collection activities were originally scheduled to take place in the summer months of 1976, however, a hold-up in the delivery of the symbol signs caused a delay in this schedule, and the "before" data was rescheduled on 19, 20, and 21 August based on a new delivery schedule. Still another delay in delivery resulted in the System A data being collected on 14, 15, 16 October and System B data being collected on 11, 12, and 13 November, 1976.

Data Analysis

The differences in erratic maneuvers between the "before" and "after" treatments or between two "after" treatments were assessed via the Z-statistic (Walker and Lev, 1953)*. This is a two-tailed test of the difference between proportions. The speed data were analyzed via a two-tailed t-test for large uncorrelated samples.

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*Walker, H. M. and Lev, J. "Statistical Inference", Holt, Rinehart, and Winston, New York, 1953. pp 77-79.

Results and Conclusions

Results and Discussion

Both experimental versions of the system were compared against the same set of baseline ("before") data, and since the second installation involved an addition of elements to the first system, the tables and results are presented for both systems together. Following the discussions of results are separate summary and conclusion sections for each system.

It will be recalled that the first system (System A) encompassed only the tabbing of the 24 x 24 inch symbol signs to the existing guide signs on the upstream approach to the site and the placement of the symbol signs in the gore and along the ramp. The second system (System B) involved the addition of "FOLLOW" and "TO" tabs to two symbol signs and the addition of upstream route/symbol association signs relating the symbols to the two movements.

The results are discussed with respect to lane changing activity, erratic maneuvers, and speeds.

Lane Changing Activity. Before proceeding into the discussion of results a note regarding lane changing activity is in order. Lane changing activity in an area approximately 600 ft (183 m) upstream of the gore was selected as a measure for two reasons. First, the pre-data collection observations indicated an excessive amount of late lane changing in the vicinity of the gore. Secondly, the guide signing on the site assigns through vehicles to the shoulder lane (lane 1) and exiting vehicles to the median lane (lane 2). It was felt, therefore, that if the color/shape system was effective, one positive outcome might be a reinforcement of the existing guidance and lane assignment information, and a corresponding reduction in directional confusion. This reduction in confusion would, in turn, be manifested and measurable in the percentage of drivers who would make a lane change near the gore. There are, however, two factors other than directional confusion which could exert an influence on the lane changing activity. The first of these is an entrance ramp located approximately 1200 ft (366 m) upstream of the site in close proximity to a shopping center. A large percentage of the presumably "local" drivers who use this ramp leave at the York exit. Secondly, when there are merging vehicles on the entrance ramp many of the mainline drivers who approach the ramp in lane 1 make a complementary change to lane 2. While the guide signing is specific as to the appropriate lanes for both through and exiting vehicles, the geometry of the site is deceptive. Thus, violation of the non-local drivers' expectancy regarding through versus exiting movements may result in late lane changes unrelated to routing/directional confusion. Further, the exiting drivers, a large percentage of whom are assumed to be familiar with the site, are able to exit from lane 1 with very little steering change.

In summary, it is difficult to say whether the late lane changes observed are in fact erratic maneuvers associated with directional, i.e., guide-sign related, confusion or whether they are associated with the combination of geometrics (driver expectancy violations) and the traffic patterns generated by the upstream entrance ramp. Because of these interpretive possibilities, system effects are treated both including and excluding late lane changes as erratic maneuvers in the discussions which follow.

In general, the overall percentage of drivers involved in late lane changes, i.e. those occurring in Zones 2 and 3 (see Site Schematic, Figure 2) was not significantly affected by either of the color/shape systems. Table 2 shows the aggregate incidence of late lane changes for each of the three conditions under consideration. It should be noted that statistical comparisons of the "before" condition with each of the treatments, for each type of lane change and for combined lane changes did not yeild significant z-values. The largest z-value in this set of comparisons was z = -0.997 for the "before"/System A comparison of late changes by through vehicles. Thus it can be assumed that the small increases and decreases noted can be attributed to sampling errors.

Table 2. Late Lane Changes

	LATE EXIT CHANGE		LATE THROUGH CHANGE		TOTAL	
	N	%*	N	%*	N	%*
"BEFORE" (N = 7366)	254	3.45	188	2.55	442	6.00
SYSTEM A (N = 6946)	237	3.41	196	2.82	443	6.23
SYSTEM B (N = 5469)	203	3.71	134	2.45	337	6.16

*% of Treatment Sample

In spite of the fact that the total incidence of late lane changes was not affected by the system, an analysis of the location of the lane changes indicates that Systems A and B had a positive effect. Table 3 shows lane changes by zone for exiting vehicles while similar comparisons for through vehicles are presented in Table 4. As can be seen in Table 3, the percentage of exiting drivers making a lane change in Zone 3, the zone which encompasses the physical gore, was reduced by 10.3% under System A and by 8.5% under System B. Both of these reductions are highly significant (z = 4.67, and z = 4.06 respectively). Table 4 shows similar results for through vehicles with a 7.0% and a 9.4% reduction in Zone 3 lane changes with Systems A and B. The reductions here were also statistically significant with respective test values of

$z = 2.03$ and $z = 2.44$. The differences between Systems A and B were not significant for either exiting or through vehicles.

Table 3. Zone of Lane Change - Exiting Vehicles

	ZONE 1		ZONE 2		ZONE 3	
	N	%	N	%	N	%
"BEFORE"	0	0.0	4	1.6	253	98.4
SYSTEM A	0	0.0	29	11.9	214	88.1*
SYSTEM B	0	0.0	21	10.1	187	89.9*

*Significant at $p < .05$ level

Table 4. Zone of Lane Change - Through Vehicles

	ZONE 1		ZONE 2		ZONE 3	
	N	%	N	%	N	%
"BEFORE"	0	0.0	161	80.9	38	19.1
SYSTEM A	41	16.6	176	71.3	30	12.1*
SYSTEM B	7	4.6	132	85.7	15	9.7*

*Significant at $p < .05$ level

Since all late lane changes are undesirable, the fact that the C/S systems resulted in a redistribution of this activity has positive safety implications in that an earlier lane change provides a driver with greater recovery time/distance before arriving at the physical gore and is more consistent with the expectations of interacting traffic. Further, it is likely to provide other drivers with greater latitude in reacting to unexpected maneuvers. The result then, suggests rather convincingly that drivers are less confused and are making their "exit/through" decision earlier with the help of the color/shape codes.

Erratic Maneuvers. It will be recalled from the discussion of the data collection methodology that the observational procedure was such that it was possible to identify and code each vehicle. Thus, erratic maneuver data were classified as to whether a given erratic maneuver was the "only" or "first" one committed by an individual driver or whether it was one in a series, notated as "subsequent". Use of the "first" or "only" EM's translates directly into the percentage of drivers involved. Since differences in traffic volumes and densities were observed across the various treatments the use of "first" or "only" (F/O) data is appropriate for the analyses; and, although "subsequent" (S) EM's are reported, it should be kept in mind that the percentage of drivers involved is the figure of merit for assessing system effectiveness. Moreover, it should be pointed out that with the "subsequent" EM's there is frequently a necessary "chaining" of events e.g., a driver must stop before he backs at the gore, thus there is a lack of independence in those measures designated as "subsequent" (S). It is reasonable to assume, however, that to the extent that the system acts to prevent the "first" EM, the "subsequent" EM's will not occur. In virtually all cases of multiple EM's, the sequence is performed over a short section of roadway, i.e., within the same zone or in adjacent zones; it was seldom that a driver performed an erratic maneuver, say, in Zone 1 and another in Zones 3 or 4.

Considering first the grouped data for the "before" condition, it was found that 124 EM's were performed by 74 drivers (that is, 1.0% of the drivers were involved in some sort of single or multiple EM's other than a late lane change), for an overall error rate of 16.8 EM's per thousand vehicles. The evaluation of C/S System A showed an involvement reduction to 109 EM's for 53 drivers (0.82% of the sample). Although the difference was in the desired direction, the reduction did not prove to be statistically significant ($z = 1.115$). The overall EM rate with the System A treatment was 15.7 EM's per thousand vehicles.

The System B evaluation showed an even further reduction with 68 EM's performed by 37 drivers, for 0.68% driver involvement, or an overall system error rate of 12.4 EM's per thousand vehicles. This reduction did achieve significance producing a $z = 1.985$ ($p < .05$). It should be noted that no significant difference was found when the two experimental treatments were compared ($z = 0.919$). As mentioned previously, alternative arguments can be advanced regarding the treatment of late lane changes as erratic maneuvers given the geometric design and operations of the site. Whatever the interpretation, however, late lane changes constitute hazardous driver behavior and in the interest of determining the overall effectiveness of the systems (particularly with regard to safety) another analysis was conducted using the combinations of late lane changes and erratic maneuvers as the criterion variable.

When late lane changes and erratic maneuvers are collapsed, the percentage of drivers involved in one or more errors becomes 7.01% for the "before" condition; and 7.05% and 6.84% for Systems A and B respectively. The differences of interest was not shown to be statistically significant (for the "before"/A comparison $z = 0.115$; and, for the "before"/B comparison $z = 0.367$). Thus, it would appear that the increase in drivers involved in late lane changes offset the significant decrease of those involved in erratic maneuvers.

Under the assumption that a majority of the drivers using the York exit were local drivers and that a larger proportion of the through drivers were unfamiliar drivers, a comparison was made collapsing erratic maneuvers and late lane changes for through drivers (i.e., excluding late lane changes by exiting drivers). The rationale for this comparison was that it is only the unfamiliar driver who can benefit from the system and therefore the use of a "through-vehicle" sub-sample provides a more sensitive and appropriate test because, presumably, it contains a higher proportion of unfamiliar drivers. These comparisons produced mixed results: a non-significant $z = 0.151$ for the "before"/A data; and a "before"/B comparison which yielded a $z = 1.625$ ($.10 > p > .05$). Thus it would appear that the second version of the color/shape system (System B) has an overall positive effect when the contaminating influence of largely familiar drivers is removed.

Although no specific erratic maneuver occurred with sufficient frequency to provide a statistically reliable sample, certain changes which were observed in some of the erratic maneuvers have implications for system effectiveness and deserve discussion. Table 5 shows the frequency of the various types of erratic maneuvers for each treatment.

Table 5. Erratic Maneuvers by Type (First or Only/Subsequent)

	"BEFORE" (N = 7366)		SYSTEM A (N = 6946)		SYSTEM B (N = 5469)	
	F/O*	S**	F/O	S	F/O	S
GORE CROSSING	1	21	0	11	0	4
SWERVE	22	5	27	2	8	8
BRAKING	16	3	15	10	13	4
STOPPING	17	9	7	8	11	3
SLOW DRIVING	5	2	7	16	2	5
REVOLVE	13	1	1	2	3	1
BACKING	0	9	0	3	0	6
TOTAL	74	50	57	52	37	31
PERCENT***	1.0	NA	0.82	NA	0.68	NA

*F/O = "First" or "Only" EM's
**S = "Subsequent" EM's
***% of treatment sample

One complex erratic maneuver, really a series of maneuvers, which is highly hazardous and constitutes a confirmed "lost" driver is the "revolve". The revolve is a maneuver in which drivers would take the York exit and downstream of the exit would apparently realize their directional decision was an error. In order to return to 83N, the drivers would cross a flat grass median to Business 83S, which parallels the exit ramp, drive on B83S to a point opposite the test site exit, and re-cross the grass median to return to 83N. This maneuver required no less than three entries into high speed lanes of traffic with each entry involving a perpendicular exposure to oncoming traffic by the offending vehicle. The last two exposures, i.e. crossing of the York exit ramp and entry to 83N, were interrupted by a gore crossing. Frequently, the gore crossing involved a rapid dash across the York exit ramp due to oncoming ramp traffic, and then a subsequent stop or slow driving in the gore for purposes of finding a gap to enter the 83N movement. This "revolve" maneuver is interesting in that it represents what is in most studies of this type the "phantom" lost driver, i.e. those drivers who make an error in the exit decision but do not exhibit any performance problems and are therefore never identified. Over half of the drivers involved in this maneuver made a smooth exit maneuver at the gore and continued smoothly for a reasonable distance down the ramp. But for the high observational vantage point and the tangent ramp which was visible for more than one-half mile, these maneuvers would not have been captured.

During the "before" condition, 14 revolves were observed. This was reduced to 3 and 4 for Systems A and B respectively.

Given the degree of hazard associated with this maneuver, occasioned by multiple opportunities for serious conflict, the curtailment of the maneuver produced by the C/S system promises a substantial safety benefit and lends support to the assumption that it aids the unfamiliar driver in route guidance.

Gore crossings <u>not</u> associated with the "revolve" EM was reduced from 22 in the "before" condition to 11 and 4 for Systems A and B respectively. With a single exception, in the "before" condition, all of the gore crossings followed another type of erratic maneuver, with the most frequent preceding EM being a swerve association with a last minute decision. Combining the gore crossing association with the "revolve" and those occurring in association with other EM's, the observed reduction was from a total of 36 in the "before" condition, to 14 with System A, and a further reduction to 8 with System B.

Swerves were operationally defined as an abrupt change in lateral placement within approximately 100 ft (30 m) of roadway where the change involved the crossing of a lane line. The differentiating feature between the swerve and the lane change was the degree of abruptness with which the manuever is performed. It should be noted that swerves made in response to the action of another vehicle were not counted as erratic maneuvers. The comparison of the "before" condition with System A showed a slight increase from 27 to 29 occurrences respectively. However, with the installation of System B, the number of swerves was reduced to 16. The majority of the swerves (75% of the total) are almost certainly the result of directional confusion in that they occurred in Zones 3 or 4, the zones which include the painted gore (Zone 3) and the physical gore (Zone 4) or, alternatively, zones which represent the final choice points for directional decision-making. A review of the occurrence of swerves by zone (see Table 6) shows that for the "before" condition 24 of the 27 swerves (or 92%) occurred in the painted or physical gores whereas with System A, 22 of the 29 (or 75%) occurred in this area. Thus, although there was a slight increase in frequency from the "before" to the A condition, the percentage of maneuvers occurring in Zones 3 and 4 was decreased, suggesting that on the average, drivers realize their directional errors earlier with information provided by the C/S symbols. With the B System, this improvement was even greater with only 44% of the swerves occurring in the critical zones encompassing the gores.

Table 6. Swerves by Zone

	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	TOTAL
"BEFORE"	0	2	21	4	0	27
SYSTEM A	1	6	20	2	0	29
SYSTEM B	0	9	7	0	0	16

Because of the site geometry and the existing signing on the site, braking as a separate erratic maneuver was not collected. That is, in Zone 2, an existing speed reduction sign advises a 40 mph (64 kph) limit for a rather severe (by Interstate standards) horizontal curve of the I-83 through movement, with the curvature beginning in Zone 3. Thus, the majority of the through drivers brake on the approach to the cruve. The brakings shown in the erratic maneuver listing were only those that were recorded in conjunction with a series of erratic maneuvers, with the majority of brakings recorded being the first in a series. The frequency of braking maneuvers associated with the three treatment conditions are shown in Table 5. In summary, there was an increase in braking frequency from 19 in the "before" condition to 25 under System A. However, the B condition accounted for 17 brakings, a very slight improvement over the "before" condition. It appears, therefore, that System A had, if anything, a negative effect upon braking behavior and that System B had essentially no effect. An inspection of the braking by zone of occurrence (see Table 7) reveals that both systems seemed to result in a concentration of braking maneuvers in Zones 2 and 3, as compared to the "before" condition where they were more concentrated in Zones 1 and 2.

Observations of the erratic maneuver entitled slow driving was based on a subjective judgment by the data collection personnel. As such, it is the least reliable of the EM's observed. It was recorded when a driver was observed proceeding at a rate which was considerably slower than other site traffic.

Table 7. Braking by Zone

	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	TOTAL
"BEFORE"	5	7	4	3	0	19
SYSTEM A	1	9	12	2	1	15
SYSTEM B	0	9	8	0	0	17

Slow driving was chosen for inclusion, in spite of the potential unreliability, because it was an event observed during the initial site review and during pilot data collection and it was felt that such a behavior was indicative of a driver being confused with respect to his directional decision. Further, since the same data collection personnel were used for each of the data collection phases, it was assumed that any problems involving the judgments would be manifested in all phases and would therefore not produce a bias favoring one condition. As can be seen in Table 5, the freuqency of slow driving observed under System A was more than three times greater than for either the "before" condition or the System B condition. The distribution of this maneuver across zones was similar in all three phases.

The most likely explanation of the increase in both slow driving and braking under the System A is that the system did not provide enough information to permit many of the drivers to make the association between their destination and the symbols. Thus the symbols, used as they were in System A, produced confusion on a site where the geometry per se generates uncertainty for the unfamiliar driver. It is hypothesized that drivers who were already confused by the site configuration detected the symbol signs and, since they were attached to the guide signs, knew that they must mean something thus engaging in more than usual braking and slowing while trying to determine the meaning. The relatively poor visibility and placement of the symbols, as discussed in the site description, is also likely to have contributed to the increase in slowing and braking.

Stopping and backing are the remaining driver errors in the erratic maneuver set. Taking the first of these, data in Table 4 shows that the incidence of stopping decreased from 26 occurrences in the "before" condition, to 15 and 14 under treatments A and B respectively. Table 8 presents the location of the stops observed. Note that the majority of the stops occurred in Zone 4, the zone encompassing the physical gore. While stopping anywhere on the site is fairly dangerous, stopping in Zones 4 and 5 is potentially even more hazardous, since it requires either a backing maneuver or a crossing of the physical gore in the event that the driver decides that he made an improper route

Table 8. Stopping by Zone

	ZONE 1		ZONE 2		ZONE 3			ZONE 4			ZONE 5		
	M*	S**	M	S	M	S	G***	M	S	G	M	S	TOTAL
"BEFORE"	-	1	-	1	-	2	3	2	5	8	2	2	26
SYSTEM A	-	3	-	1	1	-	-	1	2	5	1	1	15
SYSTEM B	-	1	-	4	1	2	-	-	2	2	-	2	14

*M = Stops in mainline (on roadway)
**S = Stops in shoulder
***G = Stops in gore

choice. It should be noted that all but one of the backing maneuvers shown in Table 5 involves vehicles which had stopped in Zones 4 and 5. Given the degree of hazard associated with stopping in Zones 4 or 5, the results suggest that the C/S system may induce a locational/safety benefit in addition to the overall reduction in frequency. That is, in the "before" condition, 73% of the stops observed occurred in Zones 4 or 5, whereas under the two system treatment conditions the percent ages occurring in these two zones was reduced to 67% for System A, and further to 43% with System B.

Speeds. It will be recalled that spot speed samples were taken via radar in the vicinity of the gore separating the exit and through movement and at two upstream locations. Means and standard deviations for the speed samples at each location are shown in Table 9. As can be seen, neither of the C/S systems had any substantial effect, and certainly no practical effect on the mean speed at any of the locations. With the exception of the speed of exiting vehicles, none of the speed changes were statistically significant. However, it should be noted that the curvature of the through movement along with the speed reduction advisory sign acts to restrict the speed and range of speeds of through vehicles. Paradoxically, for the sample of exiting vehicles, both of the C/S systems resulted in statistically significant ($p = < .05$) increases in mean speeds, each associated with a reduction in speed variance. The t-values obtained were $t = 3.02$ and $t = 3.32$ for System A and B comparisons respectively. Since the majority of the exiting vehicles are assumed to be local, familiar drivers, this significant change is not readily explainable. However, three possibilities can be offered for consideration. First, is the possibility that the decreases in volume from the "before" phase thru the two treatment phases account for the increase. However, if this is the case, the speeds in both of the upstream locations could be expected to increase. As can be seen in Table 9, this is not so; while the mean speed at the location on the approach to the gore (pre-exit speed) increases slightly, the mean speed at the free flow measurement location decreases slightly. The pattern of mean speeds then casts doubt on any volume-related explanation.

Another explanation which can be offered is that the observed reduction in erratic maneuvers associated with the C/S system improved the traffic flow characteristics with the resultant increase in exit speeds. Again, however, the pattern of speed effects from the various locations casts doubt on this explanation, as does the fact that the volumes on this site are sufficiently low that there are few stream perturbations produced by erratic maneuvers.

The final explanation is that the upstream shift in lane changes (observed under both C/S systems) was reflected in the speed increase for exiting vehicles. This explanation is based upon the assumption that drivers who enter the upstream portion of the site and continue through the exit without being required to perform a lane change will be at a higher speed upon entering the gore than will those

Table 9. Speed Data by Location

	I-83		E/B83		PRE-EXIT		FREE-FLOW	
	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α
"BEFORE"	47.4	4.8	52.2	7.5	50.9	5.6	52.3	5.9
SYSTEM A	47.8	4.7	54.3	6.4	51.3	4.7	52.0	5.1
SYSTEM B	46.9	5.2	54.9	5.0	51.5	5.4	51.8	6.0
"BEFORE"/SYSTEM A t's	t = 1.312		t = 3.02*		t = 1.32		t = .885	
"BEFORE"/SYSTEM B t's	t = 1.409		t = 3.32*		t = 1.62		t = 1.28	

*significant at p < .05 level

drivers who have had to perform a lane change in the last 200 or 300 ft (61 or 91 m) before the gore. Thus, to the extent that the lane changes are occurring earlier, the speed of lane changing vehicles will more closely match the speed of the faster non-lane changing vehicles. Given that the mean speed included both lane changing and non-lane changing vehicles, this "matching" would result in a higher mean speed and a reduced variance, as observed. This effect would not be expected to be reflected in the upstream speeds. Nor would it necessarily be expected to be reflected in the through movement gore speeds because of the restriction imposed by the curvature and/or speed advisory sign. In short, the pattern of speeds does not cast doubt on this final explanation. Thus it is the one which appears most tenable.

Summary and Conclusions - System A

It will be recalled that this first system installed on the site constituted an absolute minimum system. That is, it involved only the tabbing of the symbol signs in the best available location on the existing guide signs along with the use of symbol signs in the gore area and along the exit ramp and through movement. Generally, the symbol tabs were on the periphery of the guide signs. Further, there was no supplemental signing to inform drivers about the system. This system would be the least costly and easiest to implement for a "quick fix" on a problem interchange and for this reason, it was felt that it was a useful starting point for the field evaluations. Further, one of the contract objectives was to develop guidelines for implementation; thus beginning the field evaluations with a minimum system and proceeding to more elaborate systems on subsequent field tests was consistent with this contract goal.

The tabbing procedure was judged to be poor for two reasons. First, the format of some guide signs was such that it was not possible to place the symbol tabs in appropriate proximity to the relevant destinational information, thus reducing the potential for drivers to make the necessary association between the route and symbol. Secondly, on some of the guide signs the symbols tabbed on the periphery had poor visibility and therefore, poor target value because the sky served as background. While target value could be enhanced by using larger symbol signs, it was initially felt that symbol signs larger than the 24 x 24 inch signs used might "compete" with the guide sign information and that this was undesirable.

In summary, the overall visibility of the system was judged by the staff to be less than adequate, primarily because of the peripheral tabbing of the symbols. This subjective evaluation is at least partially supported by the results of the evaluation.

System A did not produce either a significant reduction in the total number of late lane changes or a significant reduction in the total number of erratic maneuvers. While there was a slight decrease in the percentage of exiting drivers making late lane changes, there was a slight increase in the percentage of through drivers who did so. The combined exiting and through late lane changes showed a slight increase. However, on a positive note, the system resulted in an improvement in the pattern of lane changing. That is, while the total number of late lane changes did not change significantly, there was a lower percentage of lane changes made in the area encompassing the painted gore (Zone 3) for both exiting and through vehicles. In the case of both exiting and through vehicles the difference was statistically significant. This upstream shift in lane changes results in less turbulence in the gore area and a safer operation.

While the changes were not statistically significant, there was in fact, a reduction in both the percentage of drivers involved in erratic maneuvers, and in the total number of erratic maneuvers under the C/S system.

With regard to specific erratic maneuvers; revolves, gore crossings, stopping, and backing were reduced in frequency, with swerves showing a very slight increase with System A. However, braking and slow driving showed an increase after installation of the system. It is hypothesized that the increases in these two maneuvers reflect problems in visibility and driver understanding of the meaning of the symbols. Finally, with regard to upstream speeds and gore speeds, the system produced no practical changes. However, the exit gore mean speed was increased from 52.2 mph (84 kph) in the "before" condition to 54.3 mph (87 kph) with the system and the variance was reduced from 7.5 mph to 6.4 mph (12 kph to 10 kph). The difference was statistically significant ($p = > .01$).

In summary, it is concluded that system configuration A does not merit further investigation since it was not shown to have a broad enough facilitative effect on overall driver performance.

<u>Summary and Conclusions - System B</u>

The second system involved the addition of information elements to System A. Two upstream signs were added to provide information to drivers regarding the association between the symbol signs and each traffic movement. Also, "FOLLOW" and "TO" verbal tabs were added to two symbol signs. The addition of the black-on-white "FOLLOW" and "TO" tabs added target value and some informational definition to the symbol tabs.

As with the first version of the system, there was no statistically significant effect upon late lane changing activity. However, the percentage of exiting drivers involved in late lane changing was slightly increased and the percentage of through drivers was decreased. Also there was a significant reduction in the percentage of the late lane changes which occurred in the zone which includes the painted gore (Zone 3), a favorable upstream shift in the location of the maneuver.

Unlike the first system, System B resulted in a statistically significant reduction in total erratic maneuvers and in the percentage of drivers involved in erratic maneuvers. Further, if erratic maneuvers and late lane changes by through drivers are combined, i.e. excluding exiting drivers who are assumed to be largely local and familiar, there was a statistically significant reduction in the total number of errors under System B.

With the exception of the slow driving EM, all other erratic maneuvers were reduced under the System B treatment, with the frequency of slow driving remaining the same as the "before" condition. Also, the increases in braking and slow driving which were observed in conjunction with System B, were reduced to the "before" levels observed. This "recovery" when viewed in association with the positive effects of the system, suggest that the additional information added for the System B configuration had considerable benefit.

The effects of System B on speeds are similar to the results observed with System A. That is, there were no practical differences, but the increase in exiting mean speed was larger than that of the "before" and System A conditions and variance was also decreased.

In summary, the information added to the system for this configuration appeared to have a positive benefit as evidenced by the overall significant reduction in erratic maneuvers and the improvement in other aspects of driver performance. It was concluded that the system as configured for the System B evaluation showed enough promise that further testing of this system was merited on another type of site.

PHASE II EVALUATION

Site Description

This site is on I-76 East in Philadelphia, Pa.; site configuration is depicted in Figure 7. Prior to the site, I-76 East is three lanes. Within the site these three lanes diverge and become three separate movements. Each of the three mainline lanes is augmented by an additional lane, with the lane additions being created by a widening of mainline lane 2 within the site. The left-hand median (mainline lane 3) continues through the site to become exit lane 6. With the addition of exit lane 5, this movement becomes Exit 5 to 26th Street and the Philadelphia International Airport. The center lane (mainline lane 2) widens progressively throughout the site to become exit lanes 3 and 4 serving Exit 6 to Passyunk Avenue. The right shoulder lane, (mainline lane 1) with the added lane serves as the through movement of I-76 East to the Walt Whitman Bridge.

Upon entry to the site, the roadway is approximately 36 ft (11 m) wide with each lane being 12 ft (3.7 m) wide; there is no shoulder at this point. At a point 465 ft (142 m) from the right physical gore, or 100 ft (30 m) above the sign bridge, the highway begins to diverge, being 38 ft (12 m) wide. At the sign bridge, the road width is 47 ft (14 m) with the center lane having diverged to 22 ft (7 m) while the median and shoulder lanes are 12 and 13 ft (3.7 and 3.9 m) wide respectively. Subsequent to the sign bridge, a shoulder is added. At the widest point in the site before the lanes diverge, the roadway width is 93 ft (28 m) with the increase in width reflecting solely the widening of the center lane. In the mid-section of the site, prior to the gores, lane 2 becomes a broad expanse of undelineated blacktop.

Signing for the site consists of three sign bridges with additional ground-mount guide signs as shown in Figure 8. The first sign bridge is approximately 3000 ft (914 m) upstream of the right physical gore. This sign bridge immediately precedes a right exit to 28th Street. The center sign assigns the Passyunk Avenue movement, Exit 6, to the center lane, indicating additionally that the exit is 1/2 mile downstream. The left sign assigns the leftmost lane to the 26th Street exit which is also signed as being 1/2 mile downstream. This signing also indicates, by a top tab, that the airport can be reached via the 26th Street Exit. The second sign bridge, which is 1780 ft (543 m) upstream of the right physical gore, makes lane assignments appropriate to the three movements through the site. The signing to 26th Street is again top tabbed for the airport. Signing for the through movement on I-76 is given on the rightmost sign; this sign also defines the right lane as the movement to the Walt Whitman Bridge. The sign arrangement of the second sign is duplicated in the third sign bridge with one exception. On the second sign, only the right lane is indicated as the appropriate lane for the Walt Whitman Bridge, whereas on the third sign, the signing for the Walt Whitman Bridge/I-76 movement suggests, with an additional down arrow, that the middle lane is also assigned as appropriate to the

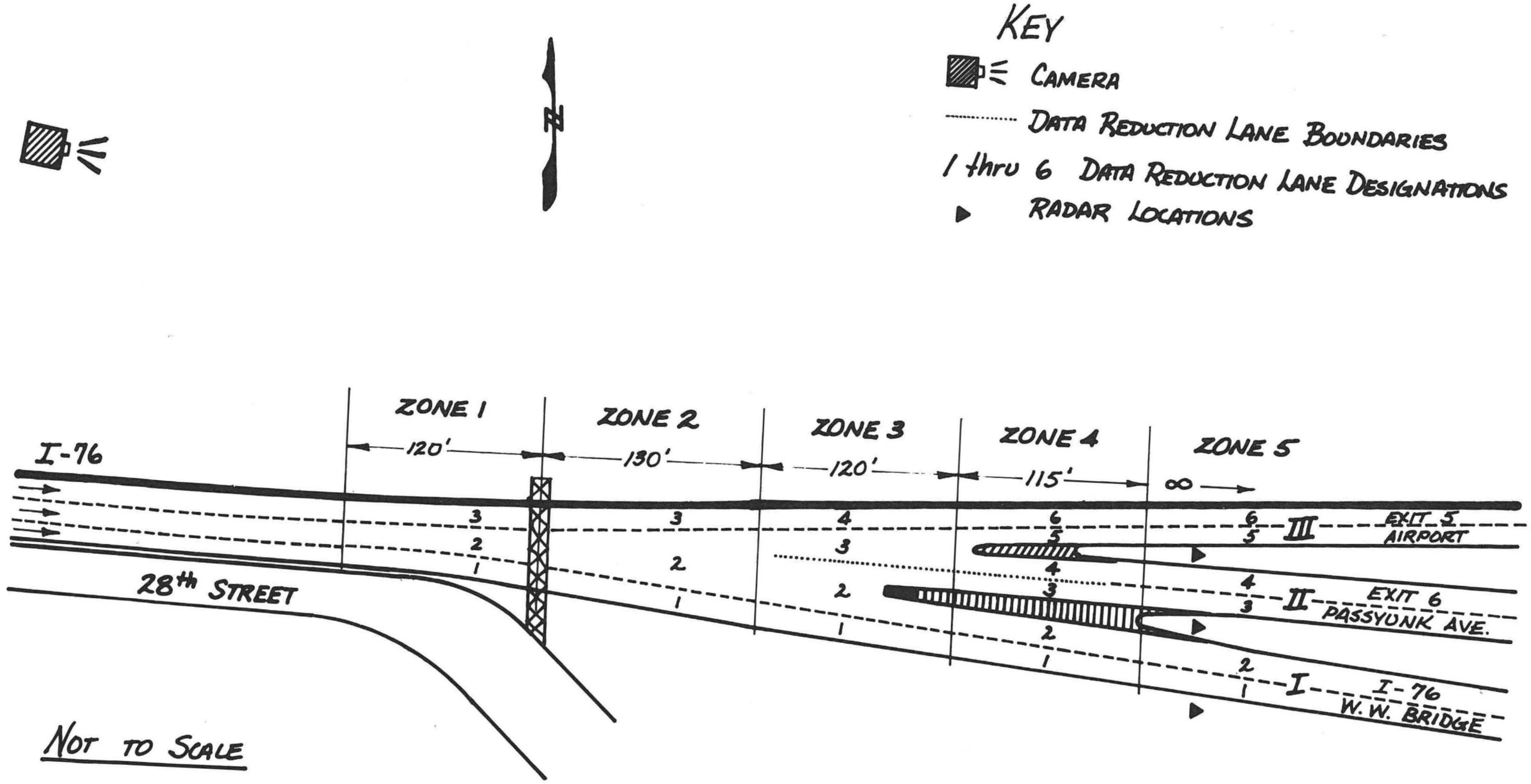

Figure 7. I-76 Philadelphia Site Schematic

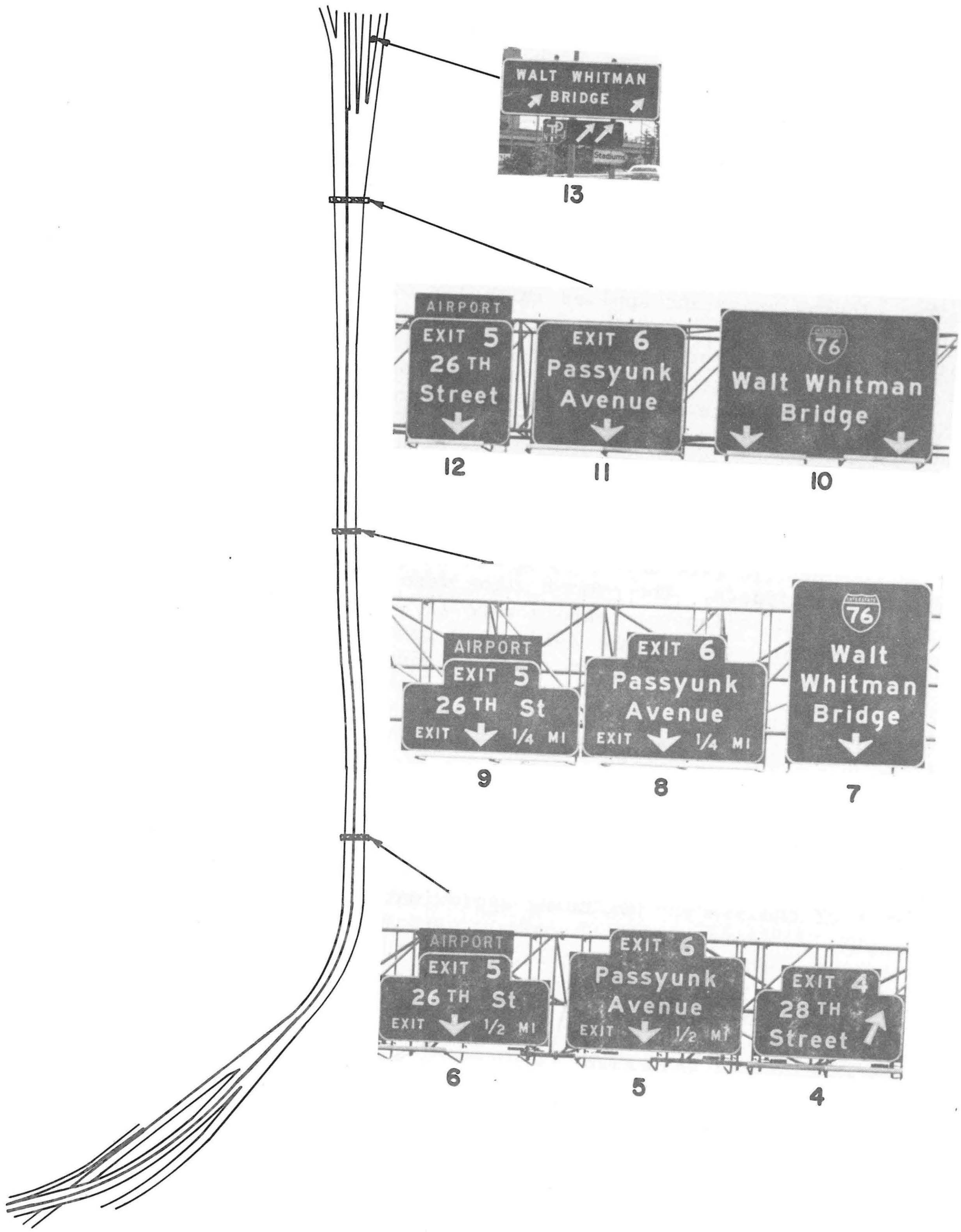

Figure 8. I-76 Philadelphia Site Existing Signing

movement. Another major component of the signing is a post-mounted sign in the right physical gore which indicates, via arrows, that the movement to the Walt Whitman Bridge via I-76 should move to the right-hand roadway; this sign is also tabbed with a turnpike route marker and a sign labeled "STADIUM".

The speed limit for the site is an unposted 55 mph (88 kph).

Signing Treatment

The signing treatment applied initially to this site in Phase II of the color/shape system evaluation was a modified version of System B as it was applied at York. System C is a modification of System B in that it omits introductory signing but uses the "FOLLOW" and "TO" message format on all site signing. The deployment of the symbols on the existing site signing is shown in Figure 9. The coral heart symbol against a black background was associated with the Walt Whitman Bridge/East I-76 movement. The purple halfmoon shape against a grey background was applied in association with the Passyunk Avenue/Exit 6 movement. The strong yellow-green barbell symbol against a black background was used in conjunction with Exit 5 to 26th Street and the Philadelphia International Airport. The symbol signs were 24 x 24 inches while the post mounted delineator symbols were 12 x 12 inches in dimension. The post-mounted gore and ramp delineator symbols were deployed differently for the three movements in order to adapt to the site configuration. The ramp delineation symbols were mounted on 100 ft (30 m) centers. For Exit 5, symbols delineated a path with five post-mounted symbols on the gore shoulder starting at the beginning of the physical gore, 40 ft (12 m) downstream of the gore tip, and three symbols mounted on the concrete median. The Passyunk Avenue/Exit 6 movement was designated by three symbols on each side of the roadway, with the first symbol on each side placed 40 ft (12 m) downstream of the tip of the gore. The I-76 East path was delineated by five symbols mounted on each side of the roadway beginning approximately 25 ft (8 m) downstream of the physical gore tip. All symbols were mounted with a four foot clearance from the roadway. Criterion for the placement of the initial gore symbols was a tradeoff between visibility and the potential hazard created by the posts.

Data Collection and Reduction

Initial efforts to manually record data on site were found to be both unreliable and inadequate in capturing a large enough sample of the population. Consequently, film data collection was chosen because it permitted the capture of a 100% sample. In addition to the film data, spot speeds were obtained for each of the six exit lanes.

Film data was obtained via a camera mounted on a billboard adjacent to the opposing (westbound) movement of I-76. The line of camera sight subtended an angle of approximately 50 degrees relative to the roadway. The camera was mounted on a tripod clamped to the sign

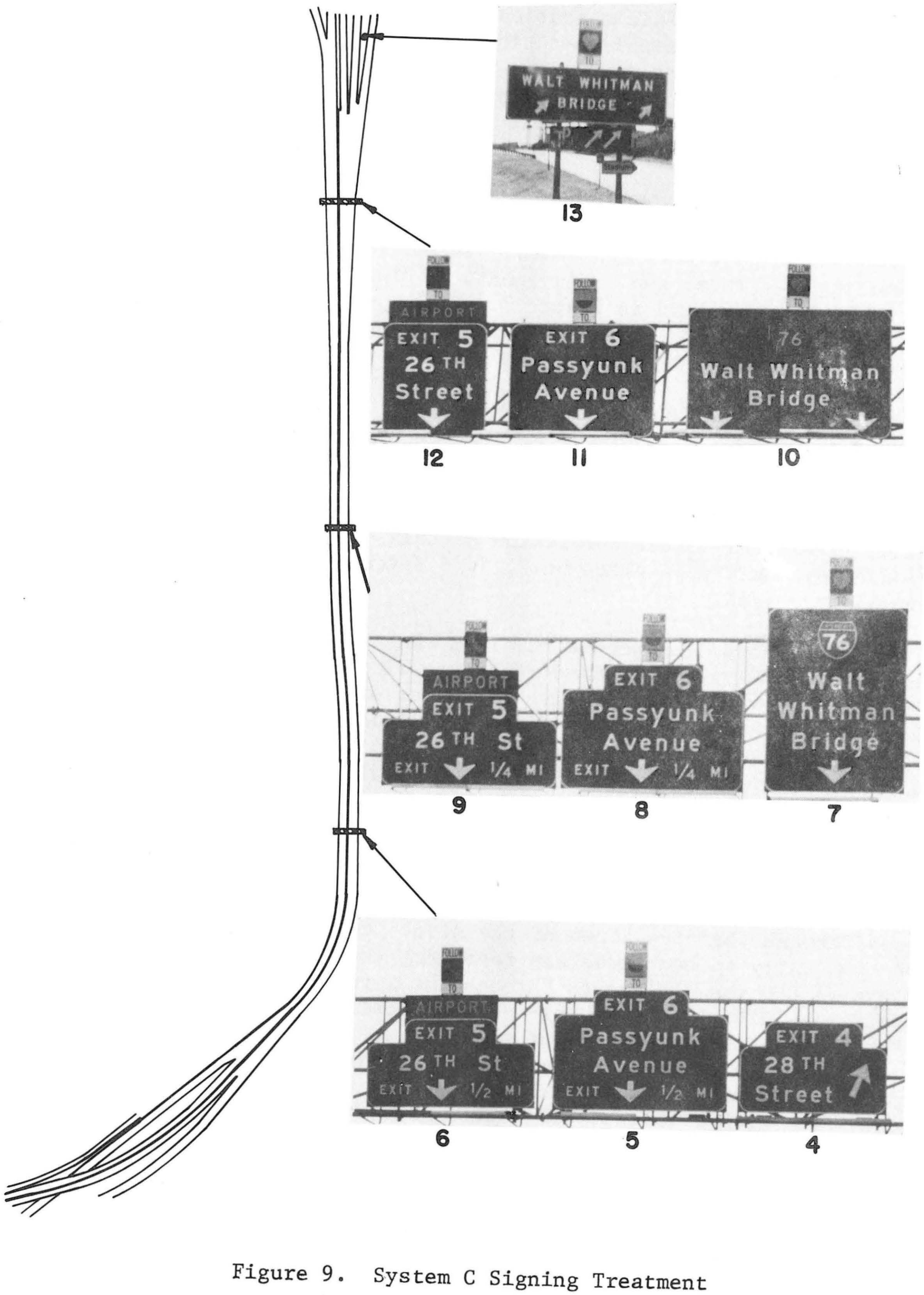

Figure 9. System C Signing Treatment

superstructure approximately 60 ft (18 m) above the roadway surface. The camera recorded traffic operations from a point 485 ft (148 m) upstream of the right physical gore tip to a point approximately 150 ft (46 m) downstream of that same gore; Figure 7 illustrates the approximate location of the camera. The camera used was a Beaulieu 4008ZM II, a Super 8 timelapse camera, recording events at a rate of 4 fps. GAF Super 8 film was used.

Speed samples were obtained for a morning and afternoon period during each day of data collection. During each speed sampling period, 50 speeds per exit lane were collected. Speeds were obtained using a CMI handheld doppler radar gun. Placements of the observer for recording exit speeds are depicted in Figure 7. Speeds were taken from a concealed position and CB Channel 19 was monitored simultaneously with speed data collection to ensure that the data collection was unobtrusive.

The data collection schedules for both filming and exit speeds are shown in Figure 10. Thirty minutes of film data, or two cassettes, were obtained for every scheduled hour of data collection and speed data collection occurred in conjunction with film data collection. The "before" data was obtained on 14, 15, 16 October and System C was installed immediately after completion of this data collection. The evaluation of System C took place on 4, 5, 6 November after a two week acclimation period.

The data reduction scheme involved the use of a grid which, when imposed upon the site, provided reference lines for lateral and longitudinal movement through the site and a set of definitions for data points to be obtained from the film. The grid was comprised of five zones, lane lines, and a supplemental "lane line" separating lanes 2 and 3 for Zones 3 and 4 to provide a more definitive reference for lateral movement in the broad undelineated area in Zones 3 and 4 of the site. The zone and boundry grid used for data reduction is reflected in Figure 7.

The data reduction plan required that the path of each vehicle be traced through the five zones of the site. For each vehicle, lane position upon entry to <u>each</u> zone was recorded, thus providing a composite picture of the vehicle's path through the site. Where a lateral change in path was initiated by a vehicle, lane position upon entry to a zone was defined by the leading front wheel of the vehicle. Within the context of the path recorded for each vehicle, erratic maneuvers were recorded by zone of occurrence. The following erratic maneuvers were reduced from each film: stops, backs, lane straddles, swerves, gore encroachments, and gore crossings. While occurrences of backing and stopping are self explanatory, operational definitions were derived for each of the other erratic maneuvers as follows:

<u>Gore encroachment</u> was coded when the leading wheel of a vehicle crossed the painted gore;

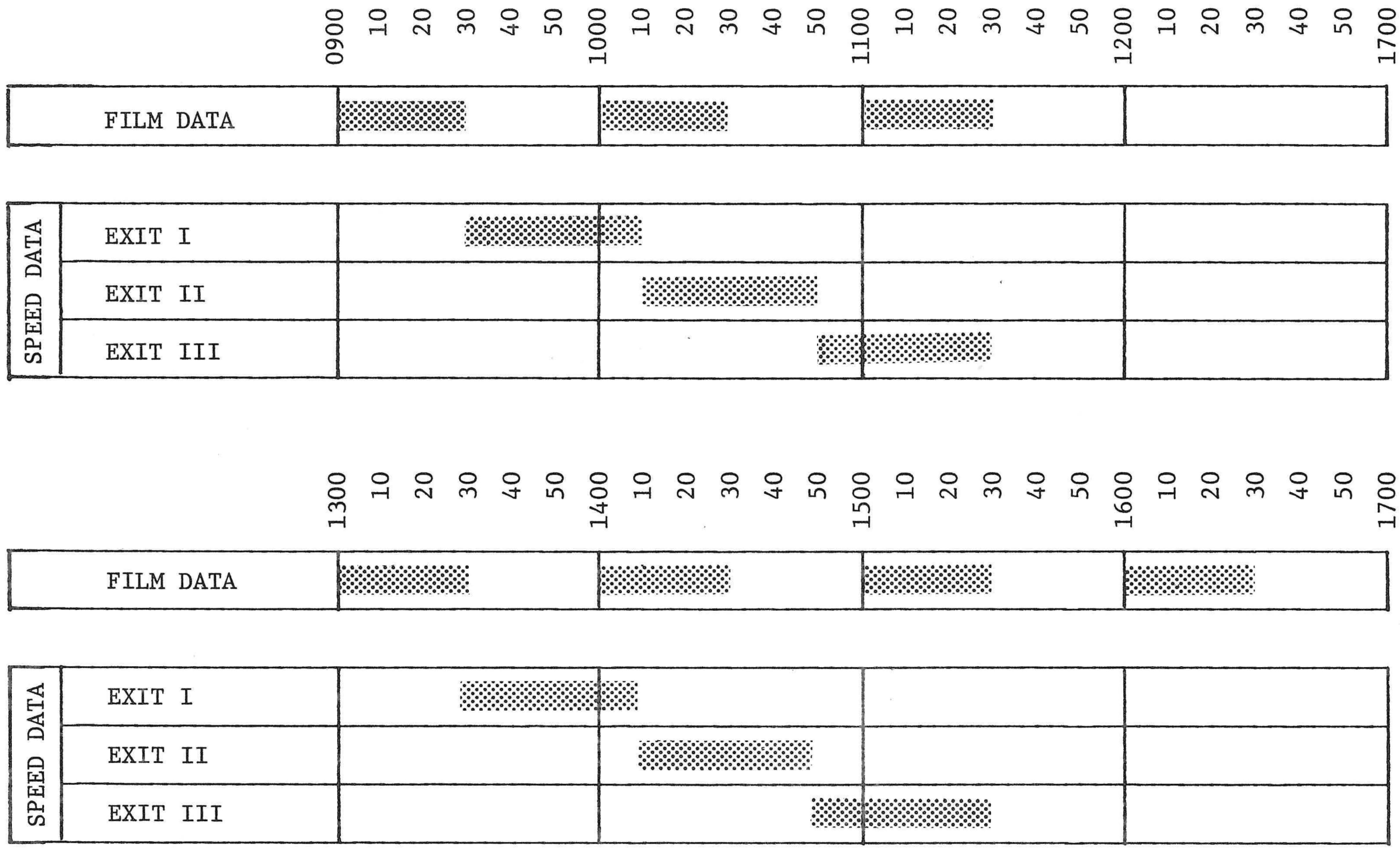

Figure 10. Phase II Daily Data Collection Schedule

Gore crossing was coded when all four wheels crossed the painted gore;

Lane straddle was coded when a vehicle crossed a lane line and then returned; this maneuver was coded by zone of occurrence not simply zone of initiation.

Swerve was coded when a vehicle was observed making a rapid, severe lateral displacement of a full lane width within approximately 100 ft (30 m) longitudinally.

While the coding of swerves required a subjective judgment on the part of the data reduction personnel, they were trained to capture this maneuver by using a number of examples chosen from the films by the research staff.

In all cases where there was a questionable data point, the data collection personnel "tagged" the maneuver via film frame number and senior personnel on the project staff made the decision regarding the appropriate code.

It should be noted that Thursday data was excluded from both sets because a maintenance crew had worked on guardrails near the entry to the site during "after" data collection, and it was felt that this situation may have had an influence on the data. For both the "before" and "after" conditions, 14 of the 28 films were reduced.

Data Analysis

After the reduction of data from the film was accomplished, the data were keypunched for computer processing. Computer sorting of the data was accomplished through application of the "Statistical Package for the Social Sciences" (SPSS).

The differences in erratic maneuvers between the "before" and "after" treatments or between two "after" treatments were assessed via the z-statistic (Walker and Lev, 1953)*. This is a two-tailed test of the difference between proportions. The speed data were analyzed via a two-tailed t-test for large uncorrelated samples.

Results and Conclusions

With two exceptions, the color/shape coding system used for the first Philadelphia field test was essentially the same as System B developed for the York site. The only differences between the experimental treatments was that the upstream informational signs which were used for System B in York were not employed in this evaluation and all symbol signs utilized "FOLLOW" and "TO" plates. Although the initial

*Walker, H. M. and Lev, J. "Statistical Inference", Holt, Rinehart, and Winston, N.Y. 1953, pp. 77-79.

plans for Philadelphia called for the installation of System A (as used on the York Site) a decision was made to include the "FOLLOW" and "TO" tabs for two primary reasons: first, the existing guide signs on this site were considerably larger than those on the York Site; thus, the symbol signs alone would have had even less visual impact (target value) on this site than they did at York. Second, it was felt that the informational value provided by the addition of the "FOLLOW" and "TO" tabs was necessary, since specific definition was not provided by the upstream system-related information regarding the proper use of the system.

The results and discussions which follow are divided into three subsections corresponding to the primary dependent variables of interest, viz., path data, erratic maneuver data, and speed data. Next, a conclusion section is provided which summarizes the overall performance of the system.

Results and Discussion

Timelapse photography was the principal means of data collection on this site, thus it was possible to trace all vehicle paths through the observation area. However, because the width of the roadway increased and lane markings were not present in Zones 2 and 3, the usual type of lane changing activity analysis was not feasible. For purposes of data reduction, then, Zone 3 was analytically divided into four "lanes" in order to more accurately specify the vehicle paths throughout the site. However, drivers did not have the advantage of such lane lines for guidance. Note also, that the extreme width provided a great deal of latitude for the driver who enters the site in lane 2, and remains in lane 2. From the site schematic (Figure 7), the reader can appreciate the fact that the transition from mainline lane 2 to exit lane 2 or 5 can be made smoothly if a lateral shift in the appropriate direction is started in Zone 2; however, the driver who is uncertain of his exit is not likely to make the lateral committment early enough. The result of such uncertainty is frequently a gore encroachment, gore crossing, or a swerve. Because of this feature of the site, path data are used as a general indication of performance related to lane assignment while erratic maneuver data serves as a more specific safety-related indicator of system effects.

Path Analysis. Path data in the most general form are presented in Table 10 which shows the number and percentage of drivers who entered the site in each mainline lane along with which exit was used. A summary calculation based upon the diagonal cells of each table, shows that the percentage of drivers who entered in the lane appropriate to the exit used (e.g., entered in mainline lane 1 and left via Exit I*) increased from 76.3% (N = 5409) for the "before" condition to 77.6% (N = 6058) for the "after" (System C) condition. Although the percent-

*It should be noted that throughout the text the through movement of I-76 to the Walt Whitman Bridge is referred to as Exit I or exit lanes 1 and 2.

Table 10. General Path Data

	LANE OF ENTRY	EXIT I	EXIT II	EXIT III	TOTAL
"BEFORE"	1	34.2% (N=2426)	0.5% (N=39)	0.0% (N=3)	34.8% (N=2468)
	2	14.2% (N=1007)	20.7% (N=1469)	8.2% (N=584)	43.2% (N=3060)
	3	0.1% (N=6)	0.6% (N=43)	21.4% (N=1514)	22.0% (N=1563)
	TOTAL	48.5% (N=3439)	21.9% (N=1551)	29.6% (N=2101)	100% (N=7091)

	LANE OF ENTRY	EXIT I	EXIT II	EXIT III	TOTAL
SYSTEM C	1	33.6% (N=2618)	0.4% (N=32)	0.1% (N=7)	34.1% (N=2657)
	2	12.4% (N=965)	20.7% (N=1618)	8.6% (N=669)	41.7% (N=3251)
	3	0.1% (N=8)	0.8% (N=65)	23.4% (N=1822)	24.3% (N=1895)
	TOTAL	46.0% (N=3590)	22.0% (N=1715)	32.0% (N=2498)	100% (N=7803)

age increase is, from a practical standpoint, rather small, it is statistically reliable ($z = 1.97$, $p < .05$). It should be recalled, however, that all of the advance guide signs assign lane 1 to Exit I, lane 2 to Exit II, etc., and that the final overhead guide sign for Exit I, which can be detected prior to entry into Zone 1, contains <u>two</u> down arrows. Since the guide signs for the other two exits each also have a down arrow for lane assignment, it may not be clear to unfamiliar drivers whether the two arrows on the Exit I sign are meant to indicate a two-lane ramp or whether mainline lane 2 is to be shared by drivers using Exits I and II. If the latter is the interpretation, then, drivers entering the site in lane 2 and using Exit I are also behaving in accordance with the signing and should in all analytical fairness be included in the "appropriate entry" group. These additions increase the percentages of "appropriate entries" to 90.4% (N = 6416) for the "before" condition and 89.9% (N = 7022) for System C condition, reversing the direction of the difference, although not to a statistically significant degree. One would have to conclude from these results that the System C configuration had no practical facilitative effect upon driver lane selection and that the symbol code did not therefore, serve as a useful supplement to the conventional lane assignment information.

The information in Table 11 shows the six vehicle paths which described the trajectories (lane x zone) of slightly more than 90% of the sample under both the "before" and "after" treatments. The numerical value of each digit indicates the lane occupied by the vehicle, while zone information is provided by the position of the digit. Note that the leftmost digit gives the lane for Zone 1 and the rightmost, Zone 5. The paths indicated can be easily traced by using the site schematic provided in Figure 7. The data presented in Table 11 are the number and percentage of vehicles which used each path under each of the treatment conditions.

Table 11. Most Frequently Used Paths

	"BEFORE"		SYSTEM C		
	N	%*	N	%	z-value
22222	985	13.9	934	12.0	3.50
22355	565	8.0	651	8.3	0.84
22344	599	8.5	389	5.0	8.48
22233	800	11.3	1177	15.1	6.83
11111	2204	31.1	2461	31.5	0.60
33466	1439	20.3	1795	23.0	4.01

*% of total sample

The listing in Table 11 orders the paths with respect to the number of drivers who made erratic maneuvers in the "before" condition, e.g. path 22222 involved the greatest number of drivers who made erratic maneuvers. While erratic maneuvers per se will be dealt with in more detail in the following section, they are indirectly addressed here simply to provide an indication of the effects of certain path shifts in overall system performance.

As might be expected, the most popular paths for both treatments were entries in mainline lane 1 or in lane 3 with a continuation through the site without a lane change (i.e. paths 11111 and 33466). Comparing the data in Tables 10 and 11, it is clear that the majority of the drivers who entered in a lane appropriate to their exit (i.e. in 1-out I, in 2-out II, etc.) traversed the site without a lane change.

In order, the first three paths listed in Table 11 led to 68, 40, and 26 drivers who committed errors in the "before" stage. Note that the percentage of drivers who used paths 22222 and 22344 were significantly reduced under the System C treatment, whereas the second highest "error" path as well as the fifth showed slight but statistically unreliable increases in usage. The remaining paths (22233 and 33466) showed a significant increase in usage, however the number of drivers making erratic maneuvers associated with these paths (12 and 9 respectively) is for practical purposes relatively small.

In summary, Color/Shape System C resulted in an overall reduction in the utilization of the paths associated with the highest error rates. The degree of reduction per se and the specific erratic maneuvers involved are covered in the following section.

Erratic Maneuvers. Considering first the total number of erratic maneuvers (EM's), the "before" data yielded a total of 380 observable incidents or approximately 54 per thousand vehicles. A rather striking contrast is apparent upon inspection of the data from the System C evaluation which shows that the total number of EM's was reduced to 57 for an error rate of approximately 7 per thousand vehicles. These numbers, while descriptively accurate, are inflated due to scoring conventions because multiple erratic maneuvers of the same type performed by the same driver are, in this case, reported as independent errors. Less apparent is the fact that the primary inflation is attributable to the lane straddle EM which was often repeated through several zones.

A more relevant overall comparison, one which is free of the independence issue, is the number of drivers who performed one or more erratic maneuvers, since this sample space defines the target population for the C/S system. The rationale for this choice stems from the assumption that the C/S system provides a driver with useful supplemental information to decrease uncertainty in his directional decisions and that the reduction in uncertainty will be reflected in the elimination of all of the errors that a multiple-EM driver would otherwise have made. It was determined using this approach that in the "before" condition 227 drivers (3.2% of the sample) were involved in erratic maneuvers. Again, under the System C treatment, a very dramatic improvement was observed; this time a reduction to 40 drivers (0.15% of the sample). The difference yielded a z = 12.35 which proved to be highly significant ($p < .001$). Table 12 provides a breakdown of the number of drivers involved in each of the specific erratic maneuvers along with the calculated EM rate. It should be noted that while this table does not include multiple maneuvers of the same type by a given driver, it does include multiple entries for those drivers who made more than one type of EM. The data indicate that the largest reduction under System C was in gore encroachments, a reduction of 12.6 errors per thousand vehicles. However, a more important finding from a safety standpoint is the significant reduction in swerves from 9 to less than 2 per thousand vehicles. Given the sustained traffic volumes on the Philadelphia site during most of the day, both swerves and gore crossings constitute extremely hazardous maneuvers and improvements such as these bear as much practical as they do statistical significance. From the uncertainty perspective, the reduction in lane straddles provides an indication that drivers were more aware of their exit paths as they traversed the site. This contention is supported more clearly through path data.

Table 12. Number of Drivers Committing Each Erratic Maneuver

	"BEFORE" (N = 7091)	SYSTEM C (N = 7803)	REDUCTION EM/1000 VEH
LANE STRADDLE	8.5* (N = 60)	0.8 (N = 6)	7.7
SWERVE	9.0 (N = 64)	1.7 (N = 13)	7.4
STOP	1.4 (N = 10)	0.38 (N = 3)	1.0
BACK	0.6 (N = 4)	0.1 (N = 1)	0.5
GORE ENCROACH	14.0 (N = 99)	1.4 (N = 11)	12.6
GORE CROSS	3.5 (N = 25)	1.9 (N = 15)	1.6
TOTAL	36.9 (N = 262)	6.3 (N = 49)	30.6

* = EM/1000 vehicles)

It is likely, given the site characteristics, that a large proportion of the lane 2 users who are uncertain as to their exit use lane 2 to "hedge their bets". This is apparent in the erratic maneuver patterns which suggest that many of the lane 2 users are misaligned with their exit of choice as they traverse the site. Table 13 compares the number of drivers committing each type of erratic maneuver under each treatment for the six most frequently used paths. While it might be assumed that drivers who traverse the site with no lane changes would be most error free, this was not the case since drivers using path 22222 committed the greatest number of erratic maneuvers in the "before" condition, including over half of the total lane straddles and approximately one-quarter of the gore encroachments. Given that in the "before" condition this path comprises approximately 14% of the total volume, it is highly overrepresented with regard to errors since it accounts for nearly 28% of the "error" drivers.

As alluded to earlier, this is due in part to the increasing width of lane 2 and the lack of pavement markings. That is, unfamiliar lane 2 drivers must align themselves with their exit purely on the basis of their interpretation of the exit configuration, and since the triple movement configuration is unusual, the interpretation may be somewhat difficult. In addition, the interpretative difficulties may be compounded by the potential confusion embodied in the lane assignment arrows. This latter problem may account for a number of the lane straddles associated with the users of path 22222. That is, a number of unfamiliar drivers probably entered the site in lane 2 with uncertainty as to whether they could continue through from that lane, and therefore, did not make a full committment to lane 2 until they could see that the movement was in fact two lanes. This supposition is supported by the fact that most of the lane straddles occurred in Zones 1 and 2. The group of drivers using this path who were involved in gore encroachment or gore crossings, on the other hand, entered the site toward the median side of lane two and did not make the lateral committment to the exit early enough to avoid the gore. The drivers using paths 22355 and 22344 are also overrepresented with respect to errors. The problem here is also one of alignment, again probably due to the combination of uncertainty and the width and absence of lane lines in lane 2. That is, the driver using these two paths did not make a lateral committment early enough as they traversed the site and consequently swerved and/or made contact with the gore in order to effect the exit. One other path which was highly overrepresented with respect to errors was path 11233. This path deserves mention because is was used by only 24 drivers (0.34% of the sample) in the "before" condition, yet was the fourth highest path with respect to errors. Drivers using this path committed 12 gore encroachments, 4 gore crossings, and 2 swerves for a total of 18 errors for the 24 drivers. Under the System C treatment, utilization of this path was decreased to 0.12% of the sample, and erratic maneuvers were reduced to zero.

Finally, of the remaining paths listed in Tables 11 and 13, it can be seen that despite the increase in utilization there was nevertheless,

Table 13. Number of Drivers Committing Each Erratic Maneuver - By Path

	LANE STRADDLE		SWERVE		STOP		BACKING		GORE ENCROACH		GORE CROSS.		ALL EM'S	
	B*	C**	B	C	B	C	B	C	B	C	B	C	B	C
22222	34	2	9	1	1	0	1	0	25	6	2	0	72	9
22355	2	1	10	0	0	0	0	0	31	0	1	0	44	1
22344	1	1	22	6	2	0	0	0	6	3	1	1	32	11
22233	2	0	3	1	1	0	1	0	8	1	3	0	18	2
11111	7	1	0	0	1	1	1	0	3	0	0	1	12	3
33466	6	0	3	0	0	0	0	0	0	0	0	0	9	0
All Other Paths	8	1	17	5	5	2	1	1	26	1	18	13	75	23
TOTAL	60	6	64	13	10	3	4	1	99	11	25	15	262	49

*B = "Before"
**C = System C

under System C, a sharp curtailment in erratic maneuvers. It is obvious from the significant reduction in erratic maneuvers found under the treatment condition that the C/S system substantially decreased driver uncertainty regarding the appropriate path. The nature and extent of the reductions in erratic maneuvers imply that two types of operational effects occurred under System C. First, there was a reduction in the percentage of drivers who used two of the three paths associated with the greatest number of errors. Secondly, of those drivers who used the "high error" paths under the System C treatment there was better alignment with the exit as they traversed the site, i.e., they were apparently more certain of their direction and path thereby making the necessary degree of lateral committment early enough to avoid the necessity to swerve, or encroach upon, or cross the gores. Although no formal analyses of the quality of traffic flow was undertaken, it is assumed that the significant reduction in erratic maneuvers under System C resulted in a much smoother operation at the exits. This contention is partially supported by the speed data taken on the exit lanes.

Speed Data. The results of the speed data taken in each of the exit lanes are shown in Table 14. As can be seen, there were no practical changes in exit speed. Mean speed differences for lanes 1 and 4 were the only comparisons ("before" vs. System C) which achieved significance, however, the general trend of the data suggest that the color/shape treatment had a favorable effect upon traffic flow. With the exception of lane 1, where the increase in mean speed was accompanied by an increase in the standard deviation, the trend at all other exit lanes showed the increase in speed to be associated with a decrease in speed variance. This trend is assumed to be largely a result of the reduction in erratic maneuvers, the majority of which occurred in the vicinity of the gores and could therefore have a considerable influence on exit speed performance.

Summary and Conclusions - System C

A gross analysis of lane selection based on comparisons between lane of entry and lane of exit resulted in the conclusion that Color/Shape System C had no substantive effect upon the transmission of lane assignment information. However, it should be noted that there is an element of confusion in the interpretation of the lane assignment information provided. That is, two of the three overhead advance guide signs assign site entry lanes 1, 2, and 3 to the corresponding Exits I, II, and III. The final overhead sign, however, contains two down lane-assignment arrows for Exit I (I-76, Walt Whitman Bridge) movement. Whether drivers interpret this information as an indication of a two-lane exit ramp or whether they interpret it as a lane assignment alternative (i.e., either lanes 1 or 2 are appropriate for Exit I) is indeed questionable. Where the appropriateness of entry is assessed by assigning to the "appropriate" category only drivers who leave the site in an exit corresponding to the lane of entry (e.g., enter in lane 1 and use Exit I, etc.), System C was shown to have a slight statistically significant positive influence. However, when "appropriateness" is expanded

Table 14. Mean Speed by Exit Lane

	EXIT I				EXIT II				EXIT III			
	LANE 1		LANE 2		LANE 3		LANE 4		LANE 5		LANE 6	
	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α
"BEFORE"	46.0	5.2	48.2	5.6	44.8	5.8	45.3	5.9	47.7	5.9	50.8	5.3
SYSTEM C	46.8	5.3	48.7	4.9	45.4	5.1	46.9	4.9	48.8	5.6	50.6	4.9
t-values	1.83*		1.13		0.81		2.0*		1.21		0.28	

*Significant at < 0.05 level

to include those drivers who enter the site in lane 2 and leave in Exit I to accommodate the competing interpretation that the second down arrow carries lane assignment information, it was found that System C had no beneficial effect.

Under the System C treatment a significant decrease was observed in the percentage of drivers who used two of the paths which, in the "before" condition, were associated with high-error rates. Along with this positive effect was an apparent improvement in vehicle position on the approach to the exits such that even for high error paths, the error rates were substantially lower under the System C treatment.

Clearly, the most substantial effect of System C was in the highly significant reduction in erratic maneuvers. The total number of erratic maneuvers was reduced from 53.6/1000 vehicles (N = 380) in the "before" condition to 7.3/1000 vehicles (N = 57) under System C. Moreover, the driver involvement rate for EM's was reduced from 3.2% of the sample (N = 227) in the "before" condition to 0.15% of the sample (N = 40) under System C. Finally, an overall improvement in smoothness of flow was suggested by exit speed data wherein the predominant trend observed was an increase in speed with a decrease in speed variance.

On the basis of these findings it was generally concluded that the positive effects observed under System B (York) were largely substantiated by the System C evaluation and that the concept and system merited further development and field testing. Since the Philadelphia site was known to be used heavily by traffic destined for the New Jersey shore resorts, it was decided to conduct a final and more sensitive series of field tests on this site during the peak vacation period, thereby ensuring a relatively high percentage of unfamiliar drivers.

PHASE III EVALUATION

Site Description

Phase III evaluations were undertaken on the I-76 East, Philadelphia site, which was already described under the Phase II site description (see Figure 7). However, since the dimensions of the symbol signs (36 x 36 inches) were larger and their placement was different for Phase III, it was necessary to modify three of the existing overhead signs to accommodate the new system. The three signs (#9, #10, #12) which were modified are shown in Figure 11; both the original and the modification are presented. Only sign #9 required a sign size modification (increase in size) and only sign #12 required a size modification in the legend (decrease in directional arrow dimensions).

It was necessary to insert a (14.5 x 2 ft [4.4 x 0.6m]) panel on the bottom of sign #9 to provide the requisite space for system implementation. In order to keep the information format consistent with the other signs, it was also necessary to reposition (lower) the lane assignment arrow. The modifications to signs #10 and #12 were minor, involving only a repositioning of the down arrows on sign #10 and a change in size from 32 inches to 24 inches of the down arrow on sign #12. Although the arrows on sign #10 were moved, care was taken in the repositioning design to retain the informational integrity of the original sign.

Signing Treatment

Two systems (Systems D and E) were deployed for Phase III evaluations. In both systems only the I-76 East (Walt Whitman Bridge) and Exit 5 (Airport) movements were treated. The center movement, Exit 6 (Passyunk Avenue), was not treated primarily because it was assumed that most of the drivers using this exit would be familiar (local) drivers, and would therefore not need supplemental route guidance information. The coding used was a strong yellow-green barbell for Exit 5 and a coral heart for I-76 East.

System D (see Figure 12) consisted of three components: (1) introductory route/symbol association signs, (2) sign-face mount guide sign tabs, and (3) gore/ramp delineator symbols. This system differed from System C in the following respects: introductory signing was utilized; symbol signs were mounted on the sign face as opposed to peripheral mounting and tabs containing the "FOLLOW" and "TO" messages were not used; the initial Exit 5/Airport sign was not treated (see sign #6, Figure 8); and no treatment was applied to the Exit 6 signs. It should be noted that mounting the symbols directly on the face of the guide signs brought the symbols into closer association with the guide sign message in addition to increasing the symbol target value by reducing background competition and visual noise.

EXISTING MODIFICATION

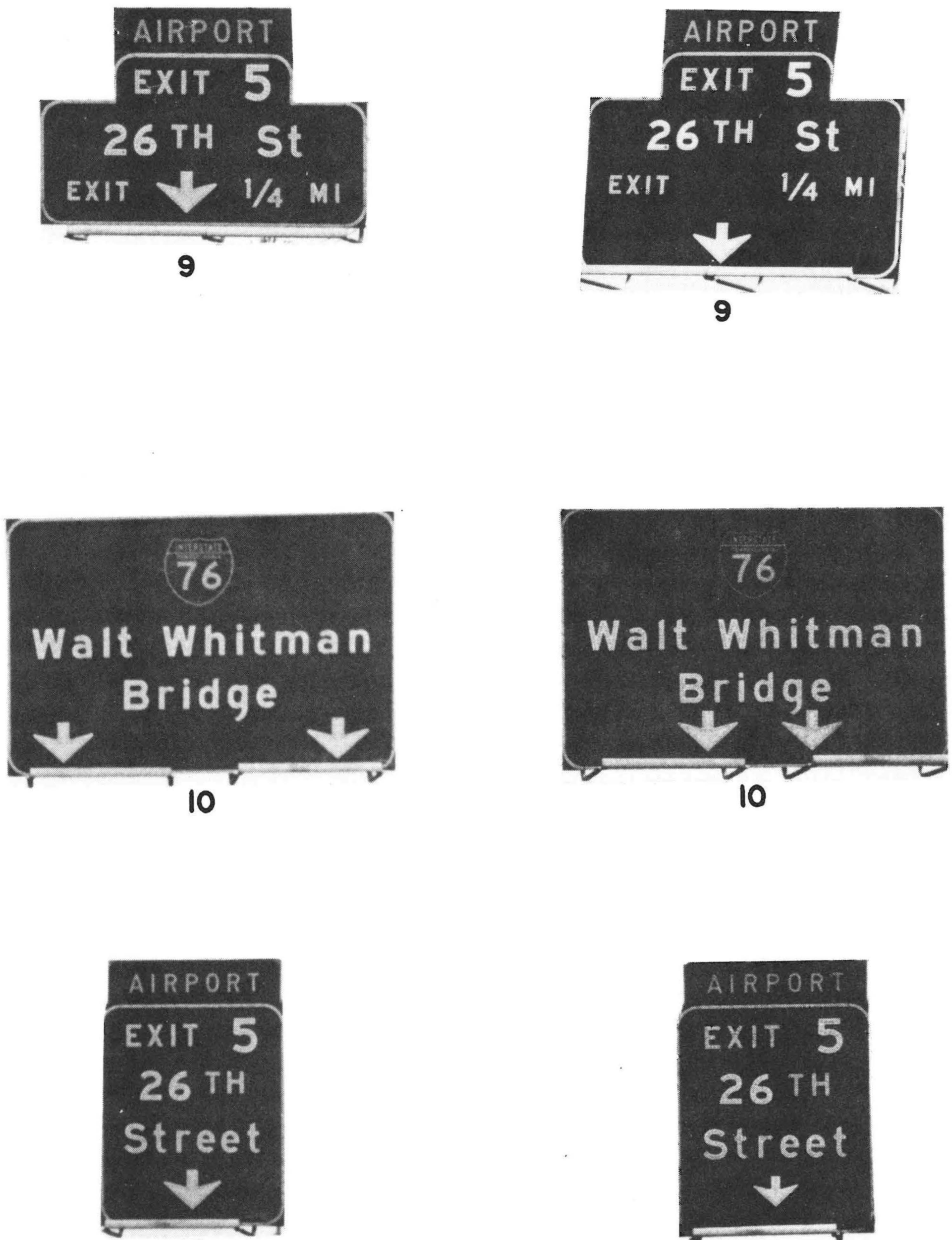

Figure 11. I-76 Philadelphia Site Existing Sign Modifications

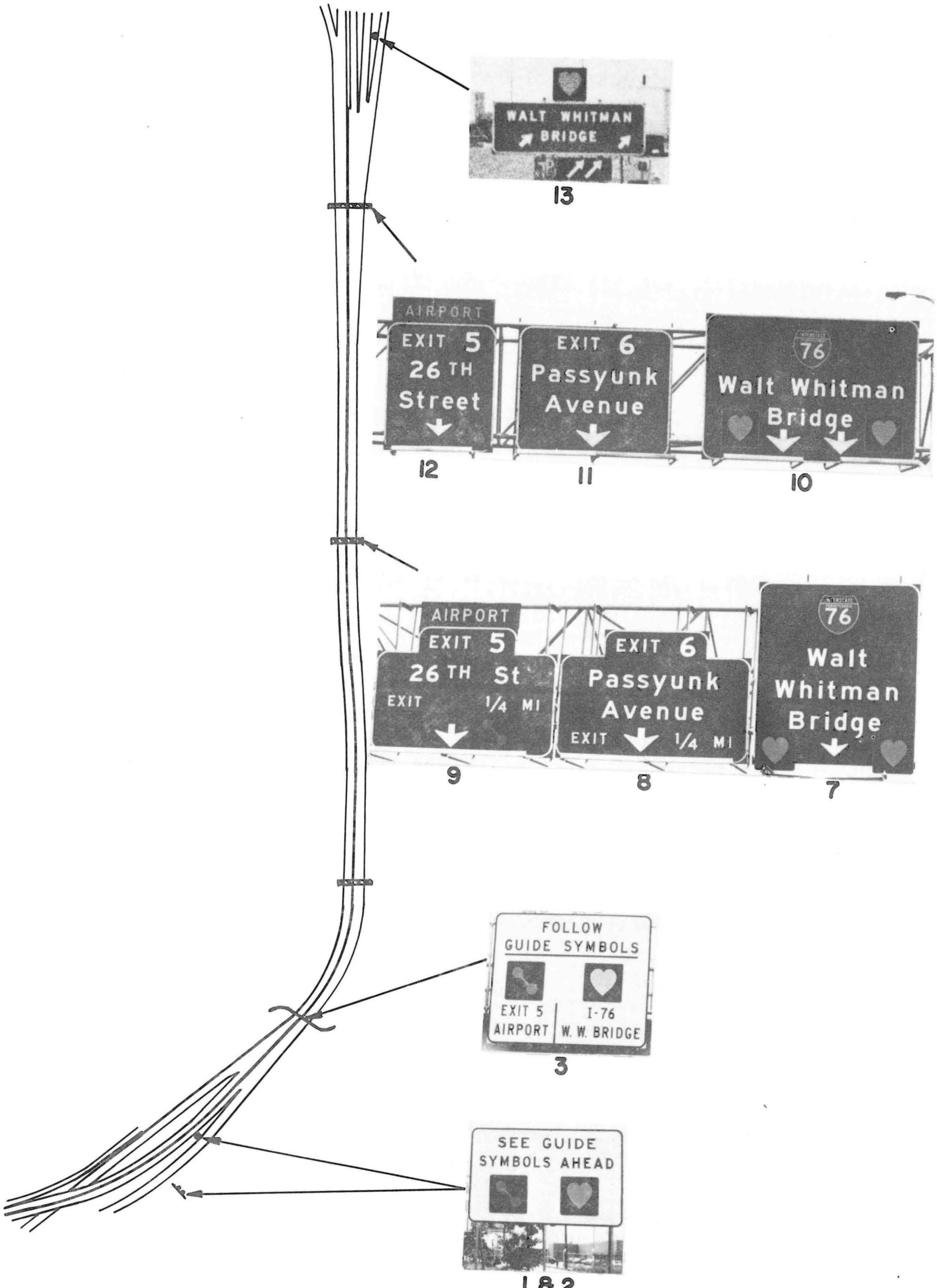

Figure 12. Systems D and E Signing Treatment

The introductory signing for System D involved three signs incorporating two different messages as shown in Figure 12. Signs #1 and #2 were designed to alert drivers to the existence of the system. The reason two signs were necessary is that a major merge is located approximately 3/4 mi (1.2 km) upstream of the test site exit gore area. In order to insure that all the drivers were alerted to the system, both legs of the merge had to be treated. Sign #1 was a 12 x 7.5 ft (3.7 x 2.3 m), right shoulder, ground-mount sign located approximately 1 mi (1.6 km) upstream of the site gore area (or approximately 1/2 mi [0.8 km] upstream of the first guide sign treated) for the right leg of the merge. Sign #2 was positioned 150 ft (46 m) upstream of the physical gore of the merge and oriented towards mainline I-76. Again, the placement was approximately 1/2 mi (0.8 km) upstream of the first guide sign treated.

The message of the final introductory sign, sign #3, was where the coding association of the symbols and the route/delineation was made. Sign #3 was mounted overhead on a pedestrian overpass approximately 3/4 mi (1.2 km) usptream of the site gore area, of 1/4 mi (0.4 km) downstream of signs #1 and #2. This placement afforded drivers of both legs of the merge an unobstructed view of sign #3. The dimensions of sign #3 were necessarily large, 10 x 12 ft (3 x 3.7 m), because of the increased message content and the competition of a rather large existing sign to which sign #3 was adjacent.

Treatment of the guide signs involved the addition of pairs of 36 x 36 inch symbols to the sign face. Signs #7, #9, #10, and #12 were treated in this manner as shown in Figure 12. The only atypical guide sign treatment was sign #13. It was necessary to top-tab this sign because message rearranging or sign modifications to accommodate face-mounted symbol signs was undesirable. However, this atypical application was acceptable since this was the only ground-mount guide sign treated. In addition, since sign #13 was located downstream of the physical gore, the peripheral tabbing technique was more in harmony with the adjacent delineator configuration than with the upstream guide signing application.

The post-mounted gore/ramp delineator symbols were deployed in the same locations (excluding Exit 6) as described in Phase II. However, there were two modifications of the Phase II treatment: (1) the addition of 21 x 15 inch directional arrow plates to the lead gore delineators. The arrow plates were added to act as a form of directional decision confirmation and to direct the drivers attention to the ramp delineation symbols.

The three different size symbol signs, 36 x 36 inches, 24 x 24 inches, and 12 x 12 inches were applied in descending size order; the lead sign was 36 x 36, the second was 24 x 24, and the last three delineators were 12 x 12. This technique increased symbol sign target value at the gore, and the tapering off in size implied the end of the treatment.

As in most of the preceding treatments, site conditions dictated one atypical application of the delineators. The left shoulder (median) lead delineator for Exit 5 was 24 x 24 inches instead of 36 x 36 inches. It was necessary to use the smaller delineator because it was mounted on a concrete median barrier and the overhand of a 36 x 36 inch symbol encroached on the shoulder. Hence, the potential for sign damage from wide vehicles and vice-versa was eliminated by using a smaller sign.

The second system of Phase III, System E, was identical to System D except for the application of supplemental colored 3 x 9 ft pavement symbols. These symbols were essentially simple linear elongations of the sign symbols and were color-matched with the other symbol signs. Applications of the symbols for both movements treated began approximately 1800 ft (549 m) upstream of the site gore area and continued downstream through the site on 200 ft (61 m) centers to a point 600 ft (183 m) past the physical gores. Since each exit treated was two lanes, the last three pavement symbols were applied in adjacent pairs, one for each lane as shown in Figure 13.

One aspect of the Phase III evaluations which requires some explanation is the fact that the System E evaluation was conducted before that for System D. Since the installation of the pavement symbols required measurement of the symbol spacings and roadway surface preparation, it could not be accomplished without a lengthy lane closure. This in turn required the assistance of PennDOT personnel and equipment. Since a lane closure was required for the installation of the symbol signs, it was decided to install the more complex system (E) first so that the traffic control for sign installation could also be used for the installation of pavement symbols, thereby requiring PennDOT assistance on only one occasion. Since the data collection schedule was partially contingent upon the availability of a PennDOT crew, this reversal of the treatments increased the probability that the data collection schedule could be maintained. Following the System E data collection, the symbols were removed i.e. peeled up, in the early morning hours using the Philadelphia Highway Patrol for traffic control and the System D evaluation was conducted after a short acclimation period.

Data Collection and Reduction

The method of data collection remained essentially the same as that used in the Phase II evaluation. The only exception being that in Phase II film data collection, GAF Super 8 film was used, while in Phase III Kadachrome 40 Super 8 film was used. The increased light levels of the summer permitted the change and the Kodachrome film provided superior resolution which facilitated reduction of the film.

The daily schedule for Phase III data collection is shown in Figure 14. While the Phase II data utilized 30 minutes of film data for every scheduled hour, this was reduced to 15 minutes per hour for Phase III. However, the data collected in Phase III encompassed more

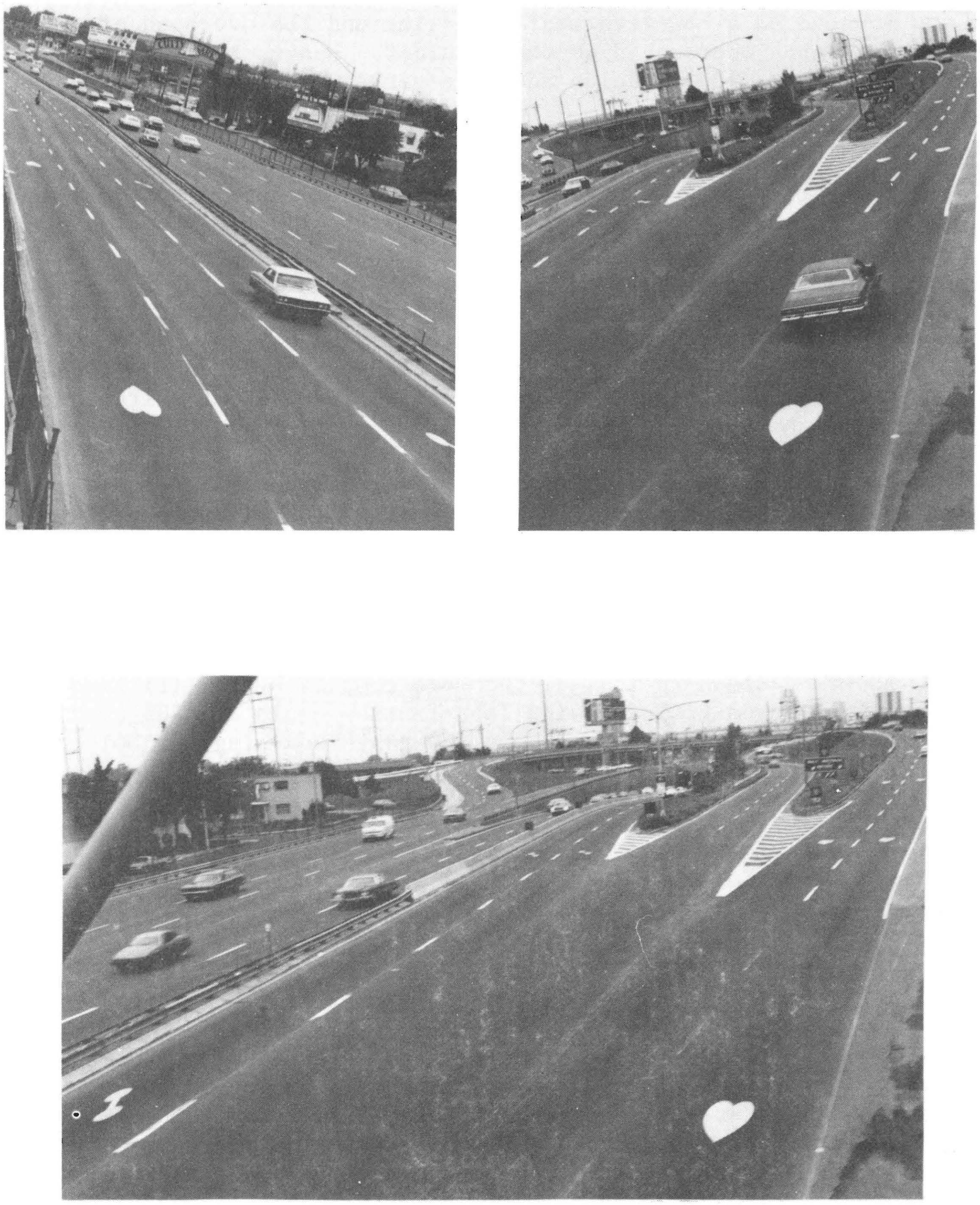

Figure 13. System E Pavement Symbols

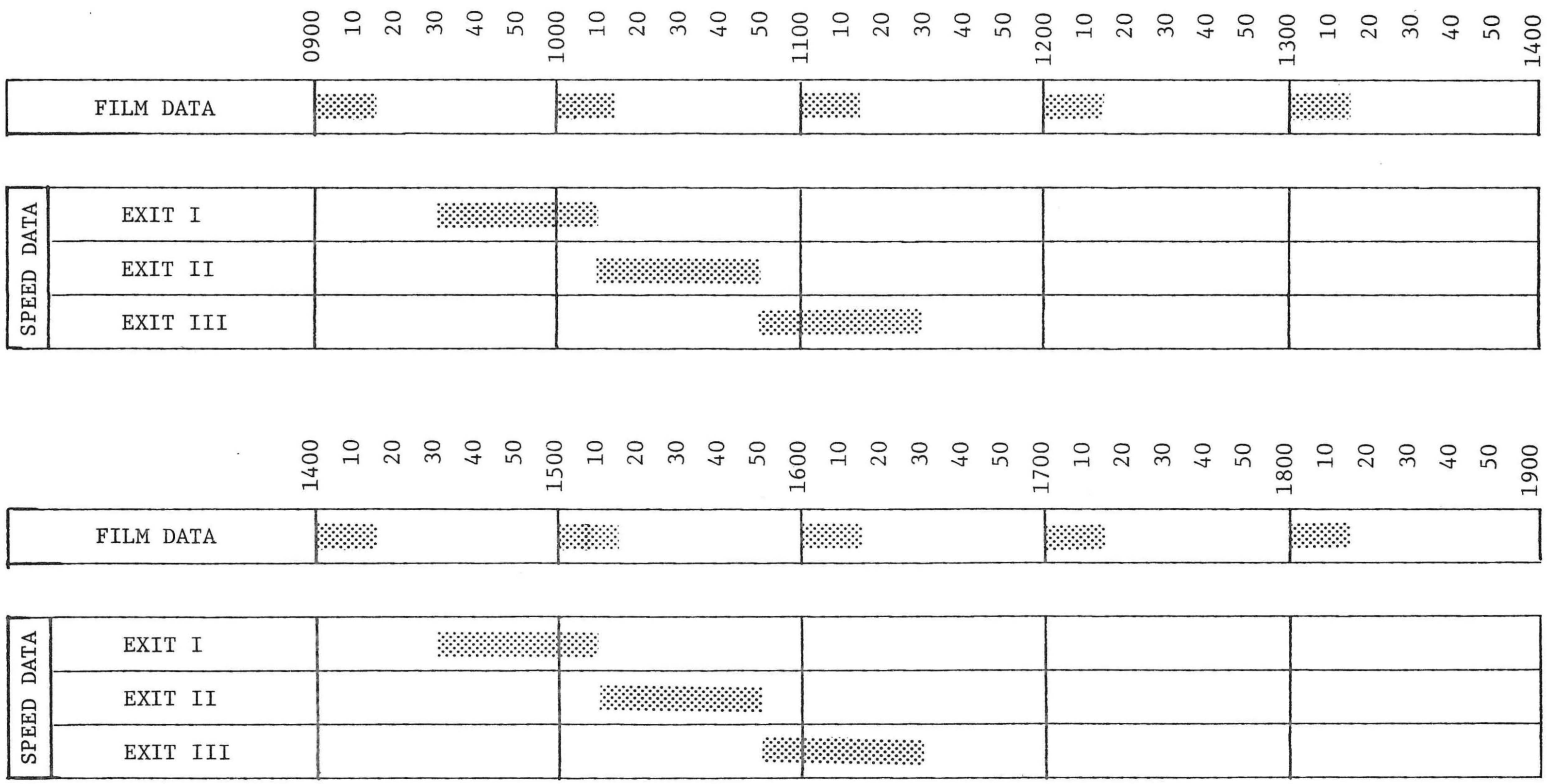

Figure 14. Phase III Dialy Date Collection Schedule

hours of site operation than the first phase, i.e. more samples of the early evening population were obtained. This change was instituted because it was felt that more vacation drivers would be travelling in the Friday and Saturday early evening hours during the summer months of Phase III. The Phase III data collection took place during three separate weeks. The "before" data was obtained on 21, 22, and 23 July; System E data collection took place on 11, 12, and 13 August; System D data collection was obtained on 18, 19, and 20 August.

Film reduction in Phase III followed essentially the same reduction plan as applied in Phase II with the exception of changes made in coding two of the erratic maneuvers. Lane line straddles, used as a measure in Phase II, were dropped from consideration in Phase III. Lane line straddles were dropped from the data set because their value as a measure of directional confusion was questionable, especially in low volume periods, and because the majority of lane line straddles during Phase III were observed in Zone 1 of the site and therefore could have been associated with upstream lane changing activity that was not related to directional confusion. In addition to the omission of lane straddles, the criterion for gore encroachments was made more stringent. That is, in Phase II data reduction, gore encroachments were coded if one wheel of the vehicle encroached on the gore. In Phase III a gore encroachment was coded only if both wheels encroached on the gore.

While this redefinition of the gore encroachment measure along with the elimination of lane straddles resulted in a sharp reduction in the total number of erratic maneuvers to be dealt with in the analysis, the revised data coding scheme provides a more adequate assessment of the safety benefits of the system and, in general, constitutes a more conservative evaluation.

Results and Conclusions

Results and Discussion

Both Systems D and E utilized symbol signs which were integrated into the guide signs, rather than being tabbed on the periphery. Further, two large introductory signs were used; one to alert the drivers that they were to receive guide symbol information, and another which associated the symbols with the exit and routing information. In addition to the above, System E utilized pavement symbols in the relevant lanes and on the ramps. As such, the color/shape coding systems for this site were the most highly developed of all of the systems evaluated.

As with the Phase I evaluations, the two systems evaluated in Phase III are evaluated against common "before" data. It will be recalled that the coding of erratic maneuvers (EM's) was modified for this evaluation, thus the EM rates are considerably lower in this "before" condition than were those of the "before" condition for the Phase II - System C evaluation on this site. However, the EM's retained and/or modified are those which are highly hazardous, particularly on this site which is characterized by high volumes during much of the day.

The discussion of some of the site characteristics as they relate to driver performance was provided in the discussion of Phase II data and is equally appropriate here. It is therefore repeated for the convenience of the reader. As with the previous evaluation on this site, timelapse photography was the principal means of data collection, thus providing a path or trace of all vehicles through the site. However, because the width of the roadway increased and lane markings were not present in Zones 2 and 3, the usual type of lane changing activity analysis for all paths was not feasible. For purposes of data reduction, Zone 3 was analytically divided into four "lanes" in order to more accurately specify the vehicle paths through the site. However, the driver did not have the advantage of lane lines for guidance in this zone. Note also, that the extreme width provided a great deal of latitude for the driver who enters the site in mainline lane 2 and remains in lane 2. From the site schematic (Figure 7), the reader can appreciate the fact that the transition from mainline lane 2 to exit lane 2 or 5 can be made smoothly if a lateral shift in the appropriate direction is begun in Zone 2; however, the driver who is uncertain of his exit is not likely to make the lateral committment early enough. The result of such uncertainty is frequently a gore encroachment, gore crossing, or a swerve. Because of this feature of the site, the path data are used as a more general indication of performance related to lane assignment conformance while erratic maneuver data serves as a more specific safety-related indication of system effects.

Path Analysis. The general path data are shown in Table 15 which displays the number and percentage of drivers who entered the site in each mainline lane along with the exit which was used. The summary calculation based upon the diagonal cells of each table shows that the percentage of drivers who entered the site in the lane appropriate to the exit used (e.g. entered in mainline lane 1 and left via Exit I)* increased from 74.1% (N = 15379) in the "before" condition to 75.5% (N = 16944) under System D, and increased further to 77.0% (N = 16943) under System E. All of these differences are statistically significant at beyond the p = < .01 level with none, including the difference between Systems D and E, yielding a z-value under z = 3.37. It should be noted that the percentage increases under both of the systems evaluated here are slightly higher than the percentage increase in "appropriate entries" obtained for the System C evaluation.

The signing and lane assignment situation as it relates to definition of an "appropriate" lane is slightly different in this evaluation (as compared to the System C evaluation) in that the original guide signs required some modification in order to accommodate the symbol

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*It should be noted that throughout the text the I-76 through movement is referred to as Exit I or exit lanes 1 and 2.

Table 15. General Path Data

	LANE OF ENTRY	EXIT I	EXIT II	EXIT III	TOTAL
"BEFORE"	1	38.7% (N=8022)	0.4% (N=88)	0.1% (N=18)	39.2% (N=8128)
	2	18.3% (N=3805)	14.9% (N=3089)	6.3% (N=1308)	39.5% (N=8202)
	3	0.1% (N=20)	0.7% (N=137)	20.6% (N=4268)	21.3% (N=4425)
	TOTAL	57.1% (N=11847)	16.0% (N=3314)	27.0% (N=5594)	100% (N=20755)

	LANE OF ENTRY	EXIT I	EXIT II	EXIT III	TOTAL
SYSTEM D	1	38.6% (N=8663)	0.2% (N=53)	0.06% (N=13)	38.9% (N=8729)
	2	17.4% (N=3901)	14.4% (N=3231)	6.2% (N=1381)	37.9% (N=8513)
	3	0.06% (N=14)	0.6% (N=134)	22.5% (N=5050)	23.2% (N=5198)
	TOTAL	56.1% (N=12578)	15.2% (N=3418)	28.7% (N=6444)	100% (N=22440)

	LANE OF ENTRY	EXIT I	EXIT II	EXIT III	TOTAL
SYSTEM E	1	38.6% (N=8495)	0.2% (N=50)	0.01% (N=13)	38.8% (N=8548)
	2	16.9% (N=3718)	15.3% (N=3359)	5.3% (N=1173)	37.5% (N=8250)
	3	0.09% (N=20)	0.5% (N=112)	23.1% (N=5089)	23.7% (N=5221)
	TOTAL	55.6% (N=12233)	16.0% (N=3521)	28.5% (N=6265)	100% (N=22019)

signs on the face of the signs. It may be recalled from the discussion of Phase II - System C that while the initial advance guide signs assigned mainline lanes 1, 2, and 3 to the corresponding exit movements I, II, and III, the final overhead guide sign which can be read prior to entry into Zone 1, contains two down arrows for Exit I. It was noted in the Phase II - System C discussion, that, since the guide signs for the other two exits each have a single down arrow for lane assignment, it may not be clear to unfamiliar drivers whether the two arrows on the guide sign related to Exit I are meant to indicate a two-lane ramp or whether mainline lane 2 is to be shared by drivers using Exits I and II. The point was made that if the lane sharing interpretation was made, then drivers entering the site in mainline lane 2 and using Exit I are also behaving in accordance with the signing and should be included in the "appropriate" entry group. Because of the guide sign modifications required for the Phase III evaluations, this situation has changed slightly in that the two down arrows on the final overhead guide sign had to be moved closer together in order to permit accommodation of the symbol signs for the System D and E treatments. Since this new placement resulted in the two down arrows being located more in line with lane 1 than lane 2, and they were closer together, the unfamiliar driver may be less likely to interpret the arrows as a lane assignment. Nevertheless the potential for misinterpretation still exists, thus, the "appropriate entry" group was expanded to include the lane 2 drivers who leave via Exit I. This expansion increases the percentage of "appropriate entries" to 92.4% (N = 19184) for the "before" condition, with a slight additional rise to 92.9% (N = 20845) for System D and further to 93.8% (N = 20661) for System E. Again, while the percentage differences are not great, they are all statistically significant. The increase resulting from the System D treatment yielded a $z = 1.84$ ($p = < .05$), and the increase associated with System E yielded a $z = 5.73$ ($p = < .001$). The increase from System D to System E was also significant ($z = 3.98$; $p = < .001$). In summary, these results show that under either definition of "appropriate entry" both C/S systems tested had a facilitative effect upon the percentage of drivers who entered the site in a mainline lane appropriate to their destination, with System E resulting in a slight but significant improvement over System D. Thus it can be concluded that both systems reinforce the lane assignment information and resulted in better lane selection. Further the difference between Systems D and E suggest that the pavement symbols aid the driver in lane choice and path selection.

The information presented in Table 16 shows the six paths which account for more than 90% of the sample under the "before" condition and each treatment condition. It will be recalled that the path data, as designated, show the lane occupied in each zone of the site. That is, the digit indicates the lane and the position of the digit relates to the zone, with the leftmost digit being Zone 1. The data presented are the number and percentage of vehicles which used each path under each of the treatment conditions. The paths are easily traced via reference to Figure 7. The paths shown in Table 16 are ordered with respect to the number of erratic maneuvers in the "before" condition.

However, the erratic maneuver rates are relatively low for all paths except 22222. It will be recalled that these same six paths were the high-use paths in the Phase II evaluations and that the same path (i.e. 22222) showed the highest rate of erratic maneuvers. As shown in Table 16, Systems D and E resulted in a reduction in use of this path. In both cases the reduction was significant with the "before"/System D comparison yielding a z = 2.999 and the "before"/System E yielding a z = 3.728. However, there was not a significant difference between the two systems. The erratic maneuver rate associated with path 22222 was 11 EM's per thousand vehicles. This rate was reduced to 3.4 and 4.4 EM's per thousand vehicles under Systems D and E respectively. The second ranking path with regard to erratic maneuvers was path 22344, with an EM rate of 6.7 per thousand vehicles. While both Systems D and E produced a statistically reliable increase in the use of this path, the erratic maneuver rates observed under C/S system conditions were reduced to 1.4 per thousand vehicles for System D and 2.1 per thousand for System E. This increase in utilization and decrease in erratic maneuvers indicates that the drivers using the path were aligning with the exit earlier and avoiding the gore encroachments and swerves which had been observed in the "before" condition. The remaining high-use paths involved so few erratic maneuvers that little can be said about them. One other factor which might be noted from the table is the effect of the C/S systems on the paths which do not involve any lane changing activity, i.e. paths 11111 and 33466. As shown there was little change in the percentage of drivers using the 11111 path. The small increase in use is not statistically significant. However, on a positive note, both Systems D and E produced a statistically significant increase in the use of the 33466 path, yielding a z = 5.208 for the "before"/System D comparison and a z = 6.652 for the "before/System E comparisons (p = < .001 in both cases). There was no significant difference between Systems D and E.

Table 16. Most Frequently Used Paths

	"BEFORE"		SYSTEM D		SYSTEM E	
PATH	N	%*	N	%*	N	%*
22222	3732	18.0	3846	17.1	3659	16.6
22344	1198	5.8	1447	6.4	1416	6.4
11111	7227	34.8	7884	35.1	7737	35.1
22355	1257	6.1	1361	6.1	1155	5.2
22233	1785	8.6	1728	7.7	1770	8.0
33466	4110	19.8	4901	21.8	4939	22.4

*% of total sample

In summary, considering the significantly increased utilization in one of the no-lane-change paths, along with the decrease in utilization of the path which had been associated with the greatest number of erratic maneuvers, in the "before" condition, the data lend support to the conclusion that the color/shape systems aided the driver in path selection. Additional support for this conclusion is provided by the finding that, while there was an increase in utilization of one of the high-error paths under the color/shape treatments, there was a reduction in the erratic maneuvers associated with that path indicating an improvement in driver alignment with the chosen exit. On the basis of the specific path data reviewed, Systems D and E do not appear to have significantly different effects.

Erratic Maneuvers. It will be recalled that the coding of erratic maneuvers was modified for the Systems D and E evaluations. The lane straddles were dropped as an EM because during the Phase III evaluations many drivers entered the site straddling the lane line and it was not known whether this was an indication of uncertainty or whether they were in the act of completing an upstream (pre-exit) lane change. As such, lane straddle data added little substantive information about system effects, being only a rather weak indication of driver certainty. The other change made was in the coding of gore encroachments. Here the criteria for coding a gore encroachment was modified to require a two-wheel rather than a single wheel encroachment for qualification. This change was made because a number of the gore encroachments observed in the previous field test involved minimal hazard. It was felt that these two changes in the coding would provide a more realistic estimate of the potential safety benefits of the color/shape system and a more conservative test on which to base further development of the concept. Further, it was known that the sample sizes for the Phase III evaluations would be considerably larger than those for Phase II. However, the erratic maneuvers observed in the Phase III evaluations are lower than would be expected on the basis of the coding modification. One factor which may account for the reduction is the increase in volume between Phase II and Phase III evaluations. Using counts from the data films, the volume through the site during data collection periods was between 550 and 650 vph greater during the Phase III studies. It is possible that under the higher volume conditions, drivers were less willing to expose themselves to the hazard associated with a stop, swerve, gore crossing, etc. Certainly, under the Phase III volume conditions (which averaged over 3600 vph) erratic maneuvers, particularly in the gore area, are highly hazardous and the potential for multi-vehicle accidents is increased.

Considering first, the total number of erratic maneuvers observed, the "before" data yielded a total of 178 or 8.6 EM's per thousand vehicles. Under the System D condition the total was reduced to 80 EM's or 3.6 per thousand vehicles. The reduction was highly significant with a $z = 6.753$ ($p = < .001$). Under the System E treatment the reduction was less, with 93 EM's or 4.2 per thousand vehicles, but still significantly different from the "before" condition. The "before"/

System E comparison yielded a $z = 5.670$ ($p = < .001$). There was no significant difference between the two color/shape treatments, the comparison producing a $z = 1.115$ ($.14 < p < .20$).

Since the total erratic maneuvers are inflated by multiple maneuvers performed by the same driver, a more crucial comparison is the number of drivers who committed one or more erratic maneuvers. As was pointed out in the Phase II discussion of results, it is this sample that defines the target population of the C/S system. This statement is based on the assumption that a decrease in directional uncertainty produced by the system will be reflected in the elimination of all of the errors the driver would otherwise have made. In the "before" condition 139 drivers or 6.6 in each thousand drivers made one or more erratic maneuvers. This was reduced to 62 drivers or 2.8 per thousand drivers under the System D condition. This reduction was highly significant with $z = 6.003$ ($p = < .001$). Under the System E condition, the reduction was slightly less, with 68 drivers or 3.1 per thousand drivers committing erratic maneuvers. While the reduction was less than that observed under System D it was still highly significant, yielding a $z = 5.375$ ($p = < .001$). The observed difference between Systems D and E was not significant.

Table 17 shows the number of drivers who committed each type of erratic maneuver under each of the treatment conditions. The entries in this table are not independent in that it includes multiple entries for those drivers who made more than one type of erratic maneuver. Similar to the results of the Phase II - System C evaluation, gore encroachments accounted for the largest number of erratic maneuvers and for the largest reduction by either System D or E. This along with the reduction in swerves and gore crossings reflect the improved path alignment discussed in conjunction with the path data. Unlike the System C study, the number of erratic maneuvers in these evaluations was not large enough to merit a table showing each type of erratic maneuver by path. However, one path of particular note is Path 22222 which exemplifies the extent of the effects which can be expected from the C/S system. As mentioned, this path involves the greatest number of errors in this data set, with nearly three times that of any other path. Among the errors were 11 swerves, 19 gore encroachments, 8 gore crossings, and 3 stops. Under System D, all of the swerves and stops for this path were eliminated, the gore crossings were reduced to a single occurrence, and gore encroachments were reduced to twelve. Under System E, swerves were reduced to 4, gore crossings to 4, gore encroachments to 6, and stops to a single occurrence. It is clear from the error reduction of this high-use path and from the total reduction in EM's that the color/shape system tested provided the driver with enough additional information to permit earlier decisions regarding his chosen exit.

With regard to the two systems tested, the erratic maneuver data indicate that neither is significantly better than the other. However, System D generally produced a greater reduction in erratic maneuvers than did System E.

Table 17. Number of Drivers Committing Each Erratic Maneuver

	SWERVE	STOP	BACK	GORE ENCROACH.	GORE CROSS	TOTAL
"BEFORE" (N=20,755)	1.4* (N=30)	0.9 (N=19)	0.1 (N=3)	3.2 (N=67)	2.1 (N=43)	7.8 (N=162)
SYSTEM D (N=22,440)	0.5 (N=11)	0.4 (N=8)	0.1 (N=2)	1.5 (N=33)	0.9 (N=20)	3.3 (N=74)
SYSTEM E (N=22,019)	0.5 (N=10)	0.5 (N=10)	0.2 (N=4)	1.5 (N=33)	1.2 (N=27)	3.8 (N=84)

* = EM/1000 vehicles

Speed Data. The results of the speed data taken in each of the exit lanes are shown in Table 18. While those cells marked with an asterisk were statistically significant at the .05 level, none of the differences are large enough to provide any supportive evidence regarding either positive or negative system performance. As can be seen, there were no significant differences between the "before" condition and System E. The general trend of System E is better than that of System D in that in all exit lanes the speed variance decreases, however, none of these changes are statistically significant.

Summary and Conclusions - Systems D and E

Since the only difference between Systems D and E is that the latter includes pavement symbols as an additional system component, the two systems are discussed together. A general analysis of lane selection which was based upon a comparison between lane of entry and lane of exit showed that both systems had a positive effect upon appropriate lane selection. It can therefore be concluded that the systems served as a useful supplement to the lane assignment information presented on guide signs. Both systems resulted in a statistically significant increase in the percentage of drivers who entered the site in the lane appropriate to the exit used. While both systems were significantly different from the "before" condition, they were also significantly different from one another, with System E producing greater increases than System D. Thus, it can be concluded that the pavement symbols associated with System E were useful to the drivers in path selection.

A more specific analysis of driver paths through the site, showed that both systems decreased driver utilization of the path that had been associated with the greatest number of errors in the "before" condition. Further, utilization of one of the major low-error paths (a path involving no lane changes) was increased under both systems. In these analyses there were no significant differences between Systems D and E.

Table 18. Mean Speed by Exit Lane

	EXIT I				EXIT II				EXIT III			
	LANE 1		LANE 2		LANE 3		LANE 4		LANE 5		LANE 6	
	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α	$\bar{X}$	α
"BEFORE"	48.5	5.5	50.6	5.7	46.4	6.1	46.4	7.1	49.0	6.0	50.2	5.1
SYSTEM D	47.5*	6.6	48.7*	6.8	45.7*	6.6	45.5	6.2	46.6*	6.7	49.5	5.7
SYSTEM E	48.3	5.2	49.8	5.4	46.4	5.7	46.2	5.4	48.1	5.7	49.5	5.0

* = t-tests between the "before" and treatment were significant at $p = < 0.05$

Systems D and E both resulted in a highly significant reduction in total erratic maneuvers and in the number of drivers involved in erratic maneuvers. The "before" data showed 8.6 erratic maneuvers per thousand vehicles. This was reduced to 3.6 and 4.2 EM's per thousand vehicles under Systems D and E respectively. In terms of the number of drivers involved in one or more erratic maneuvers, the "before" involvement rate of 6.6 drivers per thousand vehicles was reduced to 2.8 and 3.1 drivers per thousand vehicles under Systems D and E respectively. In all cases the observed reduction from the "before" condition to the C/S system treatments was statistically significant. While there were no statistically significant differences between Systems D and E in this regard, System D resulted in greater reduction than did System E.

Neither of the C/S systems had any practical effect upon the exit speeds. While System D was associated with several changes which were statistically significant, the changes were so small that they have no practical importance and cannot be used as evidence to either support or refute system performance.

In summary, on the basis of these field evaluations, it has been shown that both Systems D and E have a beneficial effect upon path selection and upon safety as evidenced by the significant reduction in erratic maneuvers. While the pavement symbols associated with System E appear to be a useful supplement in path/lane selection, they do not appear to provide any greater benefit than the basic system with regard to reduction of erratic maneuvers. This suggests that the pavement symbols could perhaps be utilized to an advantage in the upstream portion of a problem interchange to aid the driver in appropriate path selection, but would not have to be carried past the gore area.

IV. GUIDELINES FOR SYSTEM DESIGN AND IMPLEMENTATION

The process of preparing and deploying a color/shape system at a particular "problem" or complex interchange is one which requires "tailor-making" or customizing. The components of the color/shape system are integrated into the existing guide signing and must accomodate the available sign structures and the idiosyncrasies of the site geometry. For this reason, the following paragraphs are guidelines, not warrants or specifications. The guidelines provide coverage of the various relevant aspects of design and implementation, discussing the factors to be considered in each and supplying general criteria for resolving various system/site tradeoffs. These recommendations and suggestions are in some cases (e.g. color, shape, format) derived primarily from the empirical results of the laboratory studies (supplemented by findings from existing literature); for system deployment aspects (such as spacing, placement, etc.) primarily from the driver performance data obtained in the field evaluations; and for installation, from the field experience of having to deal with various types of sign structure, etc. In all cases, the recommendations have been tempered by the experience of the project staff in the installation, observation, and visual evaluation of the system configurations tested.

This chapter begins with a description of the most basic unit in the color/shape system, the symbol sign. Presented in the first section are the descriptive data on color (including mixing formulas), format, and recommended color and shape combinations. Following this is a section which provides additional descriptive information on each system element, i.e. symbol signs and associated supplements, pavement symbols, and introductory signs. The information in these first two sections provides sufficient detail to permit fabrication and/or development of specifications for purchasing materials necessary for each system element.

The third section of the chapter provides the implementation guidelines for each of the major system components: introductory signs, guide signs, gore delineation, and ramp delineation. The primary information presented here is the frequency and location of the codes and the size recommendations for the various types of signs. The final section provides the guidelines for overall system design and installation.

Symbol Signs - Description

Color

Initially the colors to be used were restricted contractually to those classified as "unassigned" in the Manual of Uniform Traffic Control Devices (MUTCD): coral, strong yellow green, light blue, and purple. However, since there are only four unassigned colors, it was necessary to expand the number of allowable colors to six in order to provide the capability of treating either one complex interchange with more than four problem movements or two consecutive problem interchanges. The two additional colors were chosen from the listing of colors approved for highway use as designated in the MUTCD. From the "assigned" colors, orange and yellow were chosen for inclusion in the color/shape system. The primary consideration in choosing these two colors was conspicuity; however, other factors which entered into the decision to reject certain colors were: (a) the rejection of red was based upon the strong general prohibitory implication of red and the fact that the stop sign and stop light constitutes a color/shape code; and (b) the rejection of green was based upon the fact that for some of the systems to be field tested, the symbol would be located on the face of the guide signs and therefore the symbol and guide sign background would be the same.

While no night field testing was attempted because the representation of "unfamiliar" drivers (the target population) would be extremely low during night hours, it was realized that any system used would have to operate on a 24 hour basis. For this reason it was judged necessary to use reflective sheeting for the symbol signs.

One problem relative to color and reflective materials is that of day/night color continuity. That is, a color chip that appears to be purple in the daylight might appear to be red or blue under headlight viewing conditions. This results from the difference in color temperature between daylight and headlights as well as from the physical properties of retro-reflective materials. Since it is far easier to color match non-reflective (opaque) colors to transparent (reflective) colors than the reverse and since the "unassigned" colors were not commercially available in high intensity sheeting, it was necessary to undertake some color development work.

This effort was undertaken with the technical guidance and materials support of the Traffic Control Products Division of the 3M Company. It should be noted that frequent reference is made to 3M Company materials in the recommendations. This occurs because a great deal of technical assistance and material was received from the Traffic Control Products Division of the 3M Company during the materials design phase of the contract. While no proprietary claims result from work on this contract, the 3M Company is recognized as an important supplier of both materials and development in the field of highway markings and signing. Hence, their assistance in the selection and development of materials for this project added substantially to this phase of the project. Implicit in the following recommendations of specific 3M products is the statement "or their equivalent".

The color development process involved the mixing of the 3M 800 series transparent process pastes, off-contact silk screening the formulas onto <u>silver</u> high intensity grade reflective sheeting, and then perceptually assessing the results under daylight and headlight illumination conditions. Through this process the colors coral, strong yellow-green, light blue, and purple were developed and tested against the criterion of day/night continuity. It should be noted that although an adequate purple was developed for field use, its performance characteristics are less than those of the other colors; it appeared lackluster in daytime and showed a slight color shift towards red at night, as well as lacking the reflective brilliance of the other colors at night. In the initial attempts at developing a purple, the 800 series 3M process pastes were used. While the 800 series pastes are those compatible with the high intensity grade reflective sheeing, all of the mixtures attemped with these pastes showed an unacceptable shift toward either red or blue under night headlight illumination. Because of the lack of success after using a large number of different mixture formulas, it was decided to try the 3M 700 series process pastes (developed to be compatible with engineering grade sheeting) on the high intensity sheeting since the 700 series pastes afforded a broader range of pigments than the 800 series. This mixing of paste and sheeting systems, although enabling the development of an acceptable purple from the standpoint of day/night continuity, is most likely the reason for the dull appearance of the final color. Keeping in mind the qualifications regarding purple, Table 19 presents the formulas for the recommended colors to be screened on 3M High Intensity Grade Silver (2870-3870) Sheeting or the equivalent.

Table 19. Field Test Color Formulas

COLOR	PASTES*	WEIGHT (Grams)**	%
Coral	812 Red	81.0	18
	816 Orange	22.5	05
	830 Clear	364.5	77
		450.0	100
Strong Yellow-Green	808 Green	85.5	19
	822 Yellow	364.5	81
		450.0	100
Light Blue	808 Green	31.4	07
	810 Blue	126.0	28
	830 Clear	292.5	65
		450.0	100
Purple	707 Toner	254.20	78.7
	710 Blue	25.84	08
	723 Magenta Red	42.96	13.3
		323.00	100.0
Orange	Use Stock Sheeting #2884-3884		
Yellow	Use Stock Sheeting #2871-3871		

*3M Company designation/stock number.

**It should be noted the pastes are mixed by weight rather than by liquid volume.

Shape

The shapes were selected on the basis of the series of laboratory studies aimed at identification of a set of shapes which were nameable, verbally discriminable, and perceptually discriminable from one another when presented in sets. The first two criteria are critical to the navigation and/or directional communication tasks and the latter is critical to rapid search and recognition.

The shape studies were not exhaustive in that there are an infinite number of shapes that could be studied. They were instead targeted at defining a set of shapes that met the stated criteria.

Since the relevant literature indicated that in some cases an interaction between shape and color exists i.e. certain shapes might "work" better with certain colors, no recommendations on shape *per se* will be made. Rather, a succeeding section on color/shape combinations presents the recommended shapes and associated colors.

Format

In addition to and concurrent with the laboratory studies, another study was conducted to identify the overall symbol sign format and materials. This study involved subjective judgments by seven project staff members as to the "best" symbol sign in a paired comparison situation where each pair judged was varied on a single dimension (i.e. border/ no border, reflective/non-reflective, etc.). Recommendations resulting from this study identified the best combination of materials and format as a high intensity symbol on a contrasting opaque background with a high intensity border.

The recommended dimensions and use for varying size symbol signs utilizing the above format are shown in Table 20.

Table 20. Symbol Sign Size Recommendations

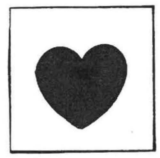
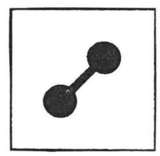
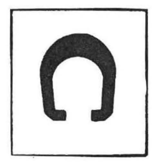
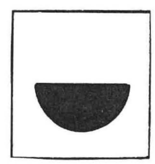
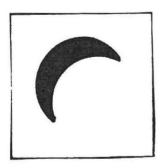
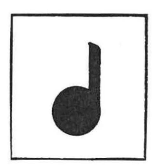
Overall Size	Border Width	Symbol Size	Use
12" x 12"	3/8"	8"	Delineator
24" x 24"	3/4"	16"	Tab, Route Marker, Gore Delineator
36" x 36"	1"	24"	Tab, Route Marker, Gore Delineator

It will be noted that the actual symbol sizes vary slightly in that the recommendation is to make the largest symbol possible from within an 8", 16", or 24" square. While this results in differences in symbol surface area and therefore in overall brightness, it is necessary from the standpoint of installation to have all symbol signs of equal overall size.

Color/Shape Combinations

Once the colors, shape set, format, and materials were identified, a final study was undertaken to determine which shapes performed best with which of the designated colors. This study, which utilized actual symbol signs fabricated from 3M High Intensity grade sheeting viewed under night headlight conditions resulted in the color and shape combinations shown in Table 21.

Table 21. Color/Shape Combinations

COLOR	NAME*	SYMBOL
Coral	Heart	
Strong Yellow-Green	Barbell	
Light Blue	Horseshoe	
Purple	Halfmoon	
Orange	Quartermoon	
Yellow	Musical Note	

*Modal name from laboratory studies

Systems Elements - Description

The field tests involved five treatments incorporating various configurations of the color/shape system elements: symbol signs, symbol sign supplements, pavement symbols, and introductory signs. The following discussions deal primarily with the use, materials, and fabrication recommendations for these elements, along with some alternative possibilities where the desired use or application may vary slightly from those employed in the current effort.

Symbol Signs

The symbol signs as designed for the field studies are extremely versatile. By varying their size, they may be used as guide sign tabs (peripheral or integral), post delineators, route markers, or gore signs. Also, their design and format is essentially in compliance with the MUTCD in terms of size, borders, legend, and reflectivity even when used as delineators.

It is recommended that symbol signs should consist of silver high intensity sheeting screened with the desired color and symbol (see Table 21) and mounted on substantial signing stock. Standard sign blanks are in most cases acceptable.

Fabrication may be undertaken in any sign shop where a dust-free, grease free, off-contact silk screening capability exists. The desired color (see Table 19) 3M 800 Series transparent process pastes should be highspeed mixed and then screened on 3M high intensity sheeting. Next, the desired symbol (see Table 21) should be screened on the colored sheeting using either 3M 805 or 845 black, with the 805 black to be used for unmounted sheeting, and 845 black to be used for mounted colored sheeting.

Where cost or materials acquisition is an issue, engineering grade sheeting or other reflective materials may be substituted. However, there are two considerations to be dealt with when substitutions appear necessary: (1) the desired color transparent process paste might not be available for the alternate system, and (2) perceptual evaluations made by the research staff showed that the symbol outlines are maintained better under night headlight conditions with high intensity sheeting.

Symbol Sign Supplements

The symbol sign supplements used for the field studies were "FOLLOW" and "TO" tabs, and directional arrow plates. They consisted of black legend (standard alphabet) and borders, on a white engineering grade reflective sheeting background, mounted on standard signing blanks. The dimensions are shown in Table 22.

The "FOLLOW" and "TO" plates were used as supplements to the symbol signs when a peripheral tabbing procedure was used, and also as components of the introductory signing configuration which utilized route markers. Figure 15 illustrates the placement and use of these symbol sign supplements.

Table 22. Symbol Sign Supplement Dimensions

Plate	Overall Size	Legend	Border
FOLLOW	24" x 24"	8"	1/2"
TO	24" x 12"	8"	1/2"
TO	15" x 12"	8"	1/2"
Directional Arrow	21 x 15	15"	1/2"

Results of the field studies showed the effectiveness of the C/S system is improved via the addition of "FOLLOW" and "TO" tabs to the symbol signs. These tabs not only add definitional information to the C/S symbols to aid the driver in making the association between symbol and destination but, also, increase the target value of the symbol signs. Based upon the comparisons of field test systems, it is not recommended that peripheral tabbing of the symbol signs be used without the supplemental tabs.

The directional arrow plate was used as a gore symbol supplement. In addition to enhancing the target value of the gore symbol it draws attention to the symbol signs used for ramp delineation, thereby providing confirmation for the driver.

Figure 15. Examples of Symbol Sign Supplements

Pavement Symbols

Pavement symbols were used for positive lane and ramp delineation. The field study pavement symbols were 4.5:1.5 (4:1 acceptable) simple linear elongations of the symbols with final dimensions being approximately 9 ft x 3 ft (2.74 m x 0.91 m). The pavement symbols were fabricated from #6250 White 3M Schotchlane Pavement Striping Tape (linered) with the symbols cut to shape and screened with a color matched opaque pigment.

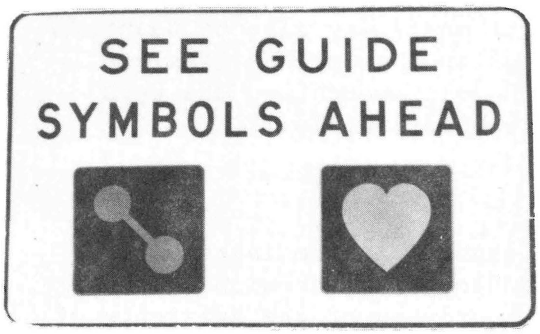
Pavement symbols may be made/applied from any of three different materials/techniques. The use of pre-cut, color-matched lane striping symbols such as those used for the current field studies appears to be the most versatile alternative. Color-matching with this method is excellent, installation is relatively quick and simple, and long-term durability may be achieved when desired via use of surface preparation solvents in the installation process. For permanent applications, the use of thermoplastic might be considered. However, color matching of the thermoplastic to the symbol signs might be difficult, particularly in the case of the unassigned colors. The symbols may also be painted directly on the road surface with the use of an appropriate template. While paint may afford adequate symbol sign color-matching, the durability of the color and symbol integrity is questionable.

Introductory Signing

The final aspect of the supplemental signing is the introductory signing used in the approach to an interchange. The function of the introductory signing is twofold: to inform drivers of the existence of the system, and to assist drivers in understanding and making the appropriate association of symbol code with destination.

Fabrication of the introductory signing used for the field tests took two forms. The first was that of a route marker assembly (see Figure 15). These introductory signs consist of the symbol signs with the "FOLLOW" and/or "TO" tabs, and either a route shield or exit sign (of the same dimensions as the symbol sign) placed in an appropriate location relative to the "TO" tab. While vertical arrangement was utilized for the field tests conducted on the current project, there is no reason to assume that a horizontal arrangement would be any less effective. If, for example, the approach to the interchange contains an overpass which is not utilized for placement of conventional guide signs, the introductory signs for the C/S system could be horizontally arranged on such a structure. Depending upon the location of the structure relative to the interchange, it may be desirable to include information as to the distance to the exit in the system introductory signs.

The second form of introductory signing used specially constructed large signs (see Figure 16) for a site specific treatment. The relevant fabrication data here is that they be large enough to "compete" with adjacent signs, and that they incorporate the necessary system information. The border and legend of the field test introductory signs were black on a white engineering grade reflective sheeting background. However, there is no reason to assume that there would be a decrement in performance or target value if some other color combination such as the standard interstate white legend on a green background should be used.



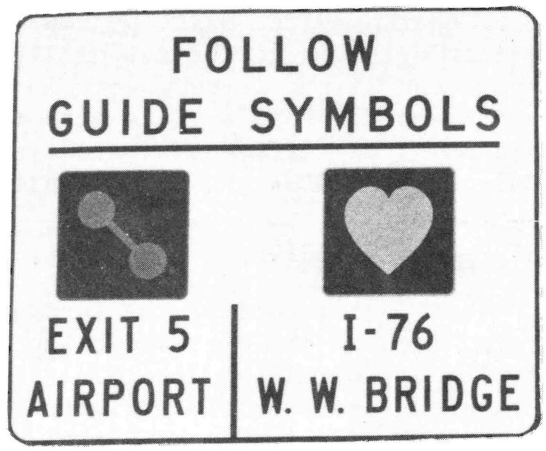


Figure 16. Custom Introductory Signs

System Components - Implementation Guidelines

This section deals with the guidelines for frequency and location of symbols and symbol sign sizes for each of the major components of the color/shape systems; the major components being: introductory signs, guide signs, gore delineation, and ramp delineation. It will be recalled that the components were not systematically varied across the various phases of field testing. Thus, while guidelines are presented for individual components, this is done primarily for documentation convenience. The guidelines, as presented, represent judgements about separate components which are based upon a combination of overall system performance results and other inputs such as visual assessment of the various components and the relationship between components.

Introductory Signing

Frequency and Location of Symbols

The function of the introductory signing is twofold: to inform drivers of the existence of the C/S system, and to assist drivers in understanding and making the appropriate association of symbol code with destination. Therefore, introductory signs should be presented frequently enough on the approach to an interchange to insure that all movements entering the site have at least one exposure prior to the start of the guide signs. Spacing will generally be dictated by site geometry and space available. However, in all applications of introductory signing, it is recommended that the spacing between information units is such that, at stream speed, at least five seconds of information processing time is available between signs (either introductory signs or introductory sign and system onset). That is, given a 55 mph (88 kph) speed limit the minimum distance interval should be 400 ft (122 m) between message units.

Symbol Sign Size

Introductory sign size and format is essentially site specific depending primarily upon the number of movements which must be accomodated. The introductory signs employed in the field evaluations varied from a simple route marker configuration of maximum height 11 ft (3.4 m) and 2 ft (.6 m) maximum width, to a 12 ft x 10 ft (3.7 m x 3 m) specially designed overhead sign.

Guide Signs

Frequency and Location of Symbols

Guide signs may be treated either with peripheral or integral symbol sign tabs. Both techniques are adaptive in nature since they are essentially modifications to the existing signing. While the integral tabs i.e. those mounted on the face of the guide sign, are more pleasing visually, both types were found to be effective. However, it will be recalled that the use of peripheral symbols without the use of supplemental "FOLLOW" and "TO" plates was not effective. Given this qualification the decision as to peripheral vs integral symbols must rest on which method results in the most appropriate spatial relationship between the symbol and the route/destinational information. In some cases neither method will be appropriate and the only alternative will be that of redesigning and installing new guide signs which incorporate the ideal placement of the symbol signs. This latter treatment will not be dealt with since it was outside the scope of the contract and therefore was not investigated.

The coding frequency or distance interval for treatment of existing guide signs is pre-determined: all relevant guide signs (to include route markers) are to be treated where possible. This criterion is independent of the type treatment, i.e. peripheral or integral tabs. Further, if the successive guide signs on a site are separated by considerable distance (e.g. more than 1/2 mile) it would seem desirable to install supplemental guide sign or route marker supplements and the associated symbol signs.

The first three color/shape systems tested utilized symbol signs which were uniformly attached to the periphery of the existing guide signs, except where a uniform peripheral attachment did not result in the symbol sign being placed in favorable proximity to the specific guidance information to which it was related. Herein lies one of the problems of peripheral tabbing. That is, some guide signs, due to the overall format of the sign do not lend themselves to uniform placement of the symbol sign. Where the symbol sign is not located in an appropriate position relative to the guidance information, the driver may fail to make the association between his route and the symbol information, thus negating the utility of the coded information. To the extent that the first few upstream guide signs permit appropriate, uniform placement of the symbol sign such that the association can be made, a location on a downstream sign which is less than ideal is more tolerable and may be used. However, even in this case, care must be taken so that the symbol signs are not placed in close proximity to other information which would confuse the association and, therefore, confuse the driver. It should be noted that a number of candidate test sites had to be dropped from consideration because the existing signs were not amenable to the peripheral tabbing technique. This problem arises not only because of sign format but also, perhaps even more frequently, because of the spatial relationship of the overhead signs. For example, a pair of guidesigns mounted side-by-side on an overpass are frequently sufficiently close together that there is not room to place a symbol sign on the right side of the left guide sign or the left side of the right guide sign. Further, the bottom of the guide signs located on an overpass are frequently at the minimum height standard and, therefore, cannot be bottom "tabbed" nor can they be top-tabbed due to the frequent existence of top-mounted luminaires. Finally, on an overpass used by pedestrians, the use of a top-tab makes the symbol sign susceptible to vandalism or theft and is, therefore, not recommended from the standpoint of maintenance.

In summary, while on the basis of the field studies conducted, peripheral tabbing appears to result in improvements in driver performance, care must be taken to locate the symbol sign in a position which permits the driver to make the correct association between the symbol and the route information and to maintain the same relative position insofar as possible throughout the site. Also, when a symbol sign peripheral tabbing procedure is used, the addition of "FOLLOW" and/or "TO" tabs is necessary.

The final two Color/Shape systems tested utilized symbol signs which were attached directly to the face of the guide signs (integral tabs), hence incorporated in the legend. Association with the guidance information was excellent and background competition/visual noise was eliminated with this method. However, this technique is contingent upon the availability of adequate space on the existing guide signs. In some cases where adequate space is not available, it may be possible to make minor modifications to the existing signs in order to accomodate the symbols as was done in two field test systems. In other cases, no amount of modification short of sign replacement/redesign can provide the necessary space; therefore, this technique is not applicable in these cases.

The positioning of the symbol signs should be uniform throughout the site (where possible) and should be such that the association between code and guidance information is readily made. For example, the symbol sign could be located below the verbal message and adjacent to the directional arrow if one exists. It should be noted that the field tests which utilized integral tabs also included introductory signing. It is therefore recommended that when an integral tabbing procedure is used and the "FOLLOW" and "TO" supplements are therefore not used, introductory signing should also be part of the system to facilitate the coding association.

Another element which can be considered part of the guide signing component is that of pavement symbols when used primarily to reinforce lane assignment information as provided by the guide signing sequence. When used in this manner symbol placement should begin after the system informational signing and at least one guide sign treatment has occurred. Initial application of the pavement symbols should be in close proximity to a treated guide sign; this will increase the probability that drivers will make the necessary association upon first encountering the pavement symbols. The pavement symbols should then either continue through the site and terminate near the gore or, if additional route confirmation is required, can continue through the gore and serve as ramp delineation. The use of pavement symbols as ramp delineation is discussed in a subsequent section.

Symbol Sign and Pavement Symbol Size

Guide sign treatments for the field evaluations utilized both 24 x 24 inch and 36 x 36 inch symbol signs. Only the 24 inch symbol signs were used for peripheral tabs and only the 36 inch symbol signs were used for integral tabs. However, there is no reason to assume that the sizes and techniques can't be interchanged. In terms of target value the choice of size should be the larger symbol sign whenever possible. The primary consideration in selection of the symbol sign size is the overall size of the guide sign. A large guide sign containing a small symbol sign will result in a loss of target value for the symbol. The size decision can be easily made via review of a scale drawing of the guide sign with symbols drawn in the available space.

The pavement symbols used for lane assignment were approximately 3 x 9 ft and were placed on 200 ft centers. This size was adequate visually and there is no basis for recommending larger symbols. While it is possible that smaller pavement symbols would be as effective, only one size was used in the field tests and it is therefore not possible to make such a recommendation.

Gore Delineation

Frequency and Location of Symbols

The systems used in the series of field tests provided gore delineation via post-mounted symbol signs. The gore delineation will generally consist of a single symbol for each traffic movement; the exception being an exceptionally wide gore in which case several symbol signs would be required at close spacing. The gore delineator is of course at or near the physical gore nose for each movement treated. The primary factor to be considered is that the posts do not present an undue safety hazard in regards to their placement, i.e., if mounted too close to the gore nose, the potential exists for increased damage/injury to those drivers using the gore as a recovery area. Where two adjacent movement are treated the relative placement of the symbol signs for each movement is contingent upon the gore configuration. The signs for both movements should, ideally, command equal attention, i.e., be placed so that drivers entering the gore area have an adequate view of the symbol signs associated with each movement. However, where the gore configuration is such that one of the gore signs must be given placement priority, the problem movement, usually the exit, must be given visual priority. It is recommended also that arrow plates mounted at the appropriate angle be included as discussed below.

Symbol Sign Size

Three sizes of symbol signs were used for gore delineation in the various field test systems. The initial test utilized 12 x 12 inch signs for both the gore and ramp delineation. On the basis of visual impact this size was judged to be too small. In order to increase the target value of the lead gore sign and provide greater information definition, the lead gore sign for the next field test was changed to a 24 x 24 inch sign. The lead gore sign was again changed for the final two field evaluations to a 36 x 36 inch sign with a supplemental directional black-on-white arrow plate mounted below the symbol sign. This sign size not only had greater visual impact, but the directional arrow was intended to draw attention to the symbol signs used for ramp delineation, thereby providing some confirmation for the driver. Although evaluation was done on the system "in toto" rather than on individual components, it is suggested on the basis of visual impact that the final gore delination treatment (36 x 36 inch symbol sign and directional arrow) be used where possible.

Ramp Delineation

Frequency and Location of Symbols

Ramp delineation configuration is determined primarily by site geometry and sight distance characteristics. Based on the field work by project staff, it is recommended that where geometry is tangent and sight distance is unobstructed, delineators should be post-mounted about four feet above the near roadway edge on 200 ft (61 m) centers continuing for 1000 ft (305 m), using the gore symbol delineator as the zero point. Where site geometry is not tangent and/or where sight distance is limited, the delineators should begin at the gore and continue on 100 ft (30 m) centers or an appropriate lesser spacing such that drivers have a view of no less than two delineators from any vantage point. One final option for more positive ramp delineation is the treatment of both ramp shoulders as opposed to only the outside of curves and the right shoulder of tangents. The need for this type of installation can be determined by visual observation/evaluation. The need for symbols on both sides of the roadway is greater on two-lane movements where traffic in one lane may obscure the view of drivers in the other lane. In addition to symbol sign delineators, pavement symbols may be added for more positive lane or ramp delineation. The frequency of pavement symbol application is dependent on site traffic conditions/composition and the size of the symbols. In the field test system which utilized pavement symbols the specifications were 9 x 3 ft (2.7 x .9 m) symbols on 200 ft (61 m) centers beginning at the gore. In the case of a two lane ramp the pavement symbols should be used in both lanes. Otherwise drivers entering the unmarked lane may feel it is necessary to use the lane employing the pavement symbols, thus engaging in unnecessary lane changing.

Symbol Sign Size

The symbol sign delineators used for ramp delineation in the field tests were 12 x 12 inches (.3 x .3 m).

System Installation Considerations

The experience of the project staff in the installation of the various C/S Systems led to the identification of several factors which dictated variations in installation procedures or installation hardware. The purpose of this section is to provide a discussion of those factors, the resulting problems, and the solutions which were applied. The section also identifies the information which must be available from the field site review in order to develop an operationally effective installation plan.

Color/shape system installation is, of course, not dissimilar from other types of sign installation and as such is well within the capability of any organization providing the necessary heavy equipment is available (platform truck, highlift, etc.) and a reasonable amount of planning and on-site observation/evaluation has been done. Actually, the most important aspect of the installation procedure is the field observation and planning stage. In some instances, it might seem more desirable and cost effective to design a system and develop an installation plan exclusively "from the office." However, because of reasons such as highway improvement programs, failure to update signing plans, or the existence of incomplete signing plans, this technique can result in installation problems and delays; hence the strong emphasis on field observation during the design stage. For example, failure to physically check the existing signs for corrosion/deteriorating prior to system installation can render an otherwise perfect planning effort ineffective in the field. Also, failure to note through actual observation that there are different types and thicknesses of existing signs within the same interchange may have the same effect as above.

Some of the items discussed may seem of little consequence, but all of them have the potential, if overlooked or unattended to, to either result in delays in the field system installation effort or result in maintenance problems sometime after installation.

Peripheral tabbing is the aspect of C/S system installation which involves the greatest number of contingencies. The ideal procedure for peripheral tabs would be to simply attach a new section of guide sign of the appropriate dimensions to accomodate the symbol sign. Ideally, this tab would be of the same material and therefore require the same mounting hardware as the original sign. However, this technique is costly and frequently impossible because of the desired location of and space available for the tab.

An alternative installation technique which is less costly and more flexible (which was used for the current field studies) is that of attaching a tab assembly consisting of a symbol sign mounted on support posts to the existing sign. Delineator posts, angle iron, or small gauge I beams are adequate materials for the support posts. This can be done in two ways: (1) using hardware specifically designed for such a procedure i.e. clamps or "feet" for laminated signs, or (2) by drilling through the guide sign and tab support posts and bolting them together. If stock hardware is used then the existing signs should be checked for corrosion/damage and also to see if channels, brackets, etc. that will accept stock hardware for the desired tab placement are available. Failure to check sign condition could halt installation if the hardware channels are corroded, a condition which frequently exists.

Wind loading is a safety consideration associated with peripheral tabbing. If stock hardware is used on corrosion weakened signs the potential exists for the tab to break free and fall on traffic below. If stock hardware is not used and bolts are used instead (a technique which is necessary when stock hardware channels are corroded) then the bolts should be steel of substantial size (5/16" minimum) rather than aluminum since the aluminum bolts tend to shear under severe wind loading. In addition to steel bolts which resist shear, it is necessary to use plates or large washers (2" x 2" minimum) on the signface under the bolt-head to dissipate the stress and prevent the bolthead from pulling through the sign stock.

Regardless of the mounting system used, spacers between the symbol sign and post are usually required to bring the peripheral tabs flush with the face of the guide sign so that the border of the symbol sign is not covered when viewed from the roadway. This problem was encountered on one of the field sites where there were three thicknesses of guide signs: 3/4", 2 1/4", and 4". In this case the tabs were made flush through the use of different size milled wood spacers. Since only minimal rear offset can be tolerated the availability of predrilled spacers will facilitate installation.

Integral tabs are easier to design and install than peripheral tabs but they are still not problem free. Mounting is relatively simple using signing grade pop-rivets. However, outdated signing plans or inadequate field observation can result in another type of problem. For example, if a sign was replaced since the original signing plans were drawn, it may be that the legend on the new sign is identical to the plans but the legend spacing might be slightly different. Failure to check the accuracy of the plans could result in inadequate space to mount an integral tab.

Gore delineation and ramp delineators are installed using standard equipment and techniques. That is, the symbol signs are mounted on conventional delineator posts. However, care should be taken in their placement during installation to avoid contact with buried conduit.

Where delineation of both shoulders of a ramp is desired and a concrete median barrier defines the one shoulder, delineators may be barrier mounted using steel L-brackets secured with concrete anchors. Steel brackets are specified because median barrier delineators are subject to significant air turbulence from large vehicles. In the case of the current project, readily available shelf brackets were successfully used.

It is obvious that none of the problems encountered on the present project were particularly difficult to solve either from an engineering or materials standpoint. The most important element in the installation effort is an adequate site review to identify the specific materials and techniques which are necessary for installation.

Public Relations Considerations

The purpose of this section is to provide potential users of the Color/Shape System with some comments concerning public relations. The comments are based on our experience with news media coverage following installation of one of the systems on the Philadelphia site. As background it should be noted that, while consideration was given to the preparation of a news release previous to the installation of the initial system on the York site, it was decided not to do so. The reasoning behind this decision was that the news release would have to be fairly lengthy in order to adequately explain the system and the concepts being tested and it was felt that the release, if used, would therefore most likely be edited. Since the nature and extent of the editing would not be under our control, there was concern that news articles derived from the release might misrepresent the project and/or system purpose. Because the system was being subjected to evaluation, the preference was to have no publicity. It was felt that if the news media deemed the system newsworthy, project personnel would be contacted and interviewed and that this would be more likely to result in appropriate coverage.

Upon installation of the system in York this, in fact, occurred and a favorable article appeared in the local newspaper. Similarly, following the initial installation of the system in Philadelphia, an interview resulted in a very short, factually correct piece in one of the daily columns in a daily newspaper. In spite of the fact that this system was up for nearly 10 months, no further news coverage resulted. Up to this point, the decision to refrain from preparing a news release was judged to be appropriate. However, during installation of the second system tested on the Philadelphia site, a newspaper reporter and a radio reporter were granted interviews by one of the project members on site. This was but the start of broad media coverage encompassing at least 14 separate instances of coverage, including newspaper (articles, editorials), radio, television, and some periodicals. This coverage also produced seven letters to the editor. This coverage continued over a period of seven weeks. The basic problem with the coverage was that much of it, even though based upon interviews with project personnel, presented an uninformed view of the purpose of the system. For example, in spite of the fact that reporters were told that the symbols were chosen from a series of laboratory studies to be applicable to any problem interchange and not chosen specifically for the Philadelphia interchange, and that they were route related rather than destination related interchanges, many of the reports suggested that the symbols should have shown a bridge and an airplane to refer to the Airport exit and the Walt Whitman bridge exit. Generally the system was treated in a jocular manner i.e. calling the barbell symbol a dumbbell, thereby resulting in article headlines such as: "Hearts to the right! Dumbbells go left!" or "Are you a Dumbbell?" In summary, much of the media coverage involved misinformed opinions and/or presented the color/shape system in a manner which is likely to have resulted in unfavorable public opinion. This occurred even though project personnel contacted for interviews attempted to specifically counter the misinformation or misinterpretations that resulted from the initial interviews. On the basis of this experience, it is recommended that future applications of the system be preceded by the preparation of a news release and the solicitation of cooperation of the various news media. It is suggested that the following information be included in the news releases: (a) general purpose of the color/shape system; (b) specification of safety and operations benefits; (c) rationale for color/shape codes; and (d) reason for the specific symbols to be employed. The use of symbol codes can be tied in with the increasing use of symbol codes to provide drivers with easily processable information.

V. FUTURE RESEARCH RECOMMENDATIONS AND SUGGESTIONS

The current project was designed to evaluate the concept of redundant color and shape coding as applied to freeway route guidance at problem interchanges. In order to provide an adequate test of the concept the initial steps were taken toward the development of a coding system designed to supplement conventional guide sign information. Since the field evaluations showed that color/shape symbol codes can enhance safety at problem interchanges by producing a significant reduction in the commission of erratic maneuvers, it is felt that additional development and testing is merited. More specifically, it is felt that three areas deserve consideration for future research: (1) additional field testing; (2) development and testing of specific system elements; and (3) extension of the C/S coding concept to other applications. The recommended types of studies are discussed below under each of the three categories.

Additional Field Testing

The purpose of additional field tests would be to determine the range of problem interchange types which would benefit from the use of the color/shape (C/S) system. In light of past research on diagrammatic signs, which showed that diagrammatics had beneficial effects on some interchange types, e.g. left exits but not on others, e.g. cloverleafs, it is felt that the color/shape system should be evaluated on several types of problem interchanges. In addition to establishing the range of applicability of the C/S system, these field tests could be designed to investigate several other questions which remain to be answered. It will be recalled that the acclimation period used in the current field tests was relatively short. While this choice was consistent with the goals of these initial field evaluations, the long term effectiveness of the system should be determined before broad scale deployment is recommended. The additional field tests could be designed to answer this question by utilizing an acclimation period of one year. This time period is recommended so that the "before" and "after" population of unfamiliar drivers would be proportionally similar.

Another area which was not investigated in the current effort is that of the effects of multiple "introductory" signs or different introductory sign formats. Since it is the association between the symbol and route or destination which acts to reduce the information load for the driver by reducing the sign reading tasks, it is possible that improved introductory signing could result in even greater benefits than those shown in the current study. The field tests aimed at long term effectiveness assessment could be designed to accomodate several levels and/or types of introductory signing by utilizing multiple data collection efforts on the same site with short acclimation periods such as those used on the current study. Following the final data collection in such a series, one of the introductory sign configurations could remain intact for the long term effectiveness evaluation. Also by comparing the short term "after" data with the long term "after" data the acclimation effect per se could be directly assessed.

In summary, it is recommended that the range of effectiveness of the color/shape coding system be established via evaluation on several sites having geometrics which are different from those used in the current project. Further, if this recommendation is accepted it is suggested that several introductory sign treatments be evaluated utilizing short adaptation periods for each treatment. Finally it is suggested that one of the systems on at least one of the sites remain intact for a period of one year in order to assess the long term effectiveness of the system.

Development and Testing of Specific System Elements

The purpose of the suggested studies under this category would be to optimize system elements such as symbol/guide sign format, frequency of symbol presentation, etc. It will be recalled that the current field evaluations utilized existing guide signs, thus the opportunity to design guide signs which incorporated the symbol signs was restricted to only minor size modifications of the guide signs. However the successful performance of the C/S System would seem to justify some laboratory and/or dynamic simulation research aimed at the development of sign design guidelines, particularly if deployment of the system is eventually going to be recommended by FHWA. There are several reasons justifying such a research program. First, signs designed specifically for accomodation of the symbols may result in better performance. Secondly, there are many existing guide signs which are not amenable to incorporation of symbols via minor modification and would therefore have to be redesigned. This latter observation is based upon the review of signs on a number of candidate test sites for the current field tests. Thus, to the extent that guide signs on some sites would have to be redesigned in order to utilize the C/S System, it would seem desirable to provide those who would be charged with that task with design guidelines. Since there are a large number of independent variables which are potentially relevant to sign effectiveness it is recommended that these guidelines be derived from the results of laboratory rather than field studies.

The specific purpose of the studies would be to identify the most visually effective and understandable placement of the symbols relative to other message elements such as exit numbers, place names, and lane assignment arrows or legends. For example, given the typical sign reading patterns it may be more effective to place the symbol signs near the top of the sign rather than the bottom. Also symbol signs of the integral type may be more effective with the inclusion of "FOLLOW" and "TO" in the overall guide sign message. The improvement in system performance when such information was added to the basic system for the field tests suggests this as a possibility. There are many different message formats which could not be dealt with in the field studies which could be studied at relatively low cost in a laboratory situation. The problem, of course, with any such static laboratory study is the translation of observed laboratory effects to the real world. For this reason it would be desirable to conduct such studies in a dynamic simulator where the driver task loading, i.e. lateral and longitudinal control tasks, could be more realistically duplicated.

A laboratory study or series of studies such as discussed above could also include other independent variables which could not be dealt with in the current project. They are suggested for consideration because they relate not only to overall system effectiveness but also to various site characteristics; characteristics which will force difficult decisions upon those charged with adapting the general C/S System to the site. The objective of including these variables in the laboratory program would be to provide the necessary guidelines for such decisions. The first of these was discussed in the section on field studies, but could also be studied in the laboratory: the design and presentation frequency of introductory signs. Certainly one would expect an interaction between the introductory signs and the guide sign information; thus data regarding the relative effectiveness of symbol/route association via introductory signing versus guide signing would be very useful. That is, on any given field site there may be restrictions on either guide sign design (particularly size) and/or space for placement of introductory signs. Given field restrictions of this type it would be desirable to be able to identify system design guidelines which specified the most appropriate tradeoffs. For example, suppose in the laboratory it was found that the inclusion of "FOLLOW" and "TO" tabs to the guide sign message was the most effective format. Suppose it was also found that the use of multiple introductory signs could compensate for a less effective guide sign format. The guidelines could then be written such that alternative system designs could be specified for various contingencies. For example, the guideline may state: If the site is such that there are restrictions on the overall size of the guide sign which can be used and therefore the "FOLLOW" and "TO" message format cannot be used it is necessary to use three introductory signs on the approach to the site.

Another independent variable which deserves consideration for inclusion into a laboratory program is the number of pairings of symbol and guide sign information. The spacing of the guide signs on the field sites used for the system evaluations on the current project were such that there was always a guide sign in view and therefore no supplemental symbol/route signs were required. However this will not always be the case. In cases where there are few advance guide signs and/or where the distance between guide signs is great, the use of ground-mount symbol/route supplements may be desirable. The general question of the number and/or frequency of associational pairings could also be studied in the laboratory so that relevant guidelines could be established.

Extensions of the C/S Coding Concept

Since the concept of color/shape coding has been shown to be effective for freeway route guidance problems, it is felt that consideration should be given to utilizing the concept for other guidance applications.

The first of these is the detour or diversion situation. Since, in a detour situation, detour signing must be installed along the detour route, it would seem that the inclusion of color/shape codes as a supplement to the conventional detour signing could be accomplished at relatively little additional cost. The use of C/S codes in this situation has several advantages. First, the overall novelty of the signs would enhance the target value of the detour signing. Secondly, the conspicuity of the detour signing would be enhanced such that the information search load on the driver would be reduced and performance should therefore be enhanced. This is particularly true for detours involving a number of urban intersection choice points where the driver must deal with signals, other traffic and search out the detour routing from among a number of other routes. Here the detour route supplemented with the C/S codes would be clearly different from all of the other route signs. The color/shape symbols could also be mounted on roadside delineator posts where there were longer distances between choice points, such that the detoured driver, having been presented with the symbol/route association, would have confirmation that he was on the correct route.

Another way in which the coding concept might be used is as a supplemental treatment to diagrammatic signs for those interchange types where pure diagrammatics were not shown to be effective. The idea here would be to color code that portion of the stem and arrow of diagrammatic related to a particular movement. The gore and ramp for each movement would also be treated with either square or rectangular reflective plates of the appropriate color to provide both guidance and confirmation. The guidance function could perhaps be enhanced via use of larger gore color plates and color coded gore arrows matched to the geometry. The disadvantage of this system, of course, would be that the redundant color and shape code is not utilized thus it would not be an aid to color deficient drivers. However, it may be possible to integrate the color/shape symbols into the diagrammatic signs and to use the symbol signs for gore and ramp delineation.

One final note regarding the future development and deployment of the color/shape system. To the extent that there is a reasonable likelihood of future widespread deployment of the system for problem interchanges, consideration should be given to a form of standardization for use of the symbols. For example certain symbols would be used only for left exits, others for cloverleafs or diamonds. In other words, by using the symbols in a specific manner, the C/S System could carry a geometric code. This of course involves the problem of many highway codes; that of the driver being aware of the code. However, such coding of geometrics via specific assignment of symbols would have no degrading effect on the system per se and with future improvement in driver education the code could have some benefit.

FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

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* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD-2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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