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HOSTETTER

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COLOR AND SHAPE CODING FOR FREEWAY ROUTE GUIDANCE

Vol. I. Executive Summary

DEPARTMENT OF TRANSPORTATION · UNITED STATES OF AMERICA

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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 an executive summary of the project activities and results.

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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 was 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 Volume II 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 "dumbbell" 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, it 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.

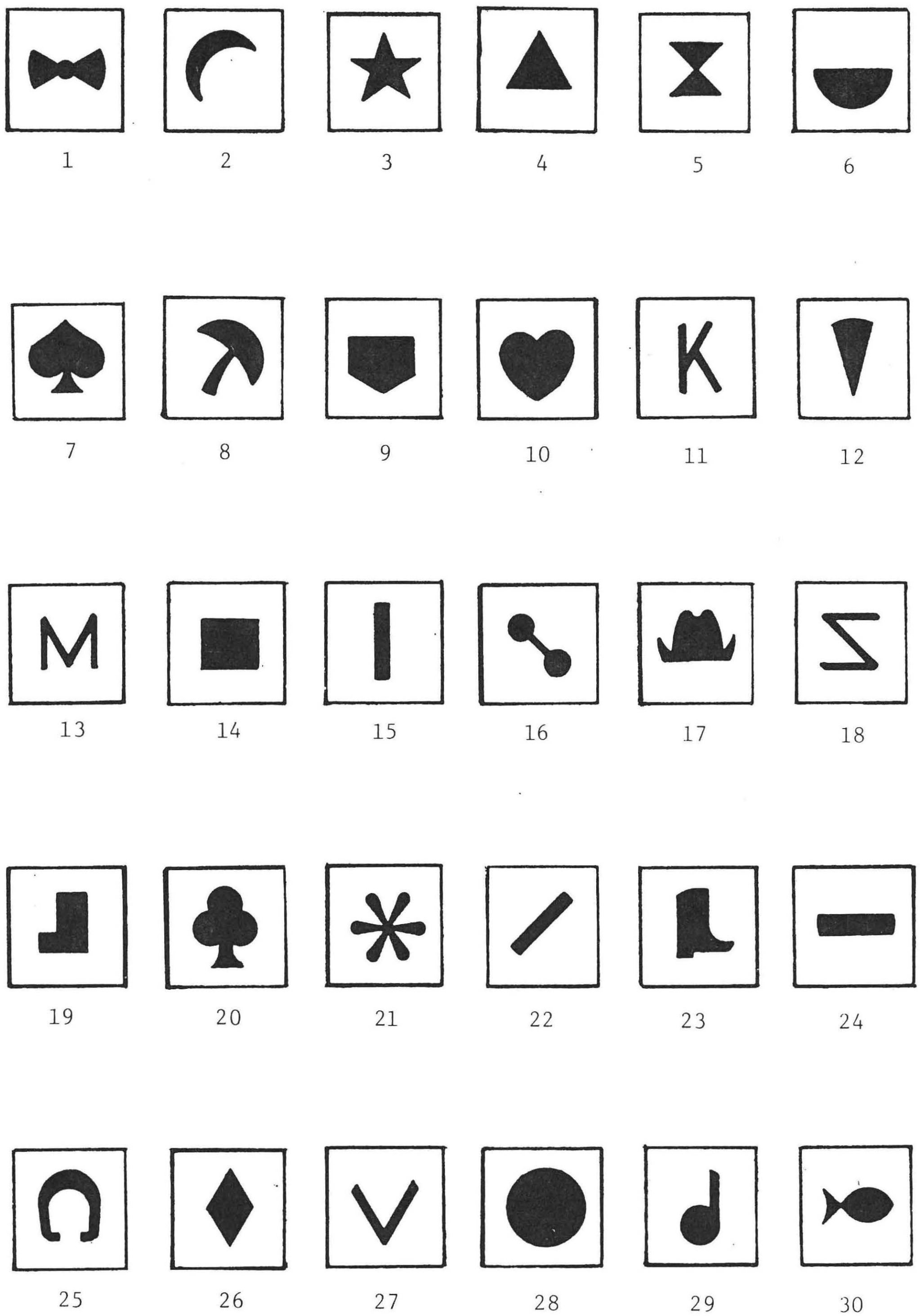

Figure 1. The 30 Shapes used in Study I

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 from 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 in this series was designed to evaluate 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 marker. 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 appeared 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, response 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 ongoing development of both the system itself and the guidelines for implementation.

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 symbols on the guide signs. The observation based judgments, validated via system performance data represented a 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 longer term research prior to widespread system deployment) is based upon the fact that the system is primarily aimed at drivers unfamiliar with 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 i.e. repeat drivers, is expected to be minimal after only a few exposures to the system.

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 Over-head and Ground mount route/ symbol associa-tion signs	36" Symbol signs - Sign face mounted	None	36" Symbol sign with Arrow Plate - Post mounted	Lead 24" subse-quent 12" Symbol signs -- both shoulders	None
E	III	Phila., PA. I-76	Upstream Over-head and Ground mount route/ symbol associa-tion signs	36" Symbol signs - Sign face mounted	None	36" Symbol sign with Arrow Plate - Post mounted	Lead 24" subse-quent 12" Symbol signs -- both shoulders	9' X 3' On 200' centers through treated site

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 direction are violated by a geometry where what appears to be the ramp is actually the through movement 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 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, consisting 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) 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 system 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 sections provides a brief description of the field sites, identifies the specifics of the C/S systems evaluated, and presents a summary of the results of the field evaluations. The detailed information regarding the field evaluations is provided in Volume II of the report.

PHASE I EVALUATIONS

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 geometrics 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, therefore, expected configuration.

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.

Signing Treatments

There were two phases of signing treatments on this site: System A, which was "baseline" treatment involving peripheral tabbing of the symbol signs (see Figure 4), 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 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.

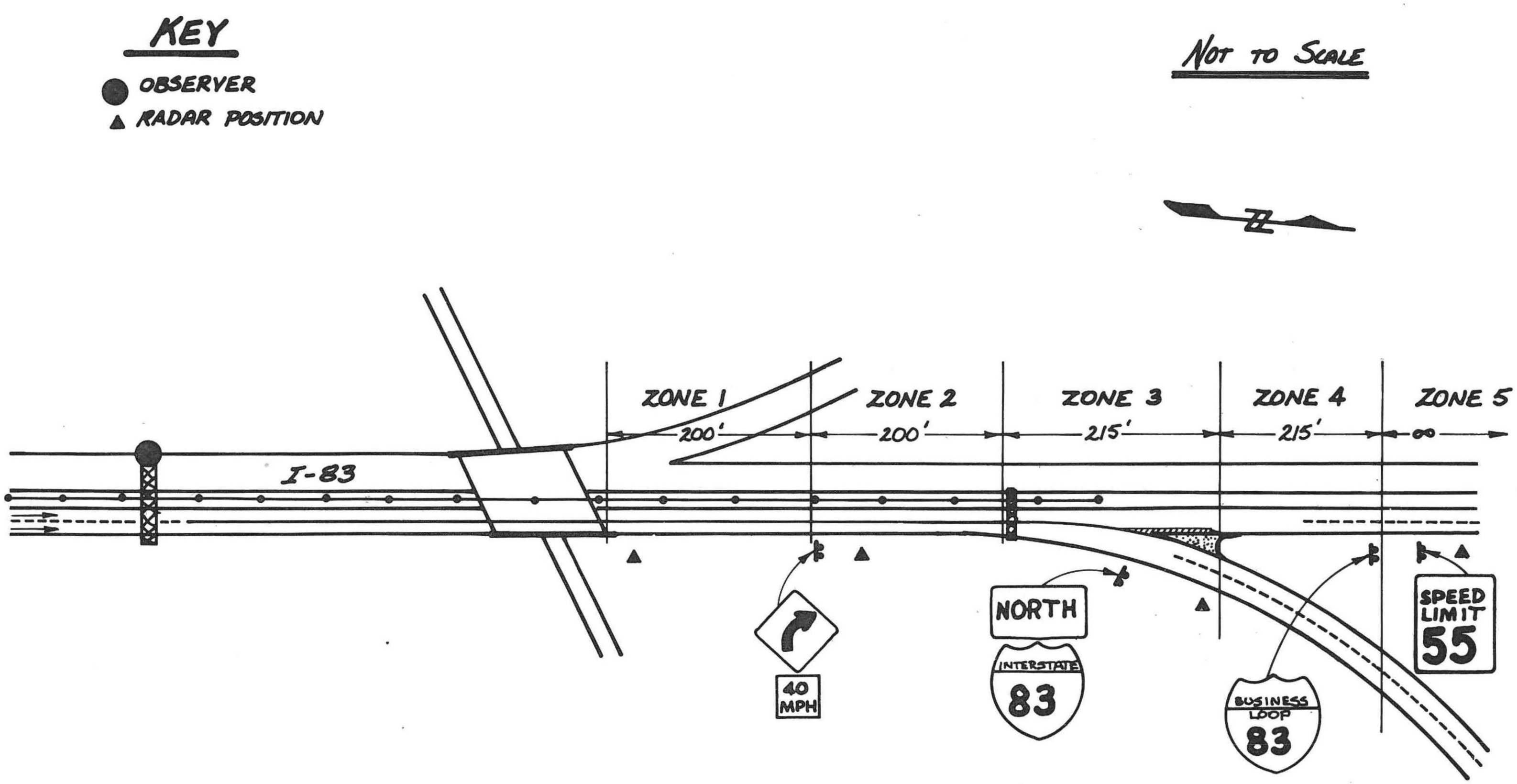

Figure 2. I-83 York Site Schematic

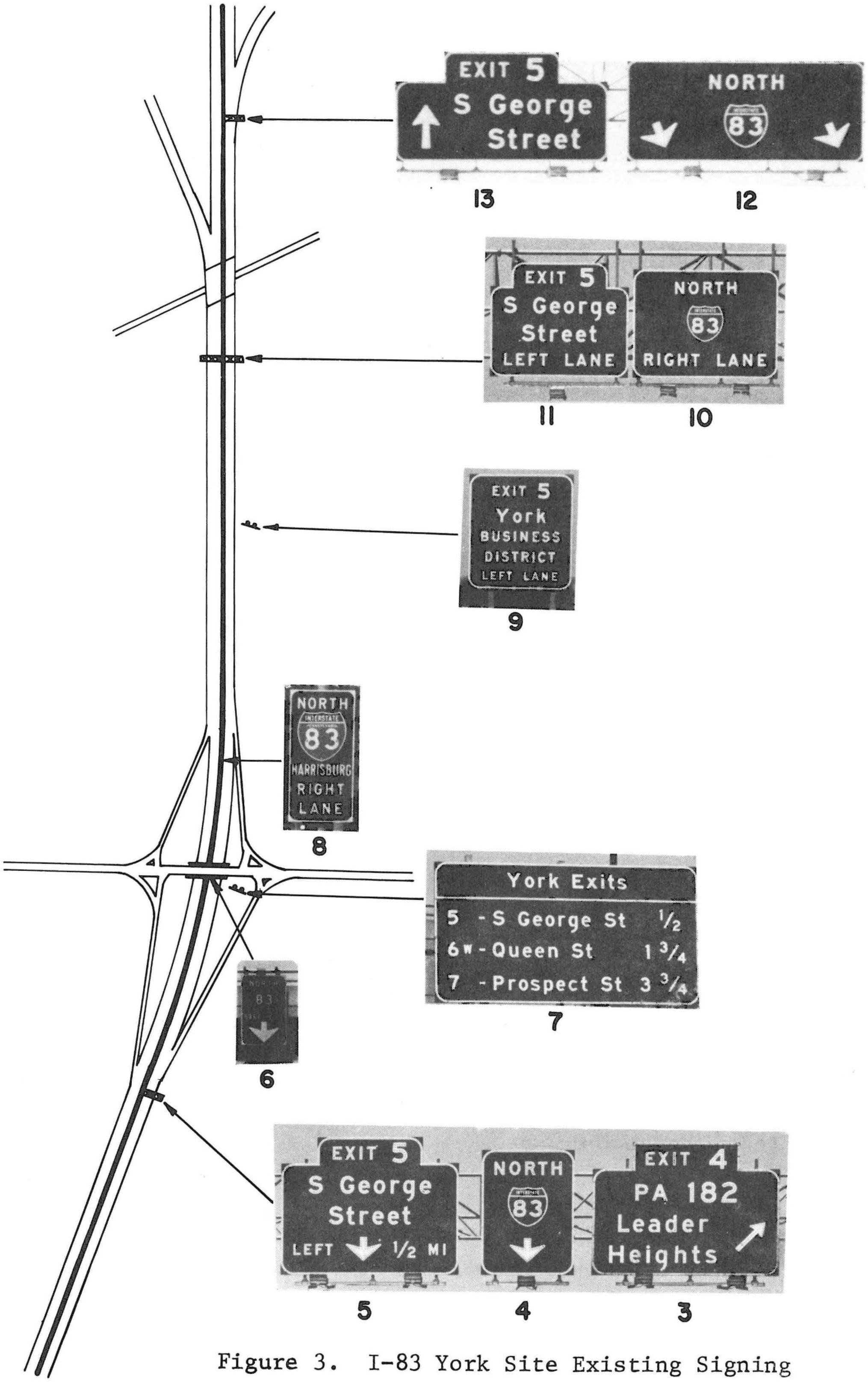

Figure 3. I-83 York Site Existing Signing

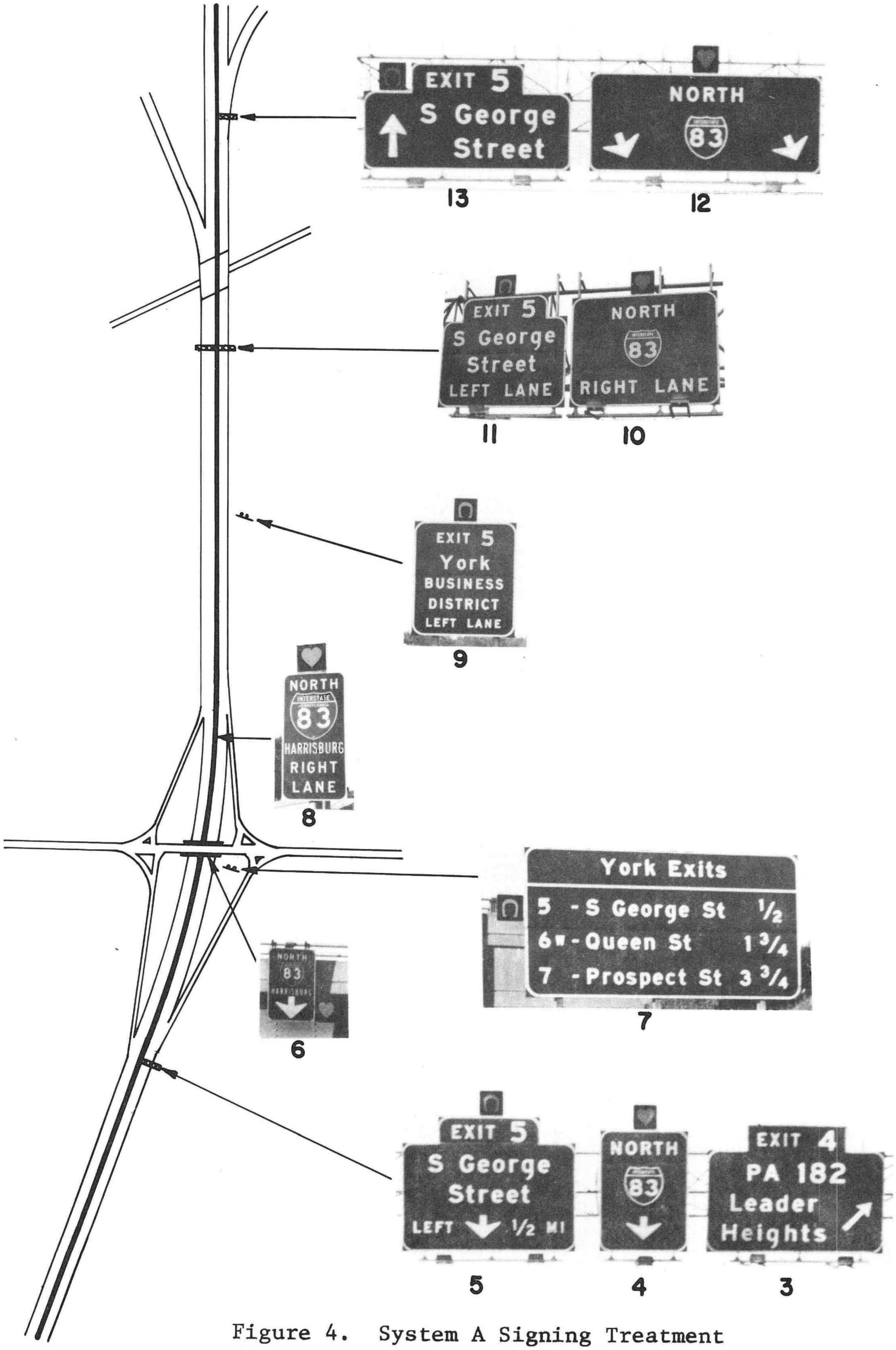

Figure 4. System A Signing Treatment

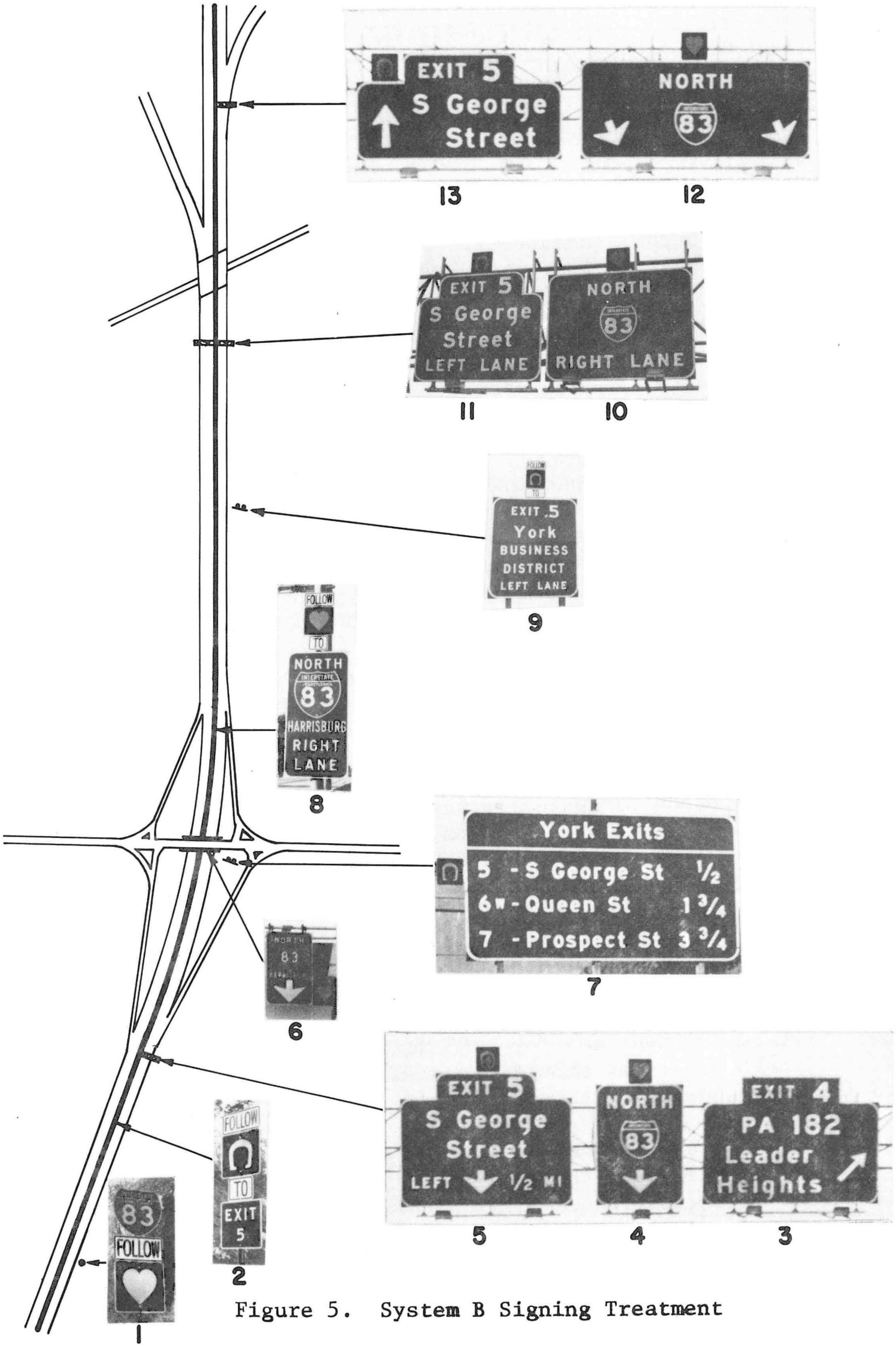

Figure 5. System B Signing Treatment

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. 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.

In order to present a uniform and predictable system, the guide signs were top-tabbed wherever possible. There were to 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 more 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 non-existent, it was necessary to install the symbol sign 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 siging.

System B was the same as System A except for the following three additions and/or modifications. The first addition was that of two signs located upstream of the first relevant guide sign (see signs #1 and #2 in Figure 5). The purpose of these signs was to provide the drivers with advance information regarding the association between his destination or route and the symbol signs. 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 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 distance 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 at 55 mph (88 kph). Both time intervals are judged to be 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 to two of the previously treated signs. This was done to reinforce the association as presented in signs #1 and #2.

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

The System B delineator symbol was placed 100 ft (30 m) further upstream than the first delineator of System A, and a 24 inch rather than a 12 inch symbol sign was used. The intent of the treatment was to increase target value and upstream visibility of the gore symbol signs for this movement. By locating the lead delineator closer to the gore (final driver decision point) it was hoped that 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 inch post-mounted symbol sign was placed 200 ft (61 m) downstream of the exit gore, and two 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 is 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.

Data Collection

The data collection procedure utilized two observers for the collection of erratic maneuvers, volumes, speeds, and traffic composition. One observer was charged with collecting volumes, speeds, and traffic composition (truck counts), and the other observer was responsible for the recording of erratic maneuvers (EM's), and monitoring two recording counters and two CB radios.

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. 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.

Observer 1 also recorded speed samples at four locations shown on Figure 2. 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 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.

There were nine different "erratic maneuvers" recorded by Observer 2: late lane change (exiting vehicles), late lane change (through vehicles), gore crossing, swerve, braking, stopping, backing, slow driving, and revolves. While most of the erratic maneuvers (EM's) listed are self-explanatary, the EM entitled "revolve" requires definition. The "revolve" is a complex maneuver, actually a series of maneuvers, which is highly hazardous. It 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.

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.

Results 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

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

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 but non-significant 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 System A treatment.

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. It perhaps should be noted that the complex and hazardous "revolve" maneuver was reduced from 14 occurrences under the conventional signing (before) condition to 3 occurrences under the System A color/shape (after) condition. Finally, with regard to the vehicle speed data it was found that System A produced a statistically significant increase in exiting speed along with a decrease in speed variance; a result which would tend to support the contention that the C/S system had a facilitative effect upon overall traffic flow characteristics in the vicinity of the exit gore. However, the changes were so small that they have no practical significance.

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

Results and Conclusions - System B

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. This upstream shift in the location of the maneuver is favorable from a safety standpoint in that an earlier lane change is more consistent with the expectations of other drivers and it provides the lane changing driver with greater recovery time/distance before arrival at the physical gore. This result suggests that drivers are less confused and are making the directional decision earlier with the aid of the color/shape coded information.

System B also 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 A, were reduced under System B 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 change in exiting mean speed was increased over both 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 B evaluation showed enough promise that further testing of this system was merited on another type of site.

PHASE II EVALUATIONS

Site Description

This site is on I-76 East in Philadelphia, Pa.; site configuration is depicted in Figure 6. 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, the highway begins to widen. 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 an additional ground-mount guide sign as shown in Figure 7. The first sign bridge is approximately 3000 ft (914 m) upstream of the right phsycial gore.

Signing Treatment

The signing treatment initially applied in the Phase II 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 8. 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

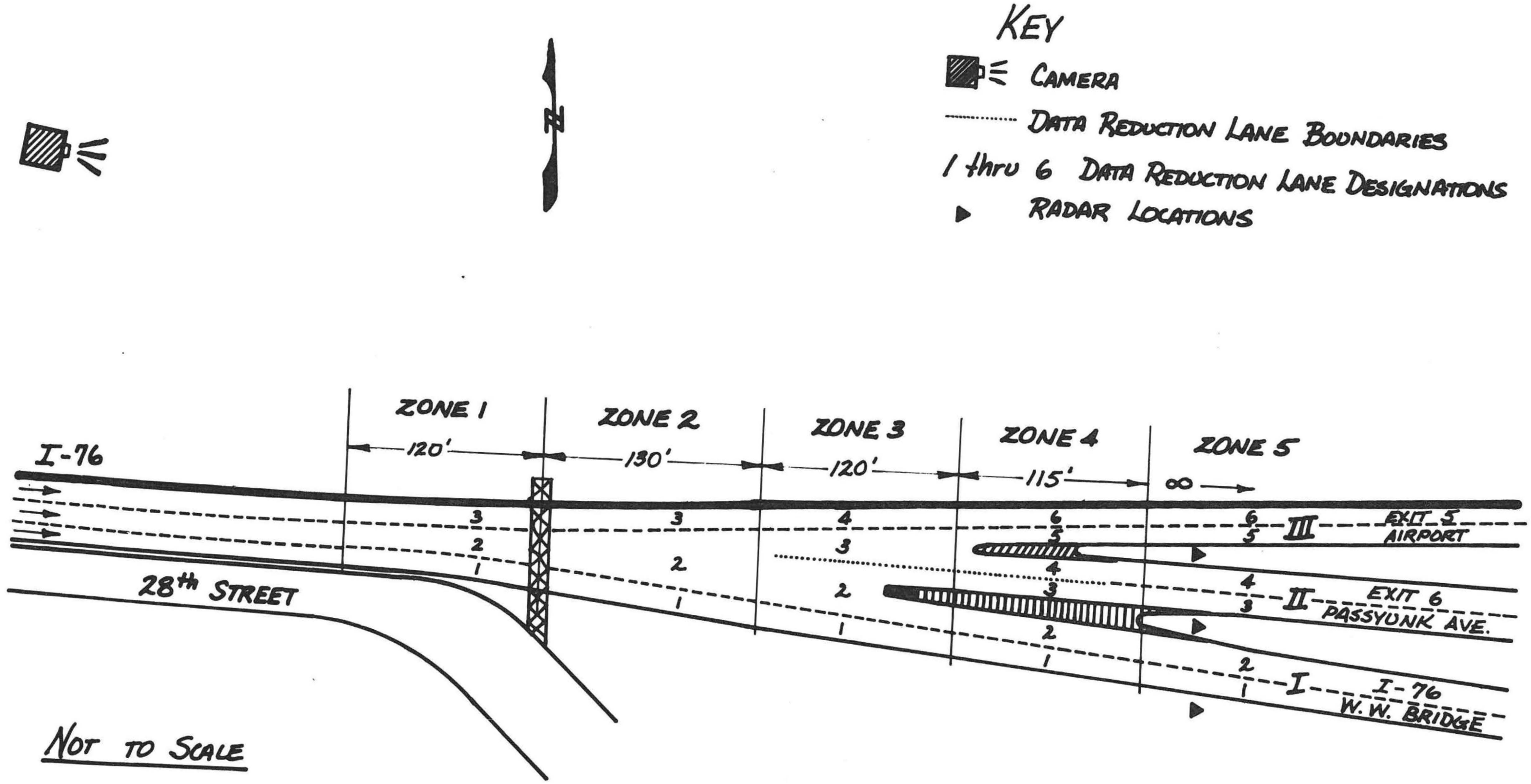

Figure 6. I-76 Philadelphia Site Schematic

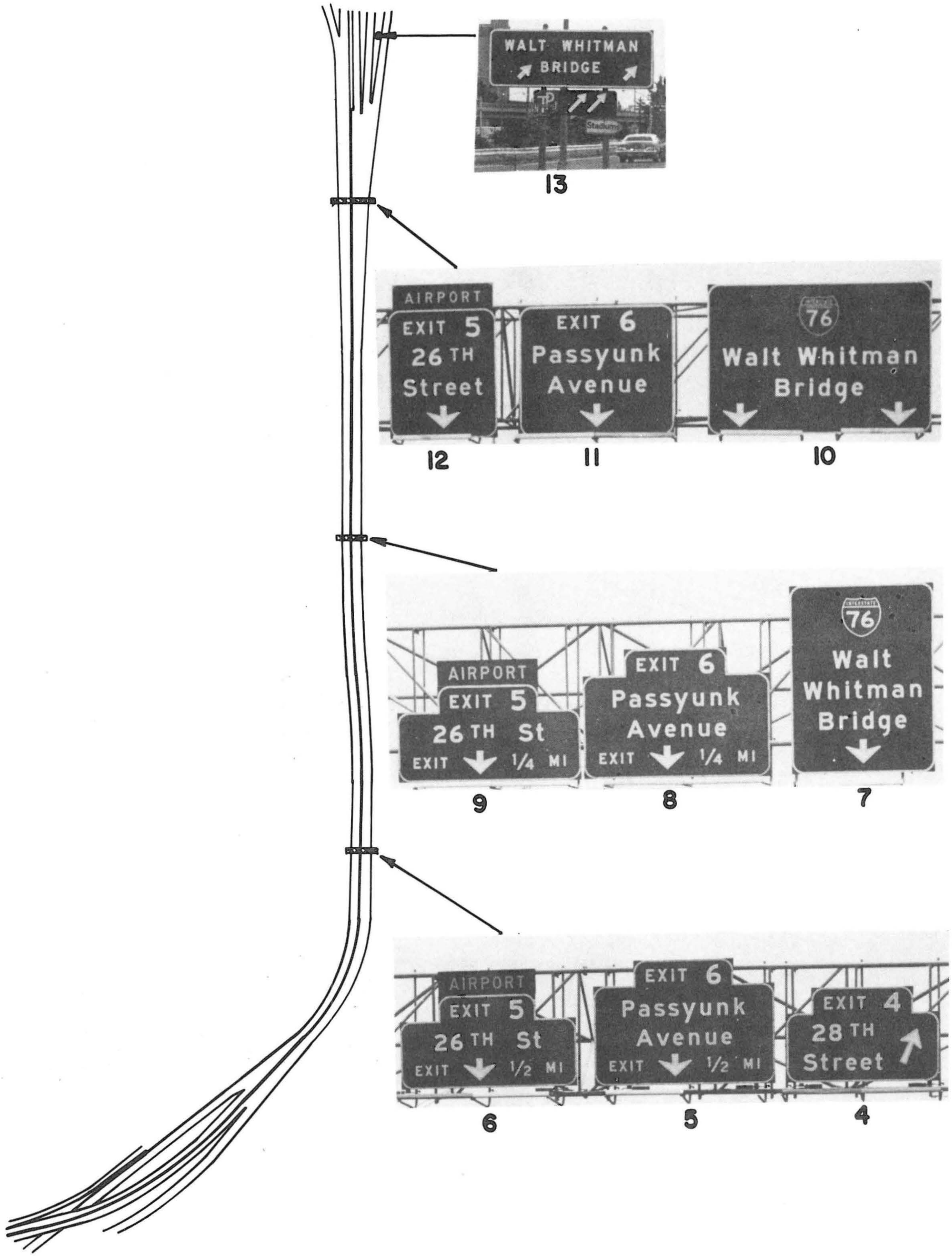

Figure 7. I-76 Philadelphia Site Existing Signing

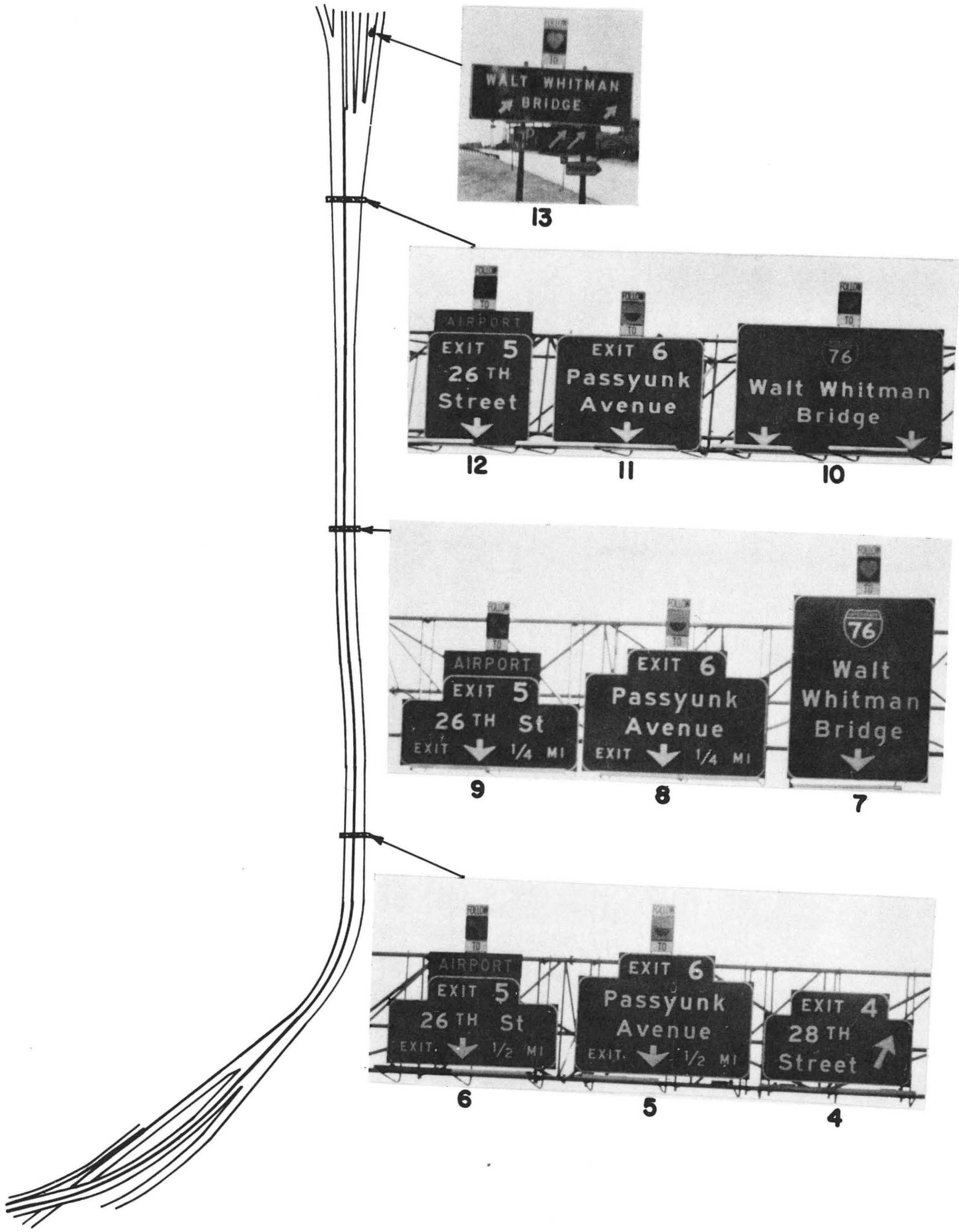

Figure 8. System C Signing Treatment

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 were a tradeoff between visibility and the potential hazard created by the posts on which the symbol signs were mounted.

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, speed data 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 camera was mounted on a tripod clamped to the sign 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 6 illustrates the approximate location of the camera.

Speed samples were obtained via radar for a morning and afternoon period during each day of data collection. 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 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 movements 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 6.

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 each 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 recroded by zone of occurrence. The following erratic maneuvers were reduced from each film: stops, backs, lane straddles, swerves, gore encroachments, and gore crossings. While incidence of backing and stopping are self explanatory, operational definitions were derived for each of the other erratic maneuvers as follows:

> Gore encroachment was coded when the leading wheel of a vehicle crossed the painted gore;
>
> 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 zones of occurrences 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.

Data Analysis

After the reduction of data from the film was accomplished, the data was 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 - 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

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

information provided. That is, two of the three overhead advance guide signs assign site entry lanes 1, 2, and 3 to corresponding Exits I, II, and III (see Figure 7). 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 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 shift was observed in the percentage of drivers who used 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 per 1000 vehicles in the "before" condition to 7.3 per 1000 vehicles under System C. Moreover, the driver involvement rate for the "before" condition was reduced by a factor of six 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. As with Systems A and B however, the system had no practical effect on exit speed.

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 6). However on the basis of the visual evaluation of System C, it was deemed desirable to increase the size of the symbol signs from 24 inches to 36 inches because of the large overall dimensions of the existing guide signs on this site. Further the design of the C/S Systems used for the Phase III evaluations called for the mounting of the symbol signs on the face of the guide signs rather than mounting on the periphery. These two related modifications were aimed at increasing the conspicuity of the symbol signs and enhancing the route/symbol association via more appropriate placement of the symbols with respect to the guide sign information. In order to accommodate the larger symbol signs in the chosen locations it was necessary to make some modifications to three of the existing guide signs. The modifications made are shown in Figure 9. These changes in the original guide signs were made previous to the collection of the "before" data so that any resultant effects would not be attributed to the color/shape treatment.

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.

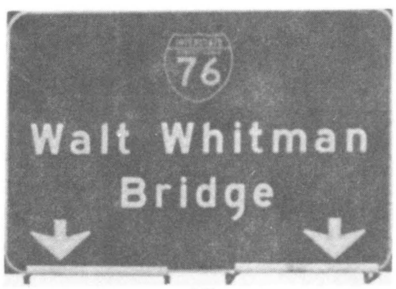
System D (see Figure 10) consisted of three components: (1) introductory route/symbol association signs, (2) sign-face mount guide sign tabs, and (3) gore/ramp delineator symbols. This system differed from System C in that it utilized introductory signing, had the symbol signs mounted on the sign face as opposed to top-tabbing, did not use the "FOLLOW"/"TO" format (except on one introductory sign), ommitted the treatment of Exit 6, modified the gore area delineation system, and it did not code sign #6 (see Figure 7).

The introductory signing for System D involved three signs incorporating two different messages as shown in Figure 10. 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 located approxi-

EXISTING | MODIFICATION

9

9



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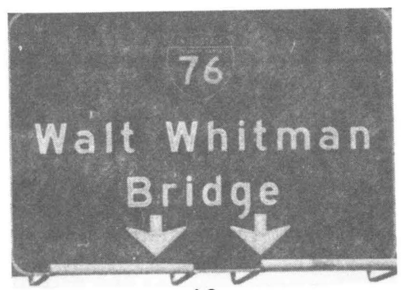

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Figure 9. I-76 Philadelphia Site Existing Sign Modifications

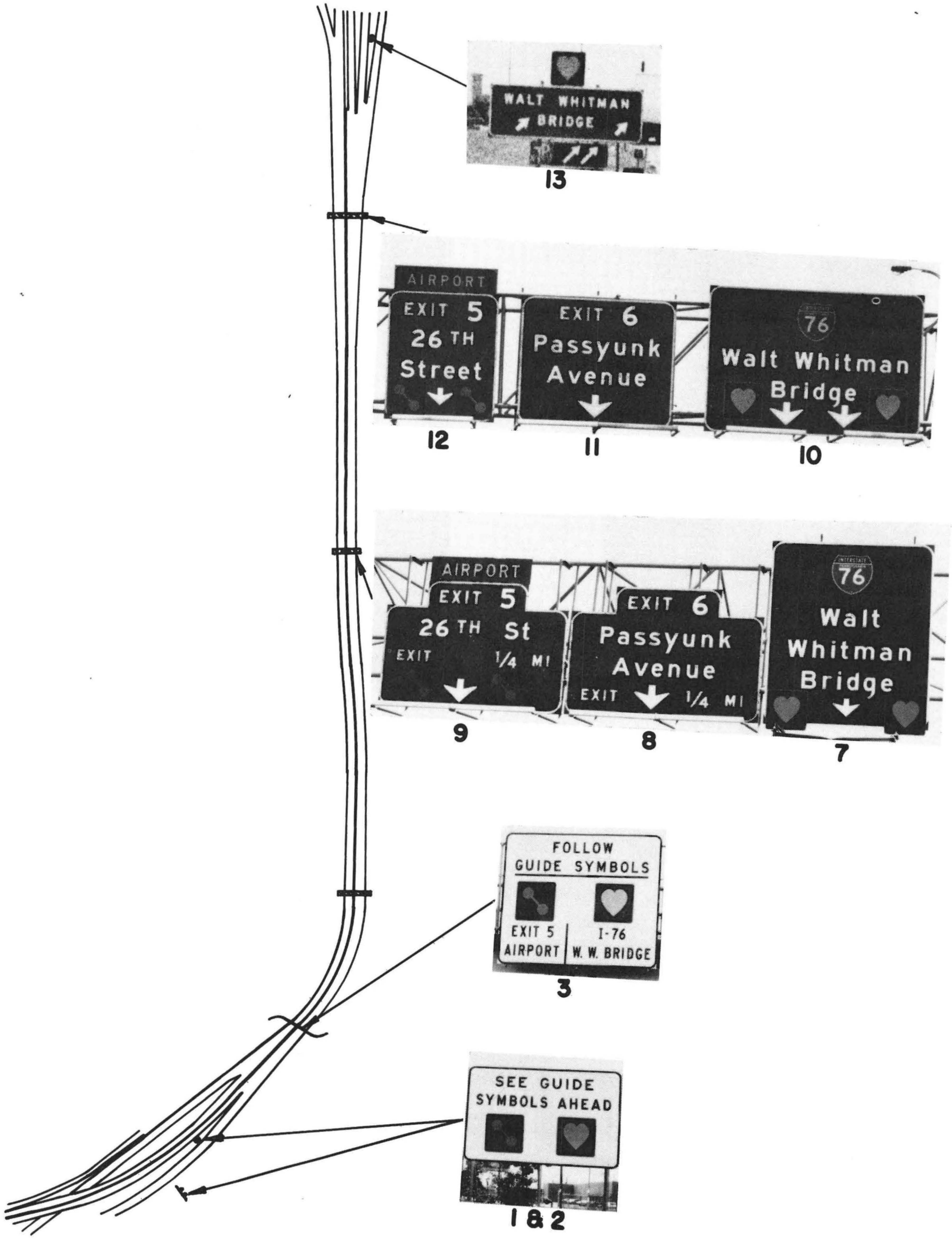

Figure 10. Systems D and E Signing Treatment

mately 1 mi upstream of the site gore area and approximately 1/2 mi upstream of the first guide sign treated. Sign #2 was positioned 150 ft upstream of the physical gore of the merge and oriented towards mainline I-76. Again, the placement was approximately 1/2 mi upstream of the first guide sign treated.

The message of the final introductory sign (sign #3) provided the initial association of the symbols and the route/destination. Sign #3 was mounted overhead on a pedestrian overpass approximately 3/4 mi upstream of the gore area, and 1/4 mi downstream of the first two introductory signs. This placement afforded drivers of both legs of the merge an unobstructed view of the third sign.

Treatment of the guide signs involved the addition of pairs of 36 x 36 inch symbols to the sign face, as shown in Figure 10. The only atypical guide sign treatment was sign #13. It was necessary to top-tab this sign because message rearranging or sign modifications to accomodate 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 that 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.

Three different size symbol signs were applied in descending size order to the gore/ramp delineation; the lead gore 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 inches instead of 36 inches. It was necessary to use the smaller delineator because it was mounted on a concrete median barrier and the overhang of a 36 inch symbol encroached on the shoulder. Hence, the potential for sign damage from wide vehicles was eliminated by using a smaller sign.

The second system of Phase III, System E, was identical to System D with the additional application of 3 x 9 ft (0.9 x 2.7 m) 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 11.

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 also required for the installation of the symbol signs, it was decided to install the more complex system (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 the same as that described in the Phase II evaluation. The data reduction procedure was also the same; however, the coding of gore encroachments was redefined to include only the more hazardous encroachments. Lane straddles were dropped as a measure of effectiveness.

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.

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

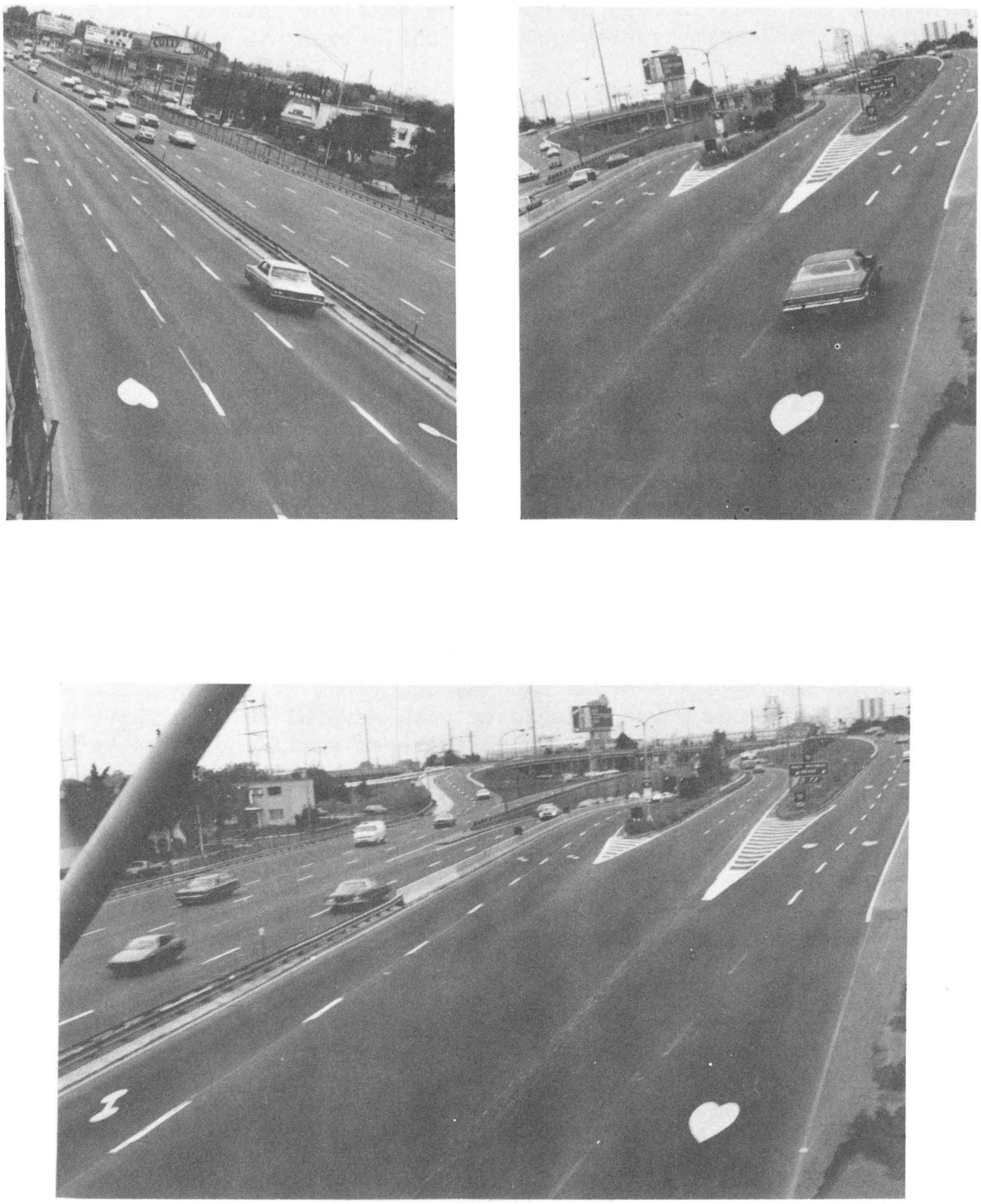

Figure 11. System E Pavement Symbols

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.

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 System 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. FIELD EVALUATION SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Of the five color/shape system configurations tested at two different problem interchanges only System A failed to produce statistically significant improvements. System A constituted a minimum system in that it involved only the attachment of the symbol signs to the periphery of the existing guide signs and the use of symbol signs in the gore area and along the exit ramp. While this would be the easiest and least costly system configuration to implement, the overall visibility and information value of the system was judged to be poor; a judgment supported by the results of the evaluation. While there were observed reductions in the number of erratic maneuvers and in the percentage of drivers involved in erratic maneuvers, the reductions were not statistically significant. The only significant safety benefit observed was an upstream shift in late lane changes. It was concluded that the System A configuration did not have a broad enough facilitative effect on overall driver performance to merit further investigation.

The System B configuration involved the addition of information elements ("FOLLOW" and "TO" tabs) to some of the symbol signs and the addition of two upstream signs to provide drivers with information regarding the association between the symbol signs and route or destination. This system configuration produced the same benefit as System A with regard to late lane changes and in addition produced a statistically significant reduction in the total number of erratic maneuvers and in the percentage of drivers involved in erratic maneuvers. It was concluded that the informational elements added to System A for the System B configuration had a positive benefit and that the system showed enough benefit to merit further testing of a similar system configuration on another type of site.

The System C configuration differed slightly from System B in that the information elements used on only a portion of the symbol signs for System B were used on all of the System C symbol signs. System C showed no substantial improvement over the "before" (conventional signing) treatment with regard to driver lane selection, but produced a highly significant reduction in erratic maneuvers, thereby substantiating the positive effects observed under System B. These positive results led to the decision to test two final versions of the color/shape system.

The System D configuration involved the attachment of symbol signs on the face of the guide signs and the installation of upstream introductory signs which informed drivers of the existence of the system and provided the association between the symbols and route or destination. Improvements were also made in the gore delineation. System E was exactly the same as System D except that pavement symbols were placed on the roadway surface through the site and on the exit ramps.

Both Systems D and E had a positive and statistically significant effect upon driver path selection as compared with conventional guide signs. System E (which included pavement symbols) provided a greater improvement than did System D; with the improvement being statistically significant. Further, both systems resulted in a highly significant reduction in total erratic maneuvers and in the percentage of drivers involved in erratic maneuvers. With regard to reduction in erratic maneuvers there was no significant difference between the two systems. It was concluded that both Systems D and E have a beneficial effect upon both operations (traffic flow) and safety as evidenced by the improvement in path selection and reduction in erratic maneuvers. The observed differences between Systems D and E led to the conclusion that while the pavement symbols associated with System E are a useful supplement to the color/shape system with respect to path and lane selection, they do not provide any greater benefit than the basic system with respect to reduction of erratic maneuvers. Finally, it should be noted that none of the system configurations tested resulted in any practical changes in exiting speed.

In summary, the field evaluations were consistent in showing that the color/shape coding concept as applied to freeway route guidance at problem interchanges results in safety benefits and that certain of the system configurations result in an improvement in operations. On the basis of these positive results it is recommended that additional field tests be conducted to determine the range of geometric situations to which such a system is applicable. It is further suggested that additional system development be undertaken in order to identify guidelines for incorporating symbol signs into overall guide sign design and for design and location of introductory signs. Finally, it is recommended that consideration be given to extending the use of the coding concept to other situations such as detour or diversion signing.

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.

* 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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