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GRAMMATIC GUIDE SIGNS FOR USE ON ITROLLED ACCESS HIGHWAYS

. II. Laboratory, Instrumented Vehicle, and te Traffic Studies of Diagrammatic Guide Signs

T. M. Mast, J.B. Chernisky, and F. A. Hooper, Jr.

December 1972

Final Report

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16. Abstract

The purpose of the diagrammatic signing research project was to develop warrants and standards for the use of diagrammatic guide signs on controlled access highways. Volume II describes research on the relative effectiveness of diagrammatic and conventional signing as measured in the laboratory and in the field with an instrumented vehicle. Relevant research conducted by State highway departments, and the results of a nationwide survey of diagrammatic guide signs are presented.

Research findings obtained under the project indicate that drivers require more time to read and interpret information on diagrammatic signs in comparison with conventional signs. Moreover, as the graphic component on the sign becomes more complex, driver information interpretation time increases. Accordingly, in those cases where diagrammatic signs have been recommended, the standards specify that simple graphic designs must be used. Research results clearly indicate that diagrammatic guide signs will produce a benefit to motorist performance at interchanges where traffic must exit to the left of the through route. Such interchanges include major forks where exiting traffic must take the left fork. Also included are interchanges where there is a single left exit from the roadway and where there is a left exit in combination with a right exit.

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FHWA-RD-No.	Vol. No.	Book title	Note on contents
73-21	I	Recommendations for Diagrammatic Guide Signs.	
73-22	II	Laboratory, Instrumented Vehicle, and State Traffic Studies of Diagrammatic Guide Signs.	
73-23	III	Traffic Engineering Evaluation of Diagrammatic Guide Signs. Part 1: Technical Overview of the I-495 (Capital Beltway)/ I-70S Field Study.	First of 3 parts, each issued as a separate book, with an additional book for Part 2 appendixes.
73-24	III	Traffic Engineering Evaluation of Diagrammatic Guide Signs. Part 2: The I-495 (Capital Beltway)/I-70S Field Study.	Second of 3 parts.
73-25	III	Traffic Engineering Evaluation of Diagrammatic Guide Signs: Appendixes A, B, & C to Part 2.	
73-26	III	Traffic Engineering Evaluation of Diagrammatic Guide Signs. Part 3: Synthesis and Conclusions.	Third (last) of 3 parts.

PREFACE

The work accomplished under the diagrammatic signing research project during the period from April 1971 to December 1972 is reported in three volumes.

Volume I contains recommendations for design standards and warrants for the use of diagrammatic guide signs on controlled access highways. It was authored by the Federal Highway Administration and BioTechnology, Inc.

Volume II, contained herein, describes the work carried out by the FHWA Office of Research as well as State Highway Departments. It is presented in three parts. Part I contains reports on laboratory work done under the project. Part II describes instrumented vehicle or controlled field studies conducted by Office of Research Staff. And Part III contains Abstracts of State traffic studies and results from a national survey on diagrammatic signs. Volume II was authored by the FHWA Office of Research, Traffic Systems Division.

Volume III describes work conducted under Contract No. FH-11-7815 between the Federal Highway Administration and BioTechnology, Inc. It is a report on the traffic engineering evaluation of diagrammatic guide signs which was carried out on the Capital Beltway (I-495) and I-70-S.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to the numerous individuals who significantly participated in the conduct of the studies reported in Volume II. While the responsibility for the conduct of the research and the contents of the report rest solely with the authors, a large share of the credit belongs to Burton Stephens. Mr. Stephens served as project manager during the initial phase of the project. Moreover, he developed a substantial portion of the work plan and authored most of the interim report submitted in November, 1971.

Fred Beuchert, Office of Research, FHWA, designed, fabricated and maintained the instrumented vehicle used throughout the series of investigations. His outstanding work was critical to the successful completion of the research effort.

The Germantown study could not have been initiated or completed without the support received from the Maryland Highway Administration, especially S. L. Caltrider, Thomas Hicks, and Richard Hunter. This study also benefited substantially from the contributions of Terry Friesz and Ray Williamson, FHWA, who assisted in the experimental design, fabrication of test signs, and data gathering activities.

Appreciation goes to Patricia Lema, Jane Burnette, and Madeline Marshall who carried out the exhaustive film data reduction work.

Lynn Runt and Stan Smith, Office of Development, FHWA, developed the computer software and conducted most of the data processing tasks.

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The authors gratefully acknowledge Dr. William W. Wolman and Mrs. Ruby Tice, Traffic Systems Division, for their administrative support throughout the project.

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VOLUME II

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PART I

INTRODUCTION AND LABORATORY STUDIES

Division, whereas the major field evaluation effort was done under contract by BioTechnology, Inc. Both the in-house and contract work efforts were conducted concurrently. The field study portion of the project was designed to evaluate several diagrammatic signs installed on the Maryland part of the Capital Beltway (I-495). This work is described in detail in Volume III of the report. The in-house laboratory and instrumented vehicle work as well as results from work done by State Highway Departments are reported in Volume II. Volume I is addressed to policy makers and contains the project's recommendations, basis for these recommendations, and nontechnical summaries of Volumes II and III.

Volume II is presented in three parts. Part I contains reports on the laboratory work done under the project and Part II presents the instrumented vehicle work. Part III contains results from the State traffic studies as well as results from the national survey on diagrammatic guide signs in use in the United States. Part III also contains the results of the staff preliminary field study and summarizes the results of the in-house research effort, placing them in perspective with other work.

Chapter II

PREVIOUS LABORATORY RESEARCH

The only previous laboratory research on diagrammatic guide signs was performed by Serendipity, Inc., under a contract with the National Highway Traffic Safety Administration. This work was initiated to develop a laboratory test method for the evaluation of highway guide signs and to examine graphic characteristics which might be incorporated into guide signs. Results from this study provided the foundation for the research reported in Volume II. Since extensive reference is made to this work throughout Volume II., a brief summary of Berger's (1970) findings and conclusions are presented in this chapter. The following summary was reproduced from the Serendipity, Inc. final report (No. DOT-HS-800-373).

Summary

This study developed and tested systems of signing designed to better communicate roadway interchange and route guidance information to the driver. Emphasis was placed on determining the applicability of graphic or map signing compared to conventional guide signing. The study was designed to consider: (1) Interchanges where graphic guide signs should be considered, (2) Techniques to test guide sign concepts in a laboratory, (3) Graphic concepts and characteristics, and (4) Presentation of results in a manner meaningful to highway and traffic engineers. As will be shown, graphic guide signs permitted significantly better route guidance performance than conventional signs on certain interchanges (collector-distributor with lane drop, and multiple split ramps). Graphic signs also convey relative exit speeds and lane drop information effectively.

Interchanges Where Graphic Signs Should Be Considered

Criteria were developed for specifying the particular locations graphic guide signing might be considered. These criteria resulted from a conceptual analysis of those interchange characteristics associated with traffic flow problems. Both the severity of the traffic flow problems and the potential impact of graphic guide signing were evaluated in developing the criteria. The criteria were used initially to select interchanges for laboratory testing. The testing, in turn, helped to select which types of interchanges would most benefit from graphic signs.

Where two or more of the following interchange characteristics occurred within a particular interchange, the use of graphic guide signing was recommended: heavy ramp volume, critical interchange points, perceptual problems (e.g., sight distance) and unexpected geometrics (e.g., inconsistent configuration).

Chapter I

INTRODUCTION

Background

Interest and demand for better guide signing has been increasing rapidly in recent years. This has been indicated in motorist surveys and reflected in the reactions of legislators. Surveys have been performed by the American Automobile Association, various State Highway Departments, and researchers in the field. These have indicated that the populace desires an improvement in guide signing. Legislators have demonstrated their interest by holding congressional hearings and providing research funds.

In the past, little attention has been paid to guide signing. There were only a few pages devoted to guide signing in the 1958 Interstate Signing Manual and the 1961 edition of the U.S. Manual on Uniform Traffic Control Devices. The 1971 manual dealt extensively with the design dimensions of shields, arrows, and letters, etc. However, little attention was given in terms of what and how sign information content should be used to assist drivers in route navigation.

In 1968, the Special Subcommittee on the Federal Aid Highway Program of the House of Representatives Committee on Public Works held hearings on freeway signing and related geometrics. In these hearings, many of the difficulties drivers were experiencing on the Interstate system were vividly described. Films and testimony of individual researchers and representatives of Federal agencies illuminated problems which had evolved with the Interstate system. It became apparent that increased usage and higher operating speeds required that new techniques be developed for the presentation of route guidance information. The impetus given to interest in guide signing by the hearings brought about a renewed interest in alternatives to conventional signing. Diagrammatic guide signs appeared to many to be a possible alternative to conventional signing. It was believed that other alternatives such as Electronic Route Guidance Systems would require highly advanced technology necessitating high investment costs.

Signs resembling diagrammatic signs have been in use in Europe and the United States for a decade or more. For example, signs warning of intersections or bends on primary roads have generally been chosen to reflect the geometry of the roadway. Furthermore, several States have experimented with the use of graphics on freeway guide signs as early as 1959 (some examples are given in Chapter VIII of this report). Some of these signs simply included a graphic insert showing the geometry of the interchange; others attempted to show a connection between the geometry of the interchange and the destinations that might be reached. For the most part, graphic signs in the United States were developed for specific interchanges which exhibited serious operating problems.

In 1968, officials within AASHO and FHWA decided to investigate the possible use of diagrammatic guide signs to improve highway guide signing in the United States. A program was established to evaluate diagrammatic guide signs. This evaluation effort included State participation, field experiments, and laboratory investigations. Demonstration projects were encouraged by the Federal Highway Administration through the provision of Federal-Aid construction funds. States were requested to design diagrammatic guide signs, install them on the highway, and perform an evaluation of their effectiveness. Approximately 20 States installed diagrammatic signs under this program and at least eight performed systematic, empirical evaluations. Reports on the eight empirical studies are abstracted in Chapter VIII.

A contract for further investigation of diagrammatic sign design was signed between the National Highway Traffic Safety Administration and Serendipity, Inc. in 1969. Serendipity developed several different graphic designs, and provided guidelines for the use of particular graphic characteristics (Berger, 1970). A large number of diagrammatic sign designs were tested using a laboratory technique especially developed for the purposes of the study. The methodological approach and findings in this study are summarized in Chapter II. The guidelines were distributed by FHWA to State Highway Departments in 1970 and States were further encouraged to develop and experiment with diagrammatic signing.

The results of both the State research projects and the laboratory work by Serendipity were generally favorable towards diagrammatic signs. However, the interchanges tested in the State studies did not include a broad variety of interchange types. Some of the results were mixed and the evaluations of the signs were plagued with methodological problems making the findings difficult to interpret. The Serendipity investigation, while more systematic and better controlled, suffered from the handicap of all laboratory studies. That is, the conclusions could not be generalized to real highway conditions without further experimentation and validation. Consequently, a more comprehensive reasearch effort was planned to further evaluate diagrammatic guide signing.

Diagrammatic Signing 1971 Research Project

In March 1971, the Offices of Highway Safety and Traffic Operations joined with the Office of Research and Development to formulate a research plan aimed at resolving inconsistencies in results obtained from various evaluations of diagrammatic signing. The research program was intended to determine whether the guidelines developed from the Serendipity study were valid, and to further augment them. A comprehensive and definitive report on diagrammatic signs was to be written prior to the end of December 1972. The report was to bring together all research findings concerning diagrammatic signs and to make recommendations for their design and deployment on controlled access highways in the United States. Furthermore, techniques for measuring sign effectiveness were to be recommended to State Highway Departments.

To meet these objectives, a work plan was developed employing a multilateral methodological approach. It included laboratory, instrumented vehicle, and field studies. Laboratory and instrumented vehicle work was conducted by in-house staff in the Office of Research, Traffic Systems

Division, whereas the major field evaluation effort was done under contract by BioTechnology, Inc. Both the in-house and contract work efforts were conducted concurrently. The field study portion of the project was designed to evaluate several diagrammatic signs installed on the Maryland part of the Capital Beltway (I-495). This work is described in detail in Volume III of the report. The in-house laboratory and instrumented vehicle work as well as results from work done by State Highway Departments are reported in Volume II. Volume I is addressed to policy makers and contains the project's recommendations, basis for these recommendations, and nontechnical summaries of Volumes II and III.

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Where two or more of the following interchange characteristics occurred within a particular interchange, the use of graphic guide signing was recommended: heavy ramp volume, critical interchange points, perceptual problems (e.g., sight distance) and unexpected geometrics (e.g., inconsistent configuration).

Application of these criteria to existing interchange types led to the testing of the following types of interchanges: collector-distributor (with lane drop), multiple split ramp, left exit downstream from right, two closely spaced rights from main road, major fork and cloverleaf.

Test results indicated that graphic guide signs for the first two types significantly improved route guidance effectiveness.

Techniques to Test Guide Sign Effectiveness

To test the effectiveness of guide signs, laboratory techniques were developed. This required the selection and development of media for presenting sign concepts, and identifying criterion measures of effectiveness.

A technique of substituting photographed artist conceptions of test signs for existing signs was developed. The technique used two 35 mm projectors with one projector showing a roadway scene with the guide signs blacked out and a second projector presenting test signs in the blacked out area for one second. The technique permitted testing numerous sign variables in a group setting in a short period of time.

Crucial to the development of a technique to determine signing effectiveness was the development of criterion measures. An analysis of the driver's route guidance task and a series of pilot studies led to the selection of: (1) Lane choice -- selecting the most appropriate lane for a particular destination, (2) Confidence in lane choice (a driver who is not confident could be expected to slow down and perturb flow), (3) Anticipated interchange characteristics such as the ability to detect safe exit speed, number of exits, location of exits of interest, lanes used for through traffic and distance between exits, and (4) Preference of sign types for different interchanges.

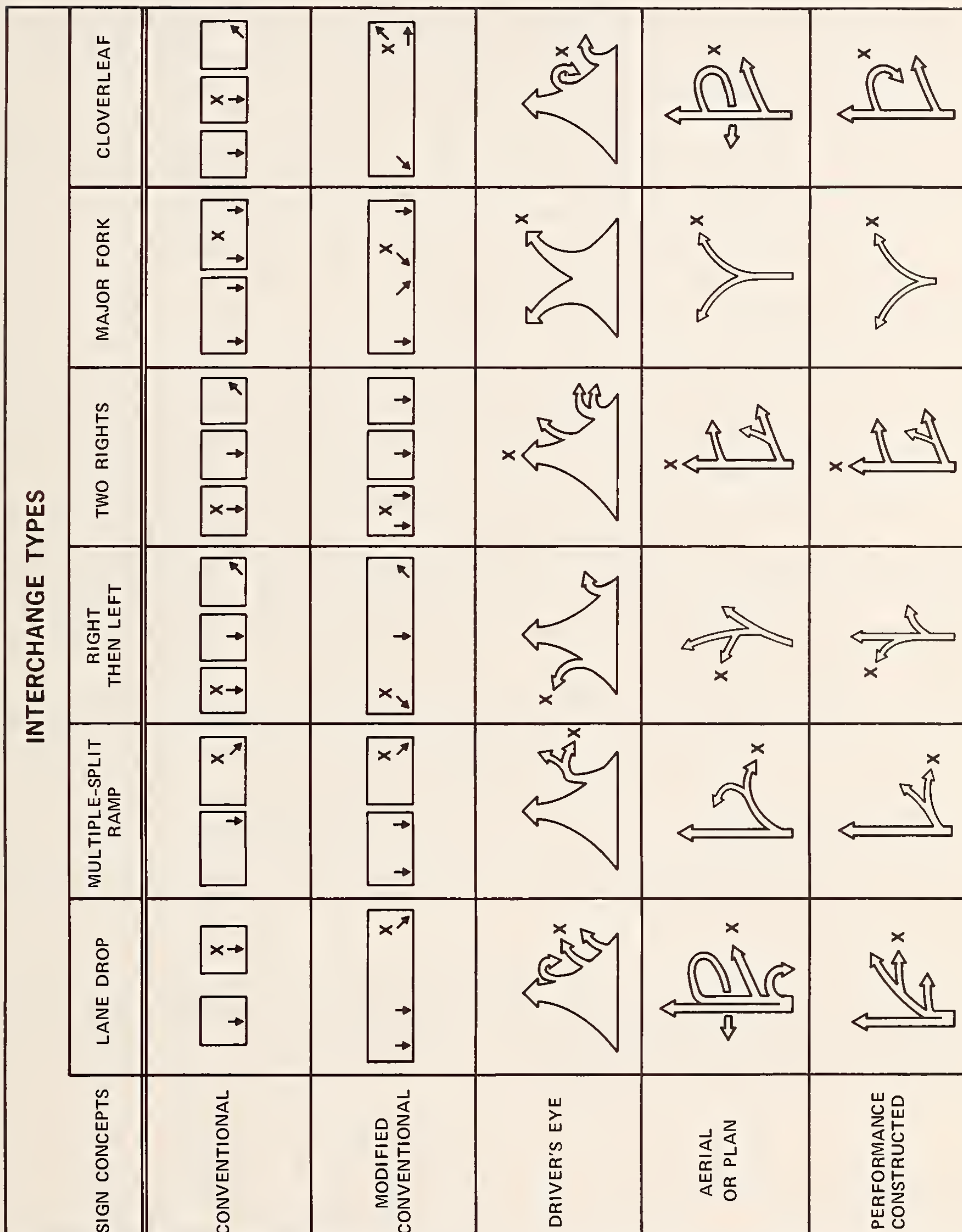
Graphic Concept and Characteristics

The primary emphasis of the study was the design and test of graphic concepts and characteristics that would be applicable to different interchange configurations. Graphic concepts were selected or developed from existing concepts and generated by a graphic artist, traffic engineers, and a human factors specialist. Although numerous concepts were generated, pilot tests and logical analyses led to three basic graphic displays and one modification of conventional signs. The graphic concepts included the driver's eye perspective, the plan view (bird's eye view) and a performance oriented plan view. These were developed and tested for the six interchange types (Table 2-1).

The results based on drivers making proper lane choice do not clearly favor one signing concept. The plan view was significantly better than the other graphic guide signs for the collector-distributor. There were no differences for the left exit, multiple split ramp, and the two rights from the main road. The plan view and performance constructed graphic guide signs were better than the modified conventional at a major fork. At a

Table 2-1

PROPER LANE CHOICE FOR VARIOUS SIGN CONCEPTS BY INTERCHANGE TYPES



The "X" indicates the location of the destination of interest.

cloverleaf, the modified conventional was significantly better than the driver's eye view or plan view. Confidence ratings were not helpful in discriminating signs.

Because of the difficulties encountered with the conventional signs and since a series of signs are normally presented at an interchange, sequential testing of conventional versus graphic guide signs was conducted. The results indicate significantly better performance using graphic signs for the collector-distributor ($P < .01$) and multiple split ramp close choice points ($P < .01$). The results generally are in agreement with the previous findings.

Graphic guide signs received significantly higher preference ratings on most of the interchanges. The aerial or plan view received significantly ($P < .05$) higher preference ratings on all but the major fork where the performance constructed graphic was preferred. The performance oriented and the plan view were similar for the major fork. It should be noted that the conventional signs were least preferred.

The mean preference ratings for the "liked best" signs, the percent choosing the correct lane, and the mean confidence ratings of subjects choosing the correct lane were pair wise correlated over the tested signs. Preference and proper lane performance was not significantly related ($r = .07$). Likewise, mean preference and confidence rating was not significantly related ($r = .26$; $P < .2$). These correlations were probably restricted by the rating method employed. The proper lane performance percentages were significantly ($P < .01$) related ($r = .53$) to mean confidence. This may be part of the reason confidence rating did not help to differentiate the signs that showed good performance.

Graphic design characteristics were tested to optimize the design of the signs. A summary of the design characteristics and their influence include:

Characteristic	Influence
1. Placement of exit information close to the termination of the exit arrow.	Increases correct lane choice.
2. Placement of exit information on the same side of the graphic as the one from which the exit departs.	Increases correct lane choice.
3. Larger amounts of graphic information.	Decreases correct lane choice.
4. Distance depicted between the exits.	No effect on correct lane choice but influences the perceived roadway distance.
5. Number of signs (given a fixed sign area).	No effect on correct lane choice.

Characteristic	Influence
6. Use of arrowheads vs. incorporation of information (e.g., shields) into the graphic.	No effect on correct lane choice.
7. Graphic size (within limits of discriminability).	No effect on correct lane choice.
8. Length of exit path.	No effect on correct lane choice.
9. Curvature of exit path.	No effect on correct lane choice but influences the estimate of the safe exit speed.

Finally, test of the ability of graphic signs to convey other information about an interchange indicate: (1) Curvature of the graphic can be used to estimate exit speed; and (2) Number of exits, exits of interest, and distance between exits can be more readily determined with graphic signs.

Table 2-2 displays the advantages of employing graphic guide signs in place of conventional 1 or 2 mile signs. Advanced guide signs of the conventional variety generally do not present lane positioning information and even in those cases where they do (e.g., the two rights in quick succession and an unusual maneuver interchange) they did not appear to be very effective. In those two cases where performance at the gore was significantly better with graphic guide signs, the difference can probably be attributed to a residual effect from the earlier graphic guide signs. These results lead one to conclude that there may be little, if any, advantage in replacing conventional overhead lane positioning signs with graphic guide signs. It should be noted that in the earlier performance experiments no significant difference was found between the plan view and conventional signs when both were presented in an overhead configuration. A large payoff appears to be in the area of replacing the 1 or 2 mile shoulder mounted advanced warning signs with graphic guide signs.

It should be emphasized that the conclusions stated above are those of Berger (1970) and were taken directly from the Serendipity final report. Some of these conclusions were supported by more recent findings presented in this report, some were not.

Table 2-2

SUMMARY OF THE PERFORMANCE ON SIX INTERCHANGE TYPES GIVEN SEQUENTIAL SIGNING

Interchange Types	First Sign Shoulder Mount	First Relevant Gore Overhead
Lane Drop Collector-Distributor	Graphic significantly better than conventional sign.	Graphic significantly better than conventional sign.
Multiple Split Ramp	Grpahic significantly better than conventional sign.	Graphic significantly better than conventional sign.
Right then Left	No significant differences.	No significant differences.
Two Rights in Quick Succession	Graphic significantly better than conventional sign.	No significant differences.
Major Fork	No relevant sign.	No significant differences.
Cloverleaf	Graphic significantly better than conventional sign.	No significant differences.

Chapter III

LABORATORY EVALUATION OF DIAGRAMMATIC GUIDE SIGNS [1/]

The present study was a follow-up of research carried out by Serendipity, Inc., (Berger, 1970) for the National Highway Traffic Safety Administration. Its objective was to verify the Serendipity findings in a separate and independent investigation since diagrammatic signs were being considered for adoption on a nationwide basis. In the Berger study, volunteer subjects recruited at the Smithsonian Institution were shown projected slides of conventional and diagrammatic freeway signs. They were asked to indicate on an answer sheet the highway lane they should be in to reach a preassigned destination. On four of the six interchanges tested, drivers selected the correct lane more frequently when diagrammatic signs were displayed. However, they reported more confidence in their choices when viewing conventional signs in 18 of the 29 cases (signs) tested. Results of the Serendipity study have been widely interpreted as an endorsement of the use of diagrammatic signs.

In this study, a number of modifications were made to the Seredipity testing procedure, although the same sign stimulus material was used. Drivers were tested individually rather than in groups. Single testing insured that subjects were not distracted, that they understood the instructions, and that all subjects viewed from the same position. In the previous study, only one destination was selected for testing at each intersection. Since interchange signs show both left and right turn destinations, both destinations were studied here. Driver performance was more thoroughly rated. Reaction times to the signs were taken. The speed of a driver's reaction to a sign is considered to be particularly important in closely spaced urban interchanges.

Method

Equipment

The Subject's Cubicle. The subjects viewed the signs in a 9 x 11 foot cubicle. At a distance of 8-1/2 feet, the 5.0 inch high letters of the projected signs subtended a visual angle of 2° 48 minutes and could be easily read. The projector and reaction time equipment were housed in the experimenter's compartment adjacent to the subject's cubicle.

The Signs. The subjects made lane choice judgments on the following types of interchange: (1) Lane drop (the Wilson Bridge interchange going into Alexandria), (2) Multiple split ramp (the Shirley Highway interchange going north into 495), (3) Left ramp downstream from right-hand ramp (Route 495 going east into Shirley Highway), (4) Two rights in quick succession (the Glen Echo exit of 495 going towards Virginia), (5) Major fork (the fork of 495

[1/] This chapter was prepared by Dr. Donald A. Gordon, Traffic Systems Division, Office of Research, Federal Highway Administration, and is based on work carried out during the summer of 1971.

and I-70 to Frederick), (6) Cloverleaf (the exit of Route 495 going east into the Washington-Baltimore Highway). These interchanges include the more difficult freeway signing situations of the Washington, D.C. area.

The projected slides viewed by the subjects showed black and white photographs of actual sign locations on which colored drawings of signs were superimposed (see Figures 3-1 to 3-6). The diagrammatic signs duplicated the Serendipity (Berger, 1970) designs; the conventional signs were drawn in conformity with the U.S. Manual of Uniform Traffic Control Devices. The artificial destinations on the signs all contained exactly nine letters. The same destinations were used on the three to six consecutive signs of each intersection. The photographs of the highway were taken on the center lane at a distance of 200 feet from the sign. Lane numbers were printed on the road surfaces of the slides to aid the subject in making his choices.

The Scoring Key. A sign's effectiveness was evaluated on the basis of drivers' lane selections and reaction times to the sign. A great deal of attention was paid to the scoring key which was used to grade the driver's lane choices.

The key finally developed was based on the following rules.

(1) At the advance guide sign, the driver was judged correct if he selected either the first or second lane. At this point it was not considered necessary for the driver to be on the exit lane.

(2) The driver was expected to be in the exit lane when the sign indicated his exit.

(3) He was expected not to be in the exit lane when an exit destination other than his was on the sign.

The scoring key of the first interchange may be given as an illustration of these principles. "Bladsworth" was given as the destination to be reached. The first advance warning sign indicated both Bladsworth and Tabernash exits on the three-lane highway. The first (right) and second (middle) lanes were graded correct. The next sign indicated a Rochdale exit. Since this was not the driver's destination, only the second lane was judged correct. The next three signs indicated the Bladsworth exit. Only the first (exit) lane was correct.

The Grandview destination was given at the next interchange. At the advance warning sign, either lane of the two-lane highway was accepted. The next sign indicated an exit for Hornbrook. The Grandview driver was expected to be on the left, non-exit lane. At the third sign, showing a Grandview exit, the driver was expected to be on the exit lane.

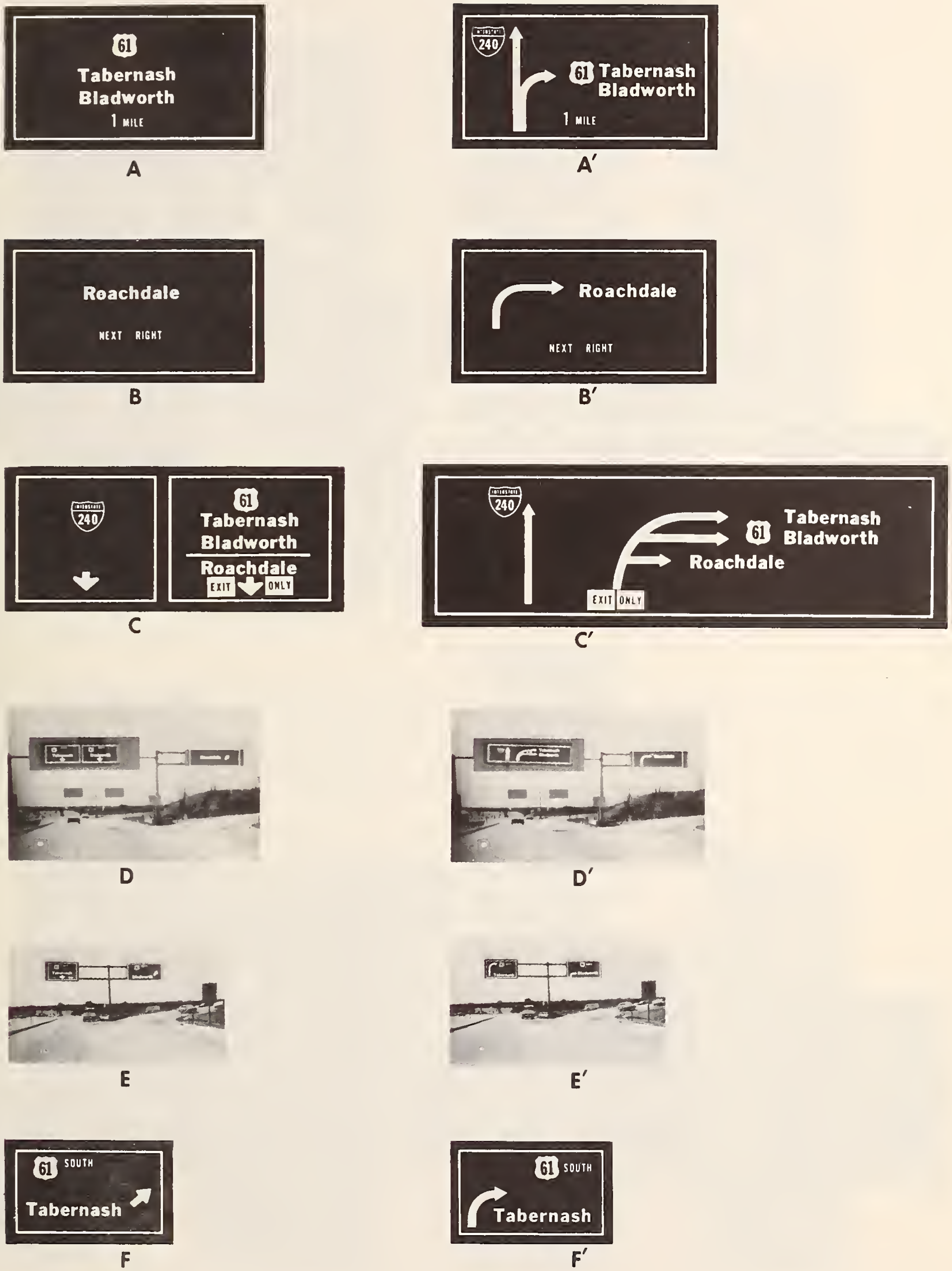


Figure 3-1. Conventional signs (left) and diagrammatic signs (right) at Interchange 1.

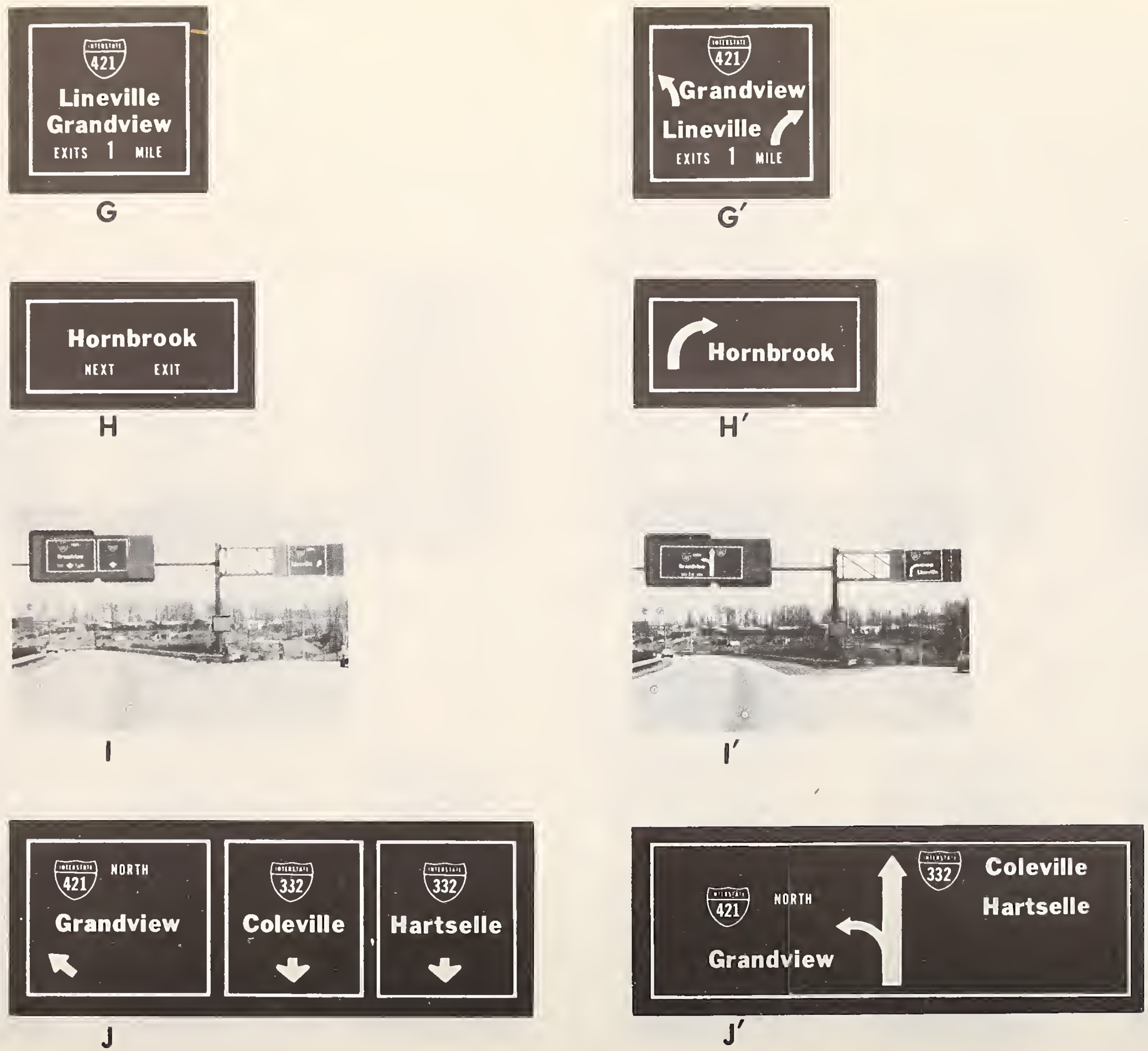


Figure 3-2. Conventional signs (left) and diagrammatic signs (right) at Interchange 4E.

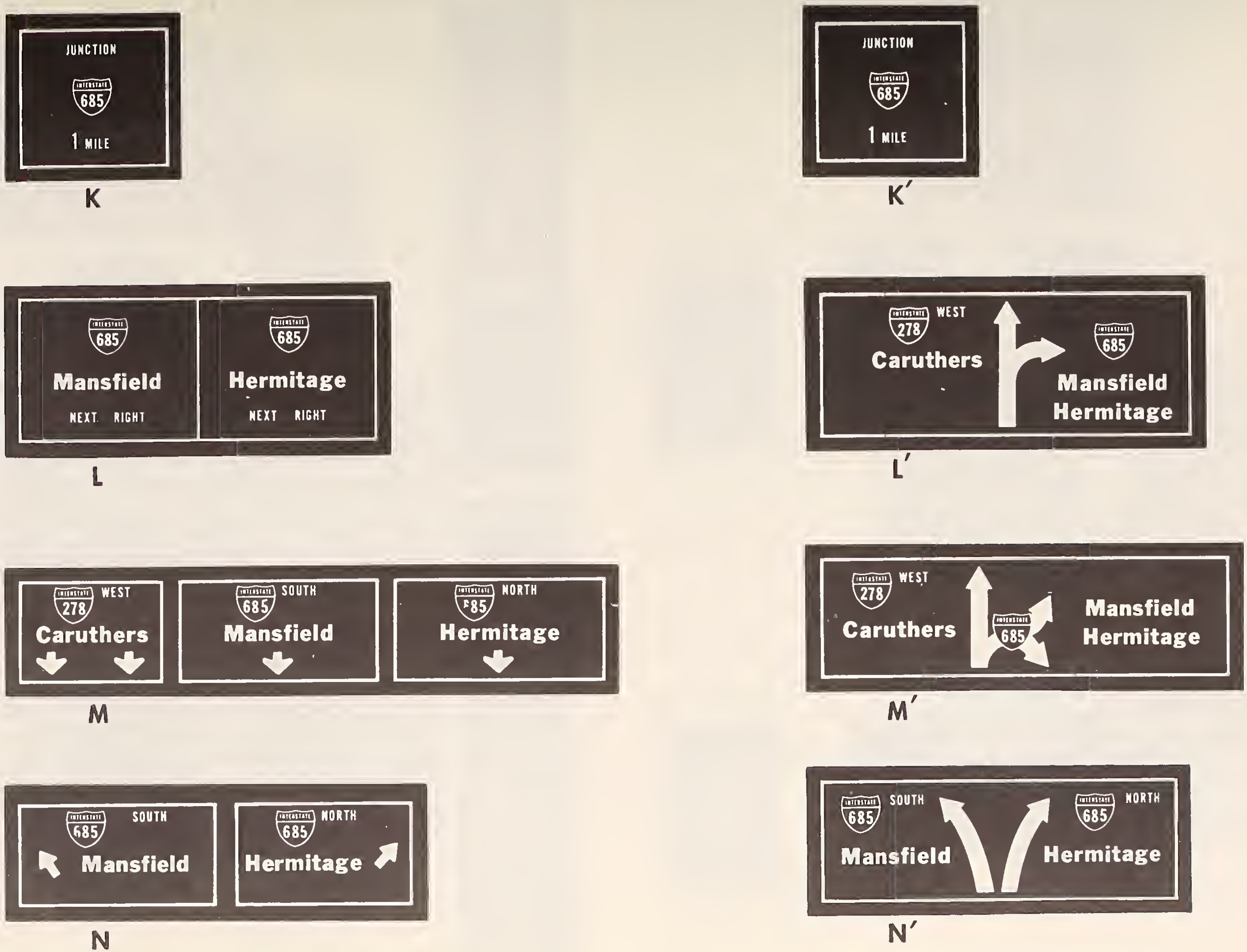


Figure 3-3. Conventional signs (left) and diagrammatic signs (right) at Interchange 4N.

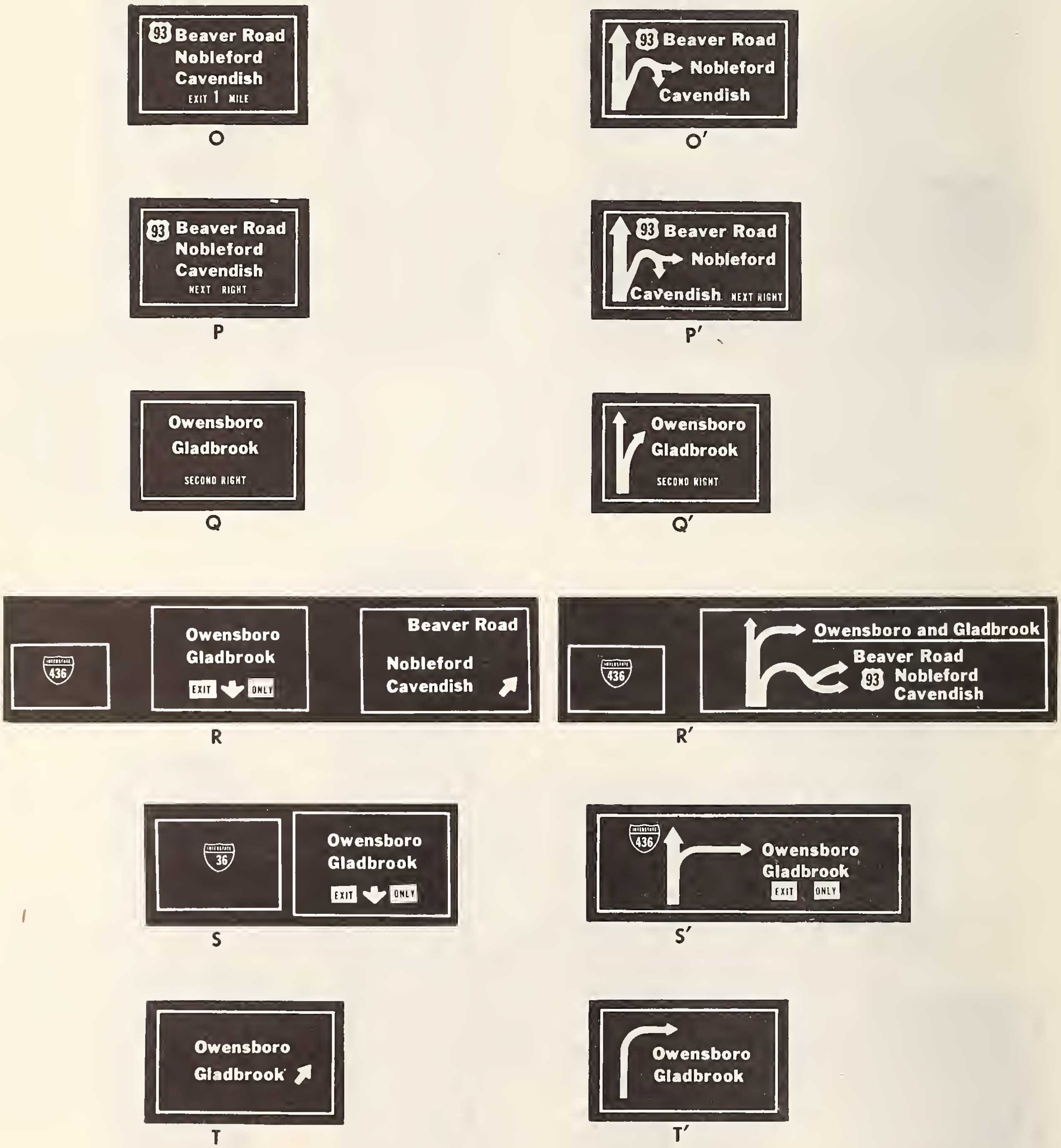


Figure 3-4. Conventional signs (left) and diagrammatic signs (right) at Interchange 16.

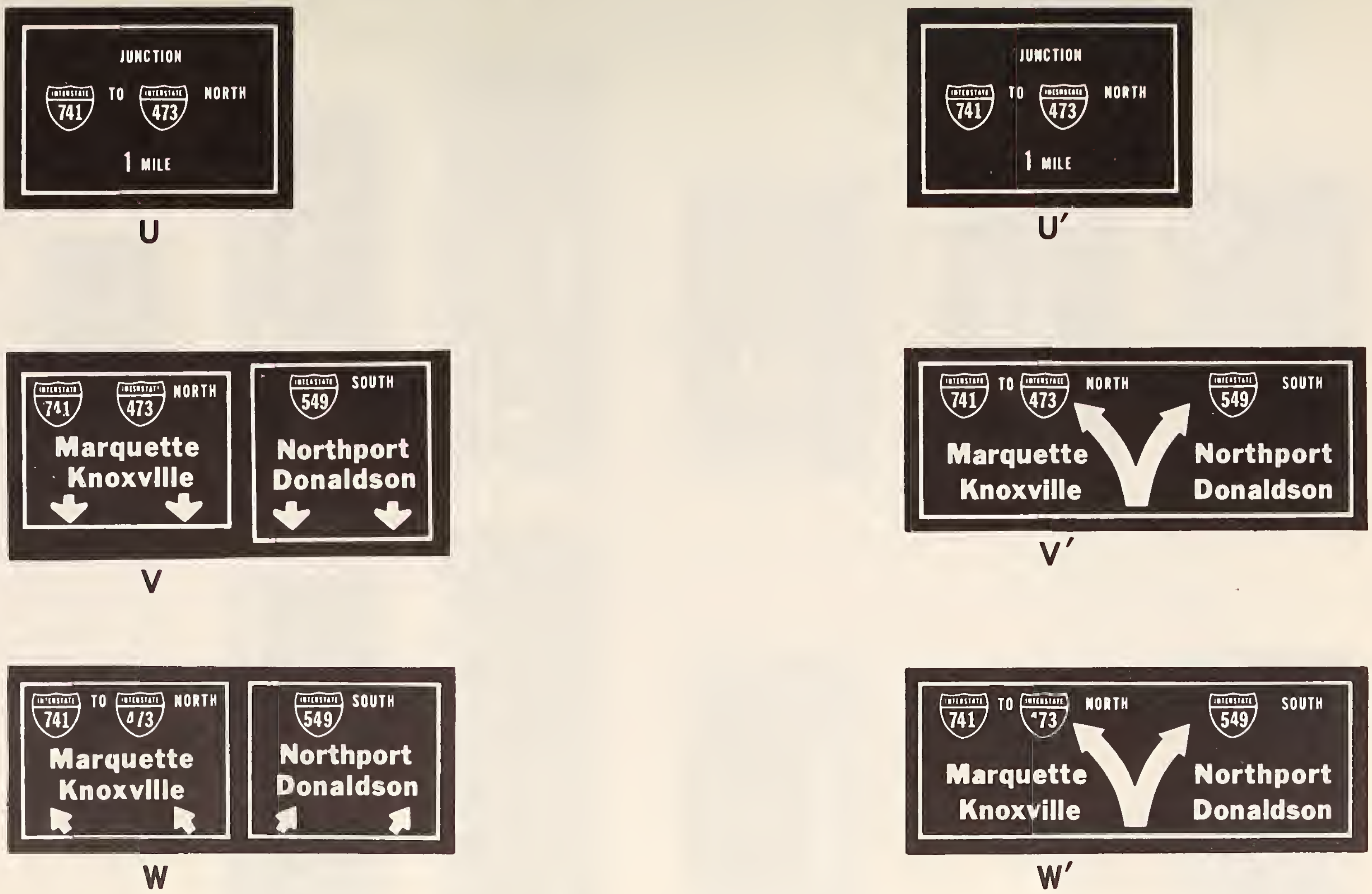


Figure 3-5. Conventional signs (left) and diagrammatic signs (right) at Interchange 17.

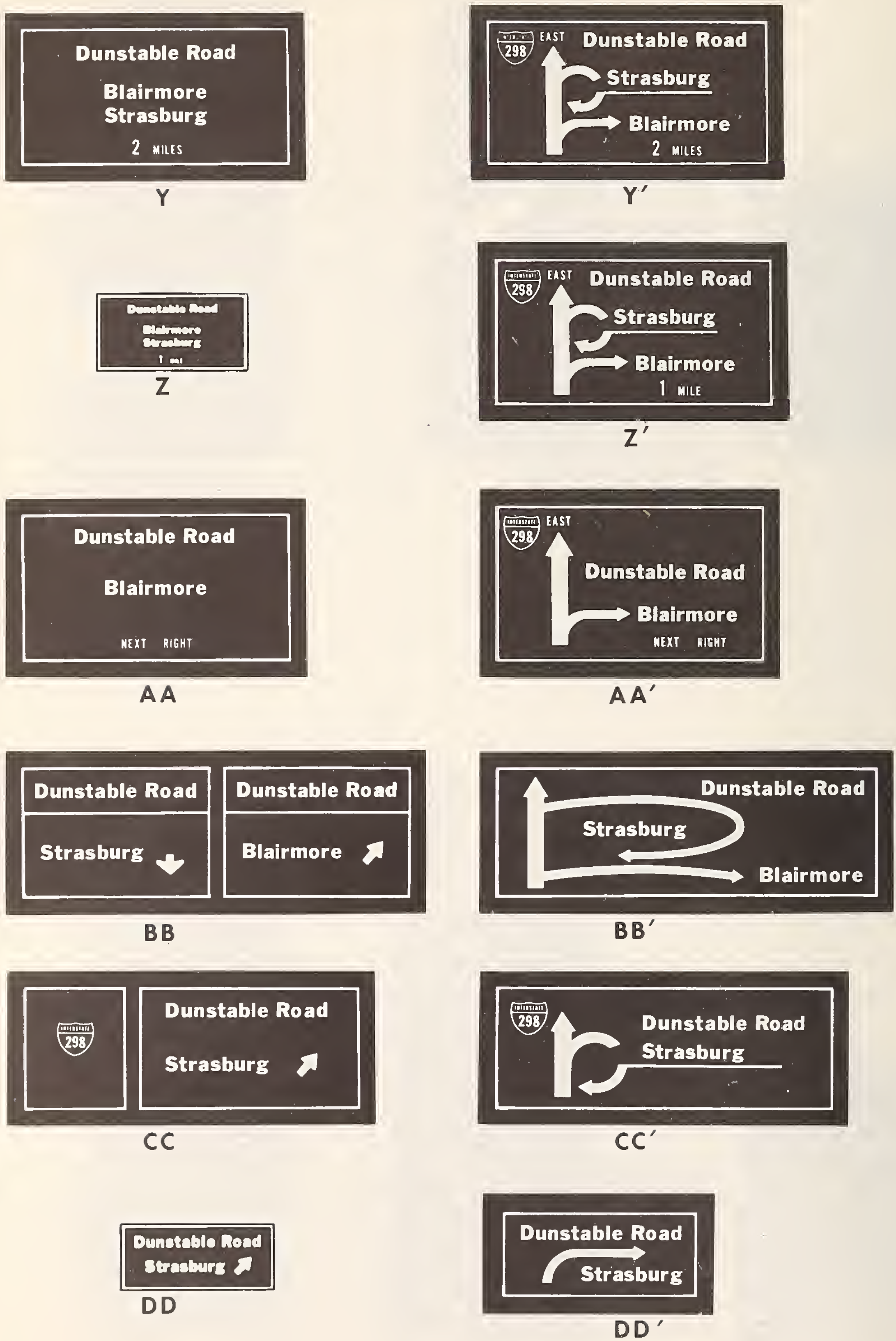


Figure 3-6. Conventional signs (left) and diagrammatic signs (right) at Interchange 29.

Subjects

Subjects included housewives, students, and drivers obtained from the local State employment office. All subjects demonstrated 20/20 or better corrected vision in both eyes, and all held valid driving licenses. There were 28 men and 32 women (60 subjects in all) in the two phases of the study. The initial familiarity advantage of the conventional signs was offset by considerable practice on both types of signs. Familiarity with the Washington, D.C. Beltway did not affect results. Subjects did not recognize the Beltway interchanges with the signs altered.

Procedure

The experiment consisted of two phases, in each of which 30 subjects were tested (see Table 3-1). If the destination led to the right in Phase 1, it was to the left in Phase 2, and vice versa. In this manner, all sign destinations were tested. The straight ahead case was not tested.

At the start of a session, the subject sat viewing the screen in the isolation compartment. He was told to push the button indicating his lane choice as quickly as possible. The first destination ("Bladsworth") was presented on the preliminary slide. The subject repeated the destination aloud to insure that he knew his goal. The first and succeeding road signs were then shown. In each case, the subject signified his lane choice by pressing the appropriate button. The experimenter tallied the subject's lane choice and reaction time, and pushed the two buttons to clear the displays and project the next sign. After the subject had viewed all the signs of an intersection, testing continued on the next destination and interchange.

The practice session of Phase 2 had the same destinations as the test sessions of Phase 1, and similarly, the practice session of Phase 1 had the destinations of Phase 2 (see Table 3-1). By this procedure, the subjects were familiarized with the sign types, but not with the particular problems asked in the test series. The first 15 subjects viewed diagrammatic signs in each series before conventional signs, the 16th to 30th subject viewed conventional signs first. Each subject went through three complete series of 58 presentations each, and therefore made a total of 174 lane choice judgments. It had been shown in preliminary studies that performance showed no improvement in longer experimental sessions.

Results

A General Comparison of Diagrammatic and Conventional Signs

Certain practical considerations must be kept in mind in interpreting the results of this evaluation. To justify replacement of conventional signs by diagrammatic signs, the new signs must provide a convincingly better

Table 3-1

The Experimental Plan

Phase 1	Phase 2
30 Subjects	30 Subjects
Practice Series Destinations A	Practice Series Destinations B
Test 1 Series* Destinations B	Test 1 Series Destinations A
Test 2 Series Destinations B	Test 2 Series Destinations A

* Each Series consisted of 6 diagrammatic and 6 conventional (signed) interchanges, with 29 signs per 6 interchanges.

performance. If a novel sign is merely as good as its conventional counterpart, there would be little reason to undergo the expense and loss of time of the changeover, and the inconvenience of re-educating the public to the new system. To warrant adoption, a new signing system must demonstrate a clear superiority over the one in use.

A detailed analysis of driver's errors and reaction times to the signs is presented in Tables 3-2 to 3-5. Phase 1 results refer to one set of destinations, Phase 2 to the alternate destinations. Each number in Tables 3-4 and 3-5 represent the mean reaction times of 30 subjects to the 3 to 6 signs on an interchange. The destinations used in the practice trials of Phase 1 were used in the test trials of Phase 2, and vice versa. The average column summarizes the results of the two phases. The final test (test 2) represents practical driver performance.

The overall comparison of errors and reaction times of diagrammatic and conventional signs is shown in Figure 3-7. The error scale is given on the left, reaction time on the right. The points plotted in Figure 3-7 are taken from the last column totals and averages of Tables 3-2 and 3-4. Each point represents 29 responses for each of the 60 subjects, or 1740 reactions in all. It may be seen from the slope of the functions, both diagrammatic and conventional performance improved with practice. The improvement in conventional signs may be ascribed to the subject's adjustment to the test routine. The format of conventional highway signs was, of course, familiar to the subjects. Improvements in diagrammatic sign performance reflects both adjustment to the test routine and familiarization with the format of ths signs. Although performance on both types of signs improved, lane selection is superior, and reaction time is, on the average, shorter on the conventional signs in all series. At the end of the session, each subject was asked to tell which kind of sign he found easier to use. The answers are tabulated in Table 3-6. Of the 60 subjects, 26 (43%) preferred the conventional signs, and 16 (27%) preferred the diagrammatic signs. Sixteen subjects (30%) did not notice the difference between the signs, or did not express a preference.

<u>Signing for Particular Interchanges</u>

Although the diagrammatic signs tested were on the average not as effective as conventional signs, the possibility remains that some may be more suitable for a particular interchange type.

These results, shown in Tables 3-2 to 3-5 would not support use of diagrammatic signs on any of the interchanges tested. On the second test, which represents practiced driver performance, diagrammatic signs excelled conditional signs on only the following 4 (of 24) comparisons.

(1) On Interchange 16, a total of 48 errors were made on diagrammatic signs, 49 on conventional signs (Table 3-2).

Table 3-2

ERRORS MADE AT EACH INTERCHANGE

		Interchange						
Session	Sign	1	4E	4N	16	17	29	Total
Practice								
Phase 1	Diagrammatic	16	19	12	32	4	40	123
	Conventional	17	17	11	56	3	18	122
Phase 2	Diagrammatic	29	13	2	38	1	4	87
	Conventional	15	14	3	30	1	5	68
Total	Diagrammatic	45	32	14	70	5	44	210
	Conventional	32	31	14	86	4	23	100
Test 1								
Phase 1	Diagrammatic	27	15	4	33	0	4	83
	Conventional	19	14	6	38	0	6	83
Phase 2	Diagrammatic	24	26	17	21	3	39	130
	Conventional	13	29	7	17	2	14	82
Total	Diagrammatic	51	41	21	54	3	43	213
	Conventional	32	43	13	55	2	20	165
Test 2								
Phase 1	Diagrammatic	21	16	9	28	1	4	79
	Conventional	21	14	4	28	0	7	74
Phase 2	Diagrammatic	29	27	12	20	0	29	117
	Conventional	19	23	4	21	1	15	83
Total	Diagrammatic	50	43	21	48	1	33	196
	Conventional	40	37	8	49	1	22	157

Table 3-3

TOTAL ERRORS MADE AT CRITICAL EXITS

Session	Sign	Interchange 1	4E	4N	16	17	29	Total
Practice								
Phase 1	Diagrammatic	0	5	0	2	2	1	10
	Conventional	0	0	0	0	2	0	2
Phase 2	Diagrammatic	0	0	0	1	1	4	6
	Conventional	0	0	0	0	0	0	0
Total	Diagrammatic	0	5	0	3	3	5	16
	Conventional	0	0	0	0	2	0	2
Test 1								
Phase 1	Diagrammatic	0	0	0	0	0	0	0
	Conventional	0	2	0	0	0	0	2
Phase 2	Diagrammatic	0	3	1	0	1	0	5
	Conventional	0	0	0	0	0	0	0
Total	Diagrammatic	0	3	1	0	1	0	5
	Conventional	0	2	0	0	0	0	2
Test 2								
Phase 1	Diagrammatic	0	0	0	0	0	1	1
	Conventional	0	0	0	0	0	0	0
Phase 2	Diagrammatic	0	5	2	0	0	0	7
	Conventional	1	1	0	0	0	0	2
Total	Diagrammatic	0	5	2	0	0	1	8
	Conventional	1	1	0	0	0	0	2

Table 3-4

MEAN REACTION TIMES AT EACH INTERCHANGE IN SECONDS

Session	Sign	Interchange 1	4E	4N	16	17	29	Avg
Practice								
Phase 1	Diagrammatic	3.94	3.55	4.06	3.94	3.81	4.11	3.90
	Conventional	3.32	3.32	3.46	3.54	3.51	3.01	3.36
Phase 2	Diagrammatic	3.65	3.10	2.85	3.24	2.82	2.90	3.14
	Conventional	3.13	3.06	2.62	2.89	2.79	2.81	2.90
Avg	Diagrammatic	3.80	3.33	3.46	3.59	3.32	3.51	3.50
	Conventional	3.22	3.19	3.04	3.22	3.15	2.91	3.12
Test 1								
Phase 1	Diagrammatic	2.94	2.84	2.81	3.01	2.78	2.97	2.89
	Conventional	2.69	2.82	2.43	2.83	2.71	2.51	2.67
Phase 2	Diagrammatic	2.89	2.77	2.85	2.73	2.87	3.34	2.93
	Conventional	2.51	2.53	2.69	2.57	2.61	2.45	2.55
Avg	Diagrammatic	2.92	2.81	2.83	2.87	2.83	3.16	2.91
	Conventional	2.60	2.68	2.56	2.70	2.66	2.48	2.61
Test 2								
Phase 1	Diagrammatic	2.41	2.50	2.28	2.59	2.25	2.41	2.41
	Conventional	2.84	2.59	1.94	2.45	2.25	2.21	2.38
Phase 2	Diagrammatic	2.54	2.57	2.53	2.53	2.30	2.84	2.58
	Conventional	2.32	2.50	2.31	2.52	2.18	2.23	2.35
Avg	Diagrammatic	2.48	2.54	2.41	2.56	2.28	2.63	2.48
	Conventional	2.58	2.55	2.13	2.49	2.22	2.22	2.36

Table 3-5

REACTION TIMES AT CRITICAL EXITS IN SECONDS

Session	Sign	Interchange 1	4E	4N	16	17	29	Avg
Practice								
Phase 1	Diagrammatic	2.70	3.80	3.82	2.40	4.07	2.36	3.19
	Conventional	2.15	3.02	2.91	2.06	3.88	1.73	2.63
Phase 2	Diagrammatic	2.04	2.12	2.28	1.84	2.40	2.78	2.24
	Conventional	1.72	2.12	2.03	1.66	2.52	1.89	1.99
Avg	Diagrammatic	2.37	2.96	3.05	2.12	3.24	2.57	2.72
	Conventional	1.94	2.57	2.47	1.86	3.20	1.81	2.31
Test 1								
Phase 1	Diagrammatic	1.90	2.51	2.36	1.98	2.61	2.72	2.35
	Conventional	1.67	2.11	1.91	1.71	2.89	1.64	1.99
Phase 2	Diagrammatic	1.83	2.87	2.50	1.78	3.04	1.85	2.31
	Conventional	1.60	2.53	2.46	1.62	2.67	1.50	2.06
Avg	Diagrammatic	1.87	2.69	2.43	1.88	2.83	2.29	2.33
	Conventional	1.64	2.32	2.19	1.67	2.78	1.57	2.03
Test 2								
Phase 1	Diagrammatic	1.52	1.93	1.85	1.75	2.21	2.13	1.90
	Conventional	1.57	1.72	1.58	1.49	1.97	1.64	1.66
Phase 2	Diagrammatic	1.96	2.80	2.40	1.59	2.40	1.69	2.14
	Conventional	1.66	2.00	2.10	1.61	1.99	1.28	1.77
Avg	Diagrammatic	1.74	2.37	2.13	1.67	2.31	1.91	2.02
	Conventional	1.62	1.86	1.84	1.55	1.98	1.46	1.72

Table 3-6

PREFERENCES FOR DIAGRAMMATIC AND CONVENTIONAL SIGNS

	Conventional Sign	
Phase	Number	Percent
1	14	46
2	12	40
1 and 2	26	43
	Diagrammatic Sign	
Phase	Number	Percent
1	8	27
2	8	27
1 and 2	16	27
	No Preference	
Phase	Number	Percent
1	8	27
2	10	33
1 and 2	18	30
	Total	
Phase	Number	Percent
1	30	100
2	30	100
1 and 2	60	100

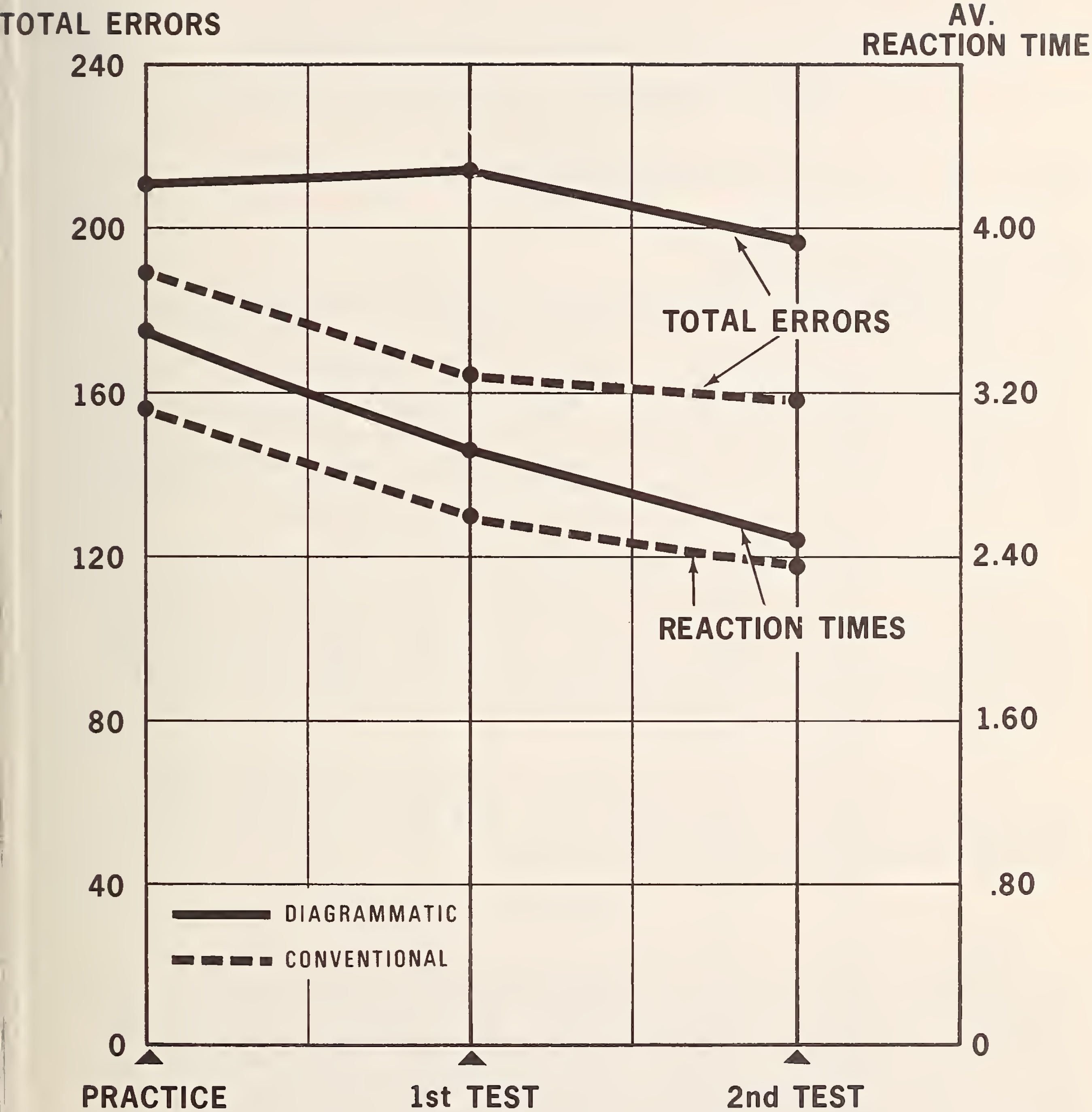


Figure 3-7. Improvement in subjects' performance with practice.

(2) On Interchange 29 no errors were made on the diagrammatic exit sign, one on the conventional exit sign (Table 3-3).

(3) On Interchange 1, average reaction time to diagrammatic signs was 2.48 seconds, conventional signs 2.58 seconds.

(4) On Interchange 2, diagrammatic signs required 2.54 seconds, conventional signs 2.55 seconds (Table 3-4).

None of these differences are large enough to achieve statistical or practical significance.

Particular Diagrammatic Signs

The question remains whether any of the variety of diagrammatic signs tested were outstanding. Results of the second test after practice, sorted by design, are shown in Table 3-7. The table shows that Symbol 1, the single arrow design that indicated an exit, appeared in six cases, i.e. Interchange 1, sign B', Interchange 1, sign E', etc. Symbol 2, the double arrow with one alternative straight ahead appeared six times, a forked arrow (Symbol 3) three times, and so on. The table gives the total number of errors made on diagrammatic and conventional signs, the average reaction times, and the significance level of the difference in average reaction times between signs.

The single arrow showed up best of the diagrammatic symbols tested. A total of 37 errors were made on the diagrammatic arrow, 52 on corresponding conventional signs. In 6 of the 10 cases listed, the reaction time to diagrammatic signs was shorter. Of these, two reached significance at least to the .05 level (T test for correlated measures, N = 30, See Fisher, 1937). Consideration might be given to increasing the size or prominence of the arrow symbol on freeway exit signs.

There is some support for the use of the forked arrow symbol at the exit direction sign used on the approach to Interchange 17, sign V'. Only one error was made on the diagrammatic (and) conventional sign, and the diagrammatic sign gave shorter reaction times.

Discussion

These results, which do not generally favor substituting diagrammatic for conventional signs, appear in contradiction to the findings of the Berger (1970) study, and some explanation of the discrepancy seems called for. It will be recalled that in the Berger study the correct lane was considered to be the right (exit) lane in all cases, although the scoring method is not given in the report. The scoring key used here, which was worked out after considerable discussion, may perhaps be more defensible than the Berger key (see discussion under "The Scoring Key" above).

TABLE 3-7

SPEED AND ACCURACY OF REACTIONS TO TYPES
OF SIGN SYMBOLS

Sign Symbol	Inter-change	Sign	Phase	Total Errors		Avg Reaction Time (sec)		* Statistical Significance
				Diagrammatic	Conventional	Diagrammatic	Conventional	
1	1	B'	1	7	10	2.26	2.24	
			2	13	13	2.21	2.68	0.05
	1	E'	1	0	0	2.18	2.28	
			2	0	1	1.96	1.66	0.05
	1	F'	2	0	0	1.52	1.57	
	4E	H'	1	14	14	2.55	2.60	
			2	3	14	2.04	2.47	0.05
	16	T'	1	0	0	1.75	1.49	
			2	0	0	1.59	1.61	
	29	DD'	2	0	0	1.69	1.28	0.01
2	1	A'	1	0	0	2.44	2.16	
			2	0	0	2.63	2.18	0.01
	4N	L'	1	3	3	2.40	2.09	
			2	3	4	2.58	2.48	
	16	Q'	1	15	12	2.52	2.49	
			2	11	13	2.69	2.39	
	16	S'	1	4	5	2.78	2.89	
			2	3	5	2.67	3.24	
	29	AA'	1	0	0	1.87	1.89	
			2	6	12	2.71	2.87	
	29	CC'	1	0	0	3.30	3.25	
			2	13	3	3.96	2.36	0.01
3	4N	N'	1	0	0	1.85	1.58	
			2	2	4	2.40	2.10	0.05
	17	V'	1	1	0	2.42	2.75	
			2	0	1	2.36	2.40	
	17	W'	1	0	0	2.21	1.97	
			2	0	0	2.40	1.99	0.05
4	4E	J'	2	5	1	2.80	2.00	0.01
5	4E	G'	1	2	0	2.22	2.42	
			2	1	0	2.75	2.30	0.05
6	4N	M'	1	6	1	2.86	2.04	0.01
			2	7	0	3.09	2.46	0.05
	16	O'	1	3	3	2.57	2.47	
			2	0	1	2.43	2.75	
	16	P'	1	2	3	2.10	2.05	
			2	0	0	2.13	2.12	
7	29	Y'	1	0	1	2.57	2.17	0.05
			2	1	0	3.38	2.68	0.05
	29	Z'	1	3	6	2.10	2.16	

TABLE 3-7 (continued)

SPEED AND ACCURACY OF REACTIONS TO TYPES OF SIGN SYMBOLS

Sign Symbol	Inter-change	Sign	Phase	Total Errors: Diagrammatic	Total Errors: Conventional	Avg Reaction Time (sec): Diagrammatic	Avg Reaction Time (sec): Conventional	Significance*
			2	8	0	2.44	2.29	
	29	BB'	1	1	0	2.13	1.64	
			2	1	0	3.96	1.92	0.01
8	1	D'	1	5	5	2.76	3.25	
			2	1	3	2.98	2.05	0.01
9	16	R'	1	4	5	3.80	3.34	
			2	6	2	2.67	3.02	0.01
10	1	C'	1	9	6	3.33	3.34	
			2	15	2	2.98	3.07	
11	4E	1'	1	0	0	1.93	1.72	
			2	18	8	2.69	3.23	0.05

*If no value is given, not statistically significant.

While the scoring of a "correct" lane may be controversial, the other assessment measures are less so. There can be little question that a sign which exits the driver at his destination ramp is superior to one which does not. A good sign should also permit the driver to quickly extract the essential information. The driver's preference for one sign over another should also be taken into consideration in evaluating sign designs. On these additional measures, conventional signs generally showed up as more effective than diagrammatic signs.

The reaction time results may be explained in terms of how the driver makes his lane choice decision. In the case of conventional signs, it may be suggested that the driver must (1) find his destination on the sign, (2) select his lane by observing which lane his destination arrow points to. Usually the lane pointed to by the arrow was clearly and easily recognized. For diagrammatic signs, the driver must (1) locate his destination on the sign, (2) interpret the road geometry represented by the lines and arrows, and (3) make a lane choice based on the geometry.

Accepting this interpretation, lane choice selection is simpler, more direct, and rapid when conventional signs are viewed. However, the diagrammatic display of road geometry may have advantages in certain situations, particularly when the geometry violates the driver's expectations. Such might be the case at a T or Y intersection, at a left hand off ramp where visibility was poor, etc.

Summary and Findings

This paper presents a laboratory assessment of diagrammatic sign designs being considered for use on U.S. freeways. Diagrammatic signs were compared with the conventional guide signs now on the road. The subjects viewed projected scenes of the Capital Beltway and indicated as quickly as possible the proper lane to be on to reach a preassigned destination. The signs tested were made by superimposing diagrammatic and conventional sign drawings on actual photographs of the highway. The road scenes presented the signs of a cloverleaf intersection, a lane drop, a multiple split ramp, a left ramp downstream from a right ramp, two rights in quick succession and a major fork. The study was a follow-up of one carried out by Serendipity, Inc. under contract to the National Highway Traffic Safety Administration.

On the basis of the subject drivers' reactions, the following findings are reported:

(1) The conventional signs tested were on the whole slightly more effective than the experimental diagrammatic signs. They produced fewer errors, fewer errors on critical exits, and they were more quickly responded to than diagrammatic signs. The conventional signs were also preferred by the subjects to diagrammatic signs.

(2) In none of the six types of interchanges tested did the diagrammatic signs provide better lane placement or shorter response times than the conventional signs.

(3) The diagrammatic symbol showing a large exit arrow showed up best of the diagrammatic signs tested. Consideration might be given to increasing the size of the conventional exit arrow.

A word of caution is in order as far as the interpretation of the results of this study is concerned. The findings are limited to Serendipity sign designs applied to freeway intersections. The effectiveness of diagrammatic signs is very much related to graphic design and the formating of graphic and legend information. This point will become more apparent later in the report when the results of field evaluations of diagrammatic signs are discussed.

References

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Fisher, R.A., The Design of Experiments (2nd Edition). London, Oliver and Boyd, 1937, page 41 f.

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PART II

INSTRUMENTED VEHICLE STUDIES

Chapter IV

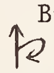
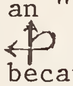
INSTRUMENTED VEHICLE EVALUATION OF DIAGRAMMATIC GUIDE SIGNS AT A CLOVERLEAF INTERCHANGE

The research reported here was conducted during the early stages of the Diagrammatic Signing Research Program. It was the first study in a series of investigations using an instrumented vehicle to evaluate diagrammatic guide signs for use on the Interstate highway system. The work was preliminary in the sense that the results were expected to reveal information about the sensitivity of instrumented vehicle measures of sign effectiveness. But it was also considered definitive in view of the fact that it was anticipated that the results would contribute to the general understanding of how drivers respond to diagrammatic guide signs.

The purpose of this investigation was to determine the influence of diagrammatic signs on the driver's ability to maintain vehicular velocity control and read and understand destination information depicted on interstate highway signs. The research was conducted under field conditions and employed a before-after experimental design. Conventional highway signs represented the before test condition and diagrammatic signs the after condition. Although this general approach has been used in previous field evaluations of diagrammatic signs, the research technique employed in this study was different in many important aspects. The use of the instrumented vehicle permitted the study of individual driver responses under conventional and diagrammatic sign conditions. This allowed the investigators to directly analyze the individual driver's ability to interpret guide sign information and maintain vehicular velocity control. Moreover, the before and after phases were conducted during the same month within a very short period of time. This minimized the influence of extraneous variables associated with seasonal variations and changing traffic parameters.

The only independent variable in this study consisted of conventional versus diagrammatic signs. The principle dependent variables measured were subject information interpretation distance (IID) and vehicle velocity noise within the different sign information processing zones and gore areas. The term, information interpretation distance, as it is used in this study, refers to the distance in advance of the sign where the driver is first able to understand the information presented in the display. This variable was measured directly by instructing test drivers to depress a response button the instant they were able to understand the information on the guide signs. A similar technique was used by Moore & Christy (1963) to evaluate British diagrammatic signs. However, their subjects were passengers in a vehicle whereas this study employed subjects as drivers who made their response as they approached each sign in a signing sequence.

The term velocity noise refers to the extent drivers varied the test vehicle's velocity while under the influence of the signs. It was measured by sampling and recording the test vehicle's velocity at a rate of one per second throughout the test drive.

A full cloverleaf was selected for the geometry of the test interchange. This choice was made for a number of reasons. First of all, the cloverleaf has a disproportionately high accident rate compared to other common interchange geometrics found on the Interstate system (Cirillo, Dietz, Beatty, 1969). It is commonly found in high population density metropolitan areas and typically carries heavy traffic volumes. Furthermore, the decision making demands on the driver negotiating a cloverleaf are fairly difficult inasmuch as a three choice decision is required while the driver is traveling in a high speed traffic stream. For this reason the view was held that the cloverleaf appeared to be a promising candidate for graphic guide sign displays. Although prior field research conducted by the Wyoming Highway Department (1969) and the Office of Traffic Operations (1968) did not support this belief, it was sustained because neither of these studies employed the graphic display recommended by Berger (1970). Both investigations used graphics displaying intersecting or crossing components. Berger reported that intersecting lines or crossovers on a graphic can result in serious confusion because such configurations greatly increase the complexity of the display. But Berger did suggest that in most situations an "implied crossover"  design as opposed to a "full crossover"  design can be successfully applied. For the reasons stated above and because the "implied crossover" graphic had not yet been evaluated in the field, a full cloverleaf was selected as the test interchange and the "implied crossover" graphic design was chosen as the graphic component on the diagrammatic test sign.

The overall conceptional hypothesis for the study was that diagrammatic sign formats would influence the driver's ability to extract information from highway guide signs at a cloverleaf interchange. The experimental hypothesis was that diagrammatic signs with "implied crossover" graphics would affect sign information interpretation distance (IID) and the velocity noise in the driver's vehicular velocity control.

Methods

Subjects

Complete measurement records were obtained from a total of 48 test subjects. All of the subjects possessed valid driver's licenses and had prior experience driving on the Interstate highway system. The subjects were male and female volunteers and each was paid $10.00 to participate in the study. Most of the volunteers were students attending colleges and universities in the metropolitan Washington, D.C. area. However, nine subjects were volunteer out-of-state drivers traveling south to Washington, D.C. who had stopped at a gas station located 4-1/2 miles north of the test interchange. All of the drivers tested in the study professed to be unfamiliar with the test interchange.

The total sample of test subjects was comprised of two equal groups of 24 subjects. One group was tested under conventional signing conditions whereas the other group was tested with diagrammatic signs. There were 14 males and 10 females in the diagrammatic group and 17 males and 7 females in the conventional group. Subjects in the diagrammatic group ranged in age from 17 to 56 years with a mean age of 25 years. Subjects tested under conventional signing conditions ranged in age from 16 to 59 years with the mean age of this group being 26 years. The number of years in driving experience ranged from 1 to 33 years with a mean of 7 years for subjects in the diagrammatic group. The mean number of years of driving experience was 9 for subjects in the conventional group and ranged from 1 to 40 years.

Test Interchange

The interchange used in the study was located in the State of Maryland at Interstate 70-S and Maryland 118. This interchange carried 4 lanes of traffic in the north-south direction on 70-S and 2 lanes of traffic in the east-west direction on 118. It was a full cloverleaf and was classified as a minor interchange with excellent sight distance. Only the signs, exit ramps, and their approaches serving southbound traffic were used in the investigation. The sign sequence used in the study consisted of four signs. The first guide sign the 70-S southbound driver encountered was an advance sign located one mile in advance of the interchange. The second sign was an exit direction sign located at the 1/2 mile point. The third and fourth signs were exit signs positioned in close proximity to the two exit gores. The third sign was the Germantown exit sign and the fourth sign was the Damascus exit sign. Presented in Figure 4-1 is a drawing of the interchange geometry depicting the locations of the guide signs serving southbound traffic.

Test Signs

Conventional Signs. All of the conventional signs originally in place at the test interchange were constructed of 3/4 inch plywood and were shoulder mounted on supporting structures made of five 6 x 6 inch posts with 2 x 6 inch crossbeams. Inasmuch as these signs deviated significantly from existing Interstate sign standards, four new conventional sign panels which were closer in conformity with interstate standards were designed, fabricated, and erected for the southbound traffic stream. The new sign panels were mounted on the original shoulder mounted structures and they were also of 3/4 inch sign quality plywood construction and painted interstate green. The letters and graphic components were constructed from .04 inch aluminum covered with white reflective material and were fastened to the plywood panels by 1/2 inch aluminum screws. All of the letters, shields, border material, and graphic components were prepared and supplied by Interstate Highway Sign Company, Little Rock, Arkansas.

The dimensions for both the 1 mile advance sign and 1/2 mile exit direction sign panels were 10 x 20 feet. The Germantown exit sign was

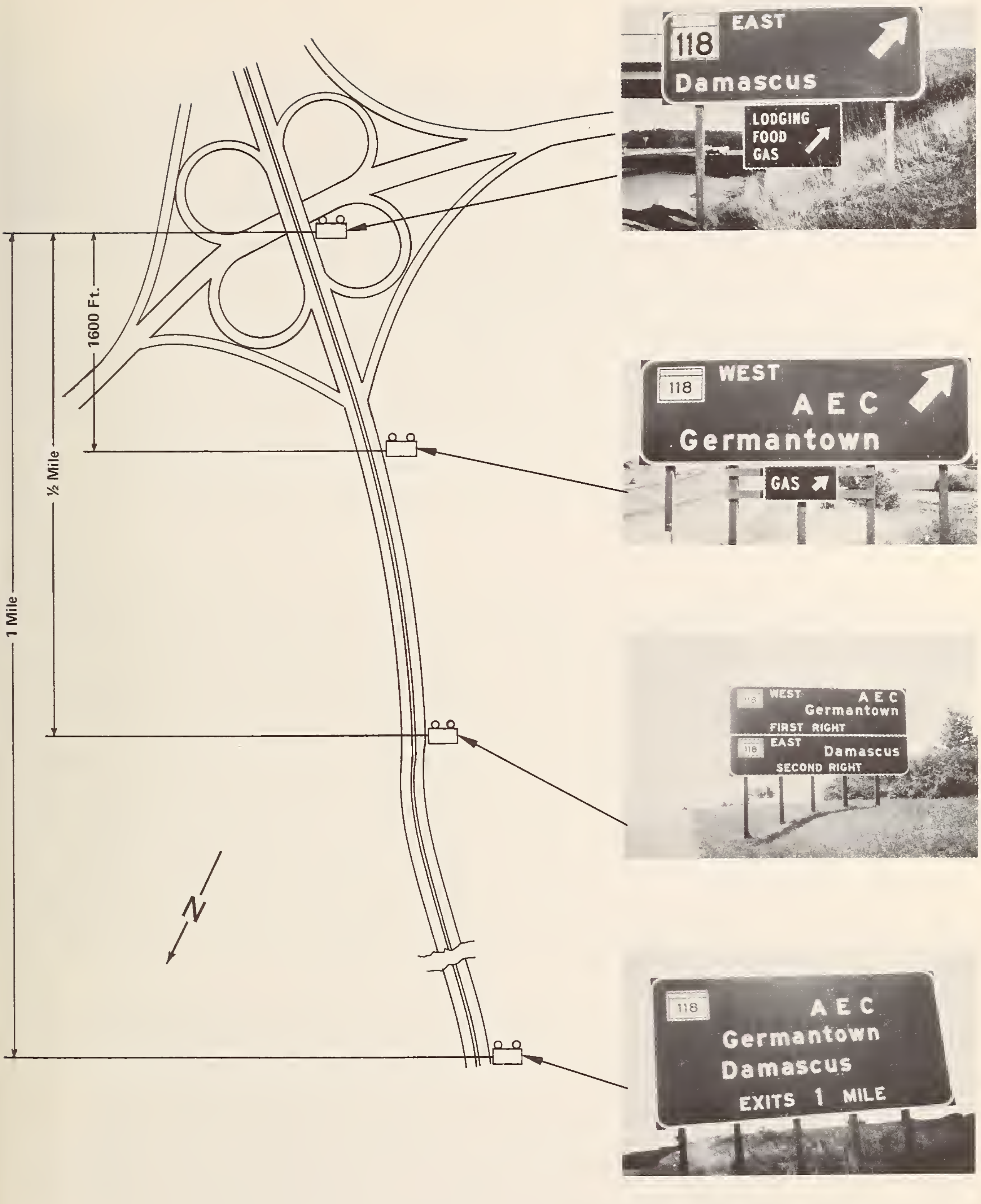


Figure 4-1. Test interchange under conventional signing conditions.

6 x 18 feet and the Damascus exit sign 6 x 16 feet. The four signs were positioned approximately 3 feet from the outside edge of the roadway shoulder with the bottom edges of the sign panels approximately 5 feet from the ground. All of the capital letters used in the destination names were 13-1/3 inches with the small letters 10 inches in loop height. The "1" in 1 mile was 13-1/3 inches. All other lettering was 10 inch capitals. The Maryland 118 sign shield dimensions were 24 x 30 inches. Pictures of the actual sign panels used for the advance and exit direction signs under the conventional test conditions of the study are presented in Figure 4-1.

The same exit signs were used for both the conventional and diagrammatic test conditions. Arrow stem dimensions on the exit signs were 8 x 18 inches with the arrowhead dimensions being those specified for the "up" arrow in the Manual on Uniform Traffic Control Devices (1971). Both of the original exit signs had separate panels mounted at the bottom of the general sign panel depicting service information. These panels remained in place under both the conventional and diagrammatic test conditions. Pictures of the exit sign panels used throughout the investigation are also presented in Figure 4-1.

Diagrammatic Signs. Only the 1 mile advance sign and the 1/2 mile exit direction sign were changed to a diagrammatic format for the "after" phase of the study. Although the diagrammatic signs incorporated a graphic component in the information display, the overall dimensions of the sign panels essentially remained the same. The only exception to this was the addition of a 2 x 3 foot extension to the upper left hand corner of both signs. This addition supported the I-70-S Interstate shield which was positioned at the top of the graphic. The graphic portion of the information display consisted of a main vertical component with two arrows emanating from its right side to represent the two exit ramps. The vertical portion of the graphic for the one mile advance sign was 8 feet long and 10 inches wide. The two arrows which extended from the top and bottom of the vertical piece were 5 inches wide. Again, the arrowheads conformed to the standards for the "up" arrow. The upper arrow depicted the second exit with an "implied crossover" and described two elipse curvatures. The lower arrow represented the first exit and described a constant radius curvature.

The graphic portion of the information display for the 1/2 mile exit direction sign was essentially the same as that for the 1 mile advance sign. The only exception being that the vertical component on the graphic was one foot shorter on the advance sign. The shorter graphic on this sign was necessary in order to accommodate the word "1 mile." Although the graphic displays for both signs were for practical purposes identical, these signs did differ in word content. The presence of the word "1 mile" on the advance sign has already been mentioned. Even though it was omitted from the exit direction sign, the exit direction sign had more information content because it contained the words "east" and "west." Presented in Figure 4-2 are pictures of the actual sign panels used for the advance sign and exit direction sign under the diagrammatic test condition.

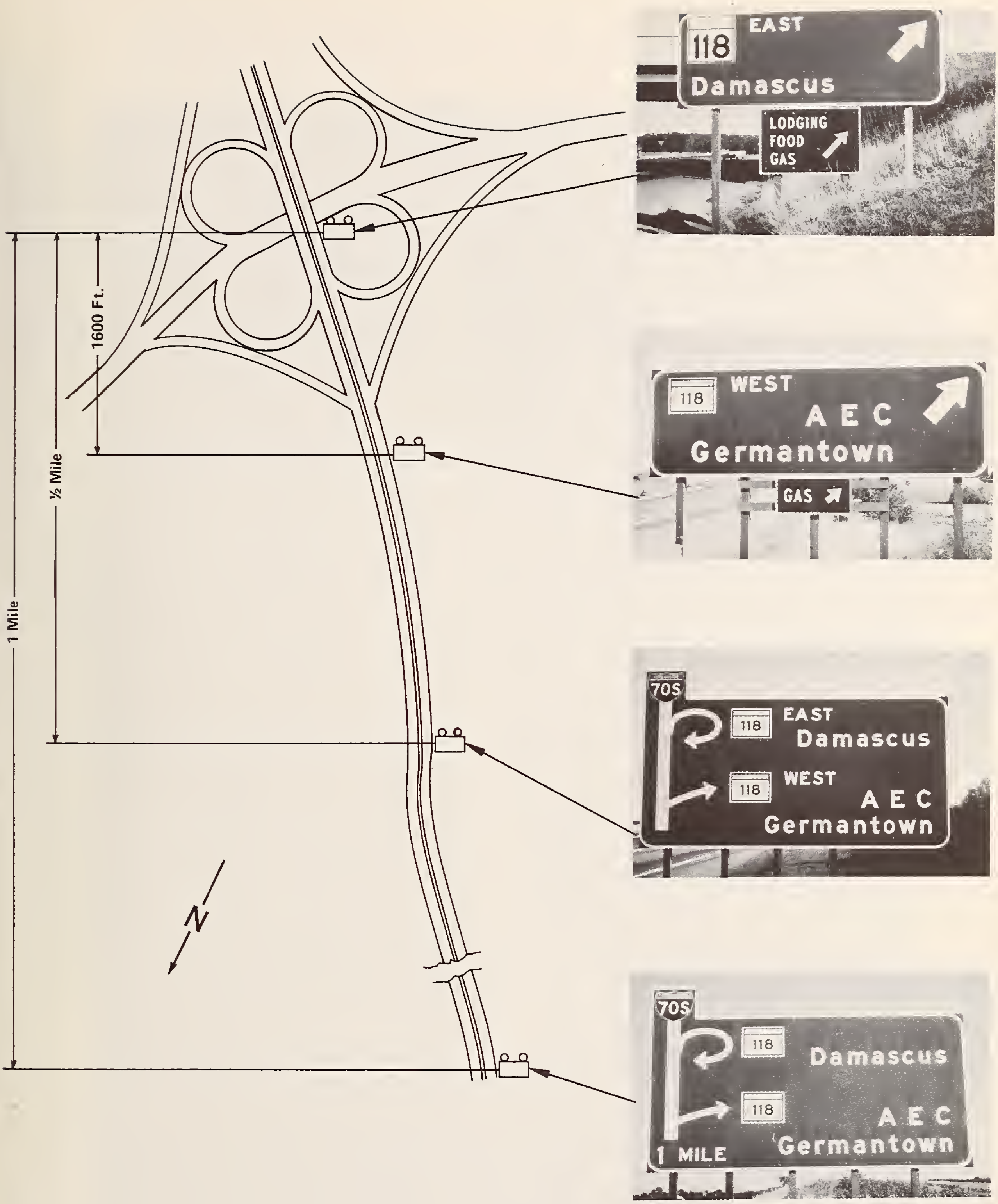


Figure 4-2. Test interchange under diagrammatic signing conditions.

Instrumented Vehicle

The vehicle used for the driver tests was a 1966, 8 cylinder Chevrolet. A picture of the vehicle is presented in Figure 4-3. It was a four door Biscayne sedan equipped with power steering, automatic transmission, air conditioning and power brakes. The tires were new steel belted, 4-ply radials. In order to accommodate part of the instrumentation package, the back seat of the vehicle was removed and special mountings were installed. The instrumentation package was comprised of an inverter, recorder, and velocity/distance measuring device. Instrumentation components were mounted in both the back seat area and on the dashboard of the test vehicle. The component mounted on the dashboard was located on the passenger's side. The inverter and recorder were positioned in the back seat area. The inverter was manufactured by Carter Company and provided 115 volts at 60 cycles per second. It was the source of power for the recorder and velocity/distance measuring equipment. The recorder was a ten channel, digital printer manufactured by Systron-Donner, Inc. It is pictured along with the inverter in Figure 4-4. The velocity/distance measuring equipment was manufactured by Zeronics Engineering Company and was mounted on the dashboard. It measured the velocity of the test vehicle in tenths of a mile per hour and the distance traversed in one hundredths of a mile or to the nearest 52.8 feet. This was accomplished by means of a photo-electric sensor attached to the speedometer cable. A picture of the Zeronics velocity/distance device is presented in Figure 4-5.

A digital display of the vehicle's velocity was available to the experimenter from the equipment mounted on the dashboard. Also, velocity and distance data were continuously recorded on printed paper tape by the Systron-Donner recorder at a sampling rate of one per second. Three event marker inputs were used with the recorder, one from the subject and two from the experimenter. When the experimenter depressed either of two momentary push buttons mounted on the front of the velocity/distance measuring device, the record was marked with a "less than" or "greater than" symbol. Furthermore, when the subject depressed with his left foot a momentary contact push button mounted on the floor of the vehicle next to the headlight dimmer switch, the record was marked with a period. An example of the data tape is presented in Figure 4-6.

Procedure

The data gathered in the study was collected during the first two weeks of August 1971. On the weekend of August 1, new conventional sign panels were installed at the test interchange. Data under the conventional signing conditions were then gathered from August 2 through August 7. On Sunday, August 8, the information display format for the advance sign and exit direction sign was changed from conventional to diagrammatic. From August 9 through 14 data were gathered using diagrammatic signs. Data gathered under both diagrammatic and conventional signing conditions were collected under clear and dry weather conditions.

Figure 4-3. Picture of instrumented test vehicle.

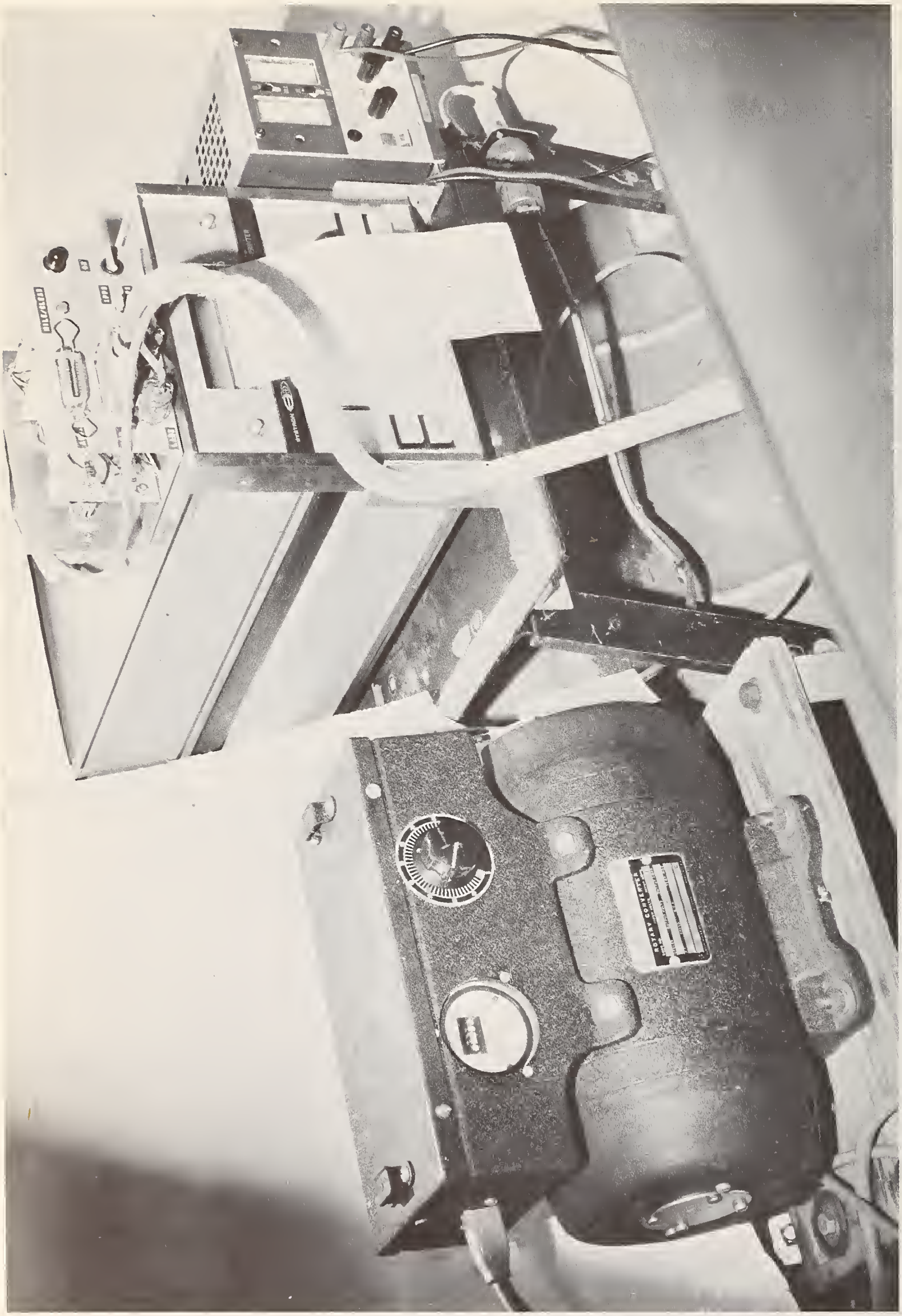


Figure 4-4. Picture of inverter (left) and digital printer (right).

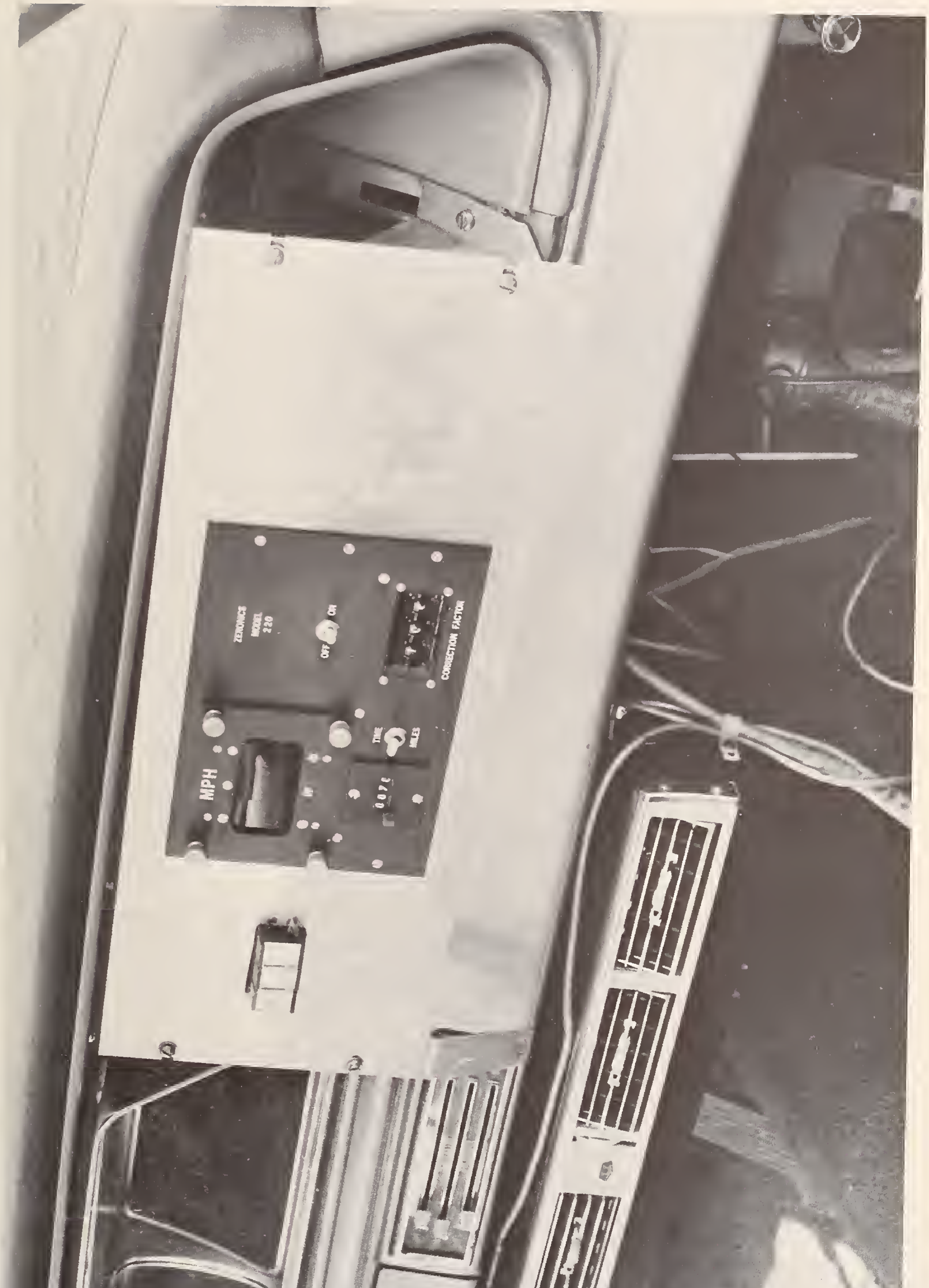
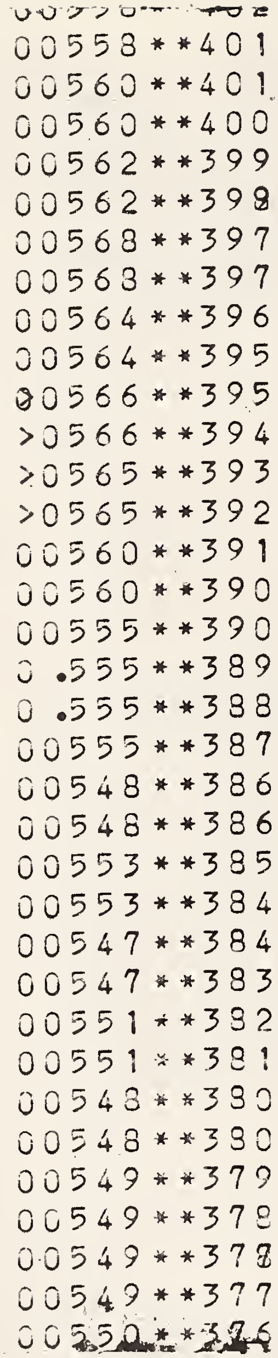


Figure 4-5. Picture of Zeronics velocity/distance measuring device.



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                    00560**401
                    00560**400
                    00562**399
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                    00564**395
                    00566**395
Experimenter        >0566**394
        mark        >0565**393
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                    00560**391
                    00560**390
                    00555**390
      Driver        0 .555**389
        mark        0 .555**388
                    00555**387
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Figure 4-6 - Example of Data Tape Collected from Instrumented Vehicle

The experimenter marked the tape by pressing a button on the dashboard. The driver (subject) marked by pressing a pedal on the floorboard. Velocity data is in 10ths of a mph. The distance data is in 100ths of a mile from the beginning point. Each line of data is separated from the adjacent lines by one second in time.

Volunteer test subjects were transported to the research base station located in the southwest quadrant of the Clarksburg Interchange (Maryland 121 and Interstate 70-S). This interchange was located 4.5 miles north of the test interchange. The research station was housed in an 8 x 25 foot air-conditioned trailer. Here subjects filled out biographical data forms and waited to be dispatched on the test drive. Care was taken to keep the subjects naive as to the exact purpose and details of the study. However, they were informed that the tests were concerned with highway signs and that they would be required to drive an instrumented vehicle through a test interchange. Subjects who had completed the test were asked not to discuss the details of the experiment with subjects not yet tested.

Upon arriving at the base station the subject's age, sex, years of driving experience, and familiarity with the test area were recorded. Next, the subject was instructed to drive the instrumented vehicle into the town of Clarksburg. The experimenter rode on the passenger's side of the front seat at all times during test drives. The subject was informed that the vehicle was a standard automobile with power brakes and power steering. In addition, he was informed that the car was equipped with special instrumentation but that it would not influence the driving performance of the vehicle.

The test drive to Clarksburg and back to the base station was designed to familiarize the subject with the performance characteristics of the vehicle. He was instructed to try out the vehicle's brakes, steering, and acceleration. Most subjects took about 15 minutes to drive the 8 miles to Clarksburg and return. The preliminary drive was also used to assess the subject's general driving performance and ability to function in the test situation. This provided the experimenter an opportunity to reject any test subjects whose driving performance was obviously substandard before entering the high speed traffic stream. None of the subjects who made the preliminary drives were rejected.

At the conclusion of the familiarization drive the subject was instructed to stop the vehicle at the entrance to the base station area facing the entrance ramp to the I-70-S southbound traffic stream. At this point the experimenter gave the following oral instructions:

> "I want you to take the entrance ramp directly in front of you and merge into the I-70-S southbound traffic stream. Drive me to (Germantown/Damascus/Darnestown) obeying the traffic laws. Since you are unfamiliar with this area, you will have to read the interstate guide signs in order to find your way to (Germantown/Damascus/Darnestown). As you approach the big green interstate guide signs ahead, you will please press the button on the floor with your left foot at the point you are able to read and understand the information on the signs (experimenter pointed to button). Go ahead and push it now so you will know how it works. Push the button for only the big green

interstate guide signs. Ignore small speed limit signs and any other small regulatory signs, as far as pushing the button is concerned. Do you have any questions? Remember, push the button just as soon as you understand the information on the sign. If you don't have any questions, go ahead and start the car and take me to (Germantown/Damascus/Darnestown)."

At this point the experimenter turned on the recording equipment. The velocity and distance traversed from the base station was recorded as soon as the test driver put the vehicle in motion. The recorded test drive was 4.5 miles in length. Ten subjects in the conventional sign group were instructed to go to Damascus, eleven to Germantown, and three to Darnestown. Similarly, twelve subjects were instructed to go to Damascus, eleven to Germantown, and one to Darnestown in the diagrammatic sign group.

During the test drive, the experimenter marked the record by depressing one of the experimenter buttons on the velocity/distance device. He first marked the record at the point the subject first merged into the traffic stream. The yield sign positioned at the entrance ramp was used as the marking point. The instant the yield sign lined up in the wing window on the passenger side of the vehicle, the experimenter pushed the button. The experimenter also pressed this button when the advance sign, exit direction sign, Germantown exit sign, and Damascus exit sign (if passed) appeared in the wing window. Similarily, he pressed the button at the yield sign serving the Damascus or Germantown entry ramps to the east-west traffic stream. As soon as the subject had entered either the Germantown or Damascus exit ramps or had driven past the second exit ramp in the direction of Darnestown, the subject was asked to answer the following questions: "How confident are you now that you are traveling to (Damascus/Germantown/Darnestown) - (a) totally sure, (b) very sure, (c) moderately sure, (d) fairly sure, (e) not at all sure?" The five alternative responses were read to the subject and his answers marked on the data sheet by the experimenter.

As soon as the driver completed the negotiation of the interchange, he was instructed to turn around and return to the base station area. After returning to the base station the subject was then asked the following questions: "For the traveler going to (Damascus/Germantown/Darnestown), do you think the signs at this interchange are (a) totally adequate, (b) very adequate, (c) moderately adequate, (d) barely adequate, (e) not at all adequate? Next question: At the speed that you were traveling, was the time available to you for reading and understanding the signs (a) much more than required, (b) more than enough, (c) just right, (d) barely enough, (e) not enough time? Next question: What aspects of these signs were confusing (experimenter showed subject pictures of the signs he used in the test)?" Subjects who performed under the diagrammatic condition were also asked whether they preferred diagrammatic or conventional signs. After the subject's answers to all of the above questions were recorded by the experimenter, the data gathering procedure for the subject was completed.

Results

Driver Velocity Control

Driver velocity records were subdivided into five zones for data analysis purposes: (1) advance sign information processing zone, (2) exit direction sign information processing zone, (3) Germantown exit sign information processing zone, (4) Damascus exit sign information processing zone, and (5) Baseline zone section. The definitions of the information processing zones for the advance sign, exit direction sign, and Germantown exit sign (first exit) were based upon the points where these signs first came into full view to the driver. That is, the zone marked by the position of the sign and the point where the sign first became totally visible to the driver was defined as the information processing zone (IPZ) for that sign. The Damascus exit sign IPZ was defined as the distance between the Germantown exit sign and the Damascus exit sign. A baseline zone section of the test drive was also defined. This section was located 2 miles in advance of the signing sequence and was of comparable length to the sign IPZs. The selection of the baseline zone was based on the criteria that it was a relatively level section of highway with more than one mile of visibility and free from the influence of roadway signs.

Presented in Table 4-1 are the means, standard deviations, and T ratios for the average vehicular velocity scores recorded in the sign IPZs and in the baseline zone under conventional and diagrammatic signing conditions. An average vehicular velocity score for a given subject for a given sign was computed by simply summing the velocity samples recorded in the IPZ or baseline zone and dividing this sum by the number of samples. T ratios were then computed on the differences between the average velocity means for the conventional and diagrammatic signing groups for the baseline zone and for each of these sign IPZs. In each instance the mean velocity was less for the diagrammatic group when compared to the conventional group. However, it is apparent from Table 4-1 that none of these differences reached the .05 level of statistical significance. Indeed, examination of the means reveals that the largest difference between the two groups has a magnitude of only 2 miles per hour.

In order to study the influence of the test signs on the driver's velocity changes, a vehicular velocity noise score was computed for each subject for each sign. The noise score was determined by computing the standard deviation of the driver's velocity samples recorded in a given IPZ. In other words, the subject's velocity standard deviation within each of the zones was treated as a variable. The means, standard deviations, and T ratios for velocity noise scores recorded in the sign IPZs and baseline zone are shown in Table 4-2.

The differences between the conventional and diagrammatic group means for the driver velocity noise scores for the 1 mile advance sign and Damascus exit sign were statistically significant beyond the .05 level.

Table 4-1

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR AVERAGE VEHICULAR VELOCITY SCORES IN MILES PER HOUR RECORDED IN SIGN INFORMATION PROCESSING ZONES

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	T Ratios	Sign Level
Baseline	24	63.9	4.30	24	62.2	4.54	0.5387	NS
Advance Sign	24	57.3	4.91	24	56.6	4.46	0.5254	NS
Exit Direction Sign	24	57.8	4.55	24	56.1	5.97	1.1084	NS
First Exit Sign	24	56.2	4.92	24	54.9	4.81	0.9620	NS
Second Exit Sign	12	57.0	4.42	12	55.0	4.62	1.0965	NS

Table 4-2

MEANS, STANDARD DEVIATIONS AND T RATIOS FOR VEHICULAR VELOCITY NOISE

SCORES IN MILES PER HOUR RECORDED IN SIGN INFORMATION PROCESSING ZONES

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	T Ratio	Sign Level
Baseline	24	1.38	.659	24	1.22	.552	0.9088	NS
Advance Sign	24	1.31	.731	24	1.88	.928	2.3572	P < .05
Exit Direction Sign	24	1.24	.489	24	1.42	.867	0.8856	NS
First Exit Sign	24	1.16	.401	24	1.24	.641	0.5234	NS
Second Exit Sign	12	2.33	1.721	12	3.68	1.221	2.2084	P < .05

For both the advance sign and Damascus exit sign driver velocity noise means were greater under the diagrammatic signing condition. This was also true for the exit direction sign and Germantown exit sign even though the differences between the experimental conditions for these signs were not statistically significant.

Driver Information Interpretation Distance

In order to assess the ease with which the driver was able to process the information depicted on the test signs, an information interpretation distance (IID) score was computed for each driver at each of the signs. This score was determined by measuring the distance between a given sign and the point at which the driver indicated he understood the sign. As indicated above, the subject was instructed to push a button as soon as he had read and understood the sign. Presented in Table 4-3 are the means, standard deviations, and T ratios for IID scores measured in feet for each sign under conventional and diagrammatic signing conditions. It is evident from this table that the mean IID scores are consistently smaller in magnitude under the diagrammatic signing condition. The difference between the means for the conventional and diagrammatic signs reached statistical significance for the advance sign and the Germantown exit sign. Both of these differences were significant beyond the .05 level.

Questionnaire Results

Subject responses to the three questions were scored by assigning numerical values to the five possible question response alternatives. A value of one was assigned to the most favorable response alternative, two to the next favorable, and so on with a value of five assigned to the least favorable alternative. The Median statistical test, a nonparametric statistical model, was used to test the differences between the conventional and diagrammatic groups on their responses to the three questions. Recorded in Table 4-4 are the means along with standard deviations for subject responses for both groups for each of the three questions. The group means for the subject responses were extremely close with none of the statistical comparisons reaching significance.

Driver Sign Preferences and Maneuver Errors

The sample of 24 drivers who drove through the test interchange under the diagrammatic signing condition were asked to indicate, after looking at colored pictures of conventional and diagrammatic signs for the test interchange, which signs they preferred. Out of the drivers thus queried, 12 indicated they preferred conventional signs and 11 indicated that the diagrammatics were better. One subject indicated that she would prefer a combination of conventional and diagrammatic signs.

Out of the total sample of drivers tested, exit errors were committed by four drivers. An exit error was defined as subject failure to take the appropriate exit at the interchange. For example, if the driver was instructed

Table 4-3

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR DRIVER INFORMATION

INTERPRETATION DISTANCE (IID) SCORES FOR EACH SIGN

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
	N	Mean (ft.)	SD (ft.)	N	Mean (ft.)	SD (ft.)	T Ratio	Sign Level
Advance Sign	21	787	359	21	465	433	2.615	$P < .05$
Exit Direction	21	554	232	21	496	322	0.666	NS
First Exit Sign	21	644	238	21	454	296	2.317	$P < .05$
Second Exit Sign	10	781	359	10	639	169	1.131	NS

Table 4-4

MEANS AND STANDARD DEVIATIONS FOR SUBJECT QUESTIONNAIRE RESPONSES

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
	N	Mean	SD	N	Mean	SD		
Driver Confidence	24	1.57	0.98	24	1.58	1.02		
Sign Adequacy	24	1.66	0.58	24	2.00	0.88		
Reading Time	24	2.48	0.68	24	2.54	0.72		

to travel to Germantown and he exited at the Damascus ramp, he was charged with a driver error. Three such errors were committed by drivers tested under the "before" condition and one by a subject in the "after" condition. Since the sample size and number of errors were not large enough for adequate analysis, it is not possible to determine if this difference is due to the influence of the signs or simply random variation.

Discussion

In this report the term "information interpretation distance" refers to the distance in advance of the sign where the driver was first able to interpret information displayed on the sign. It is considered to be a direct measure of "sign interpretability" which was defined by Mace, Hostetter, and Seguin (1967) as the extent to which information presented to the driver facilitates ease, speed, and accuracy of interpretation. In this study the assumption was made that the subjects pressed the response button at the point where they first understood the alternative courses of action available to them at the interchange. The relative smaller IID values measured at the advance sign and Germantown exit sign for subjects in the diagrammatic sign group suggest that it took more effort and longer to assimilate information from diagrammatic signs than from conventional signs. In other words, the smaller IID scores indicate that the drivers had to approach the sign at a closer distance before they were willing to report that they understood the information displayed. For the driver traveling 57 miles per hour or 84 feet per second, it took an average of 3.8 seconds longer to interpret the information on the graphic display at the advance sign. The increased velocity noise in the driver's velocity control further suggests that the drivers had more difficulty processing information on the advance sign under the diagrammatic condition.

There were no differences in driver velocity noise or IID between the diagrammatic and conventional sign conditions at the exit direction sign. This was in spite of the fact that under the diagrammatic condition the advance sign and exit direction sign were essentially the same in information format. In other words, the driver in the diagrammatic group was afforded a second opportunity to process the same information display. However, the driver in the conventional condition was required to process new information in a different format at the exit direction sign. In effect this produced a bias in favor of the diagrammatic sign. Regardless of this bias, however, the diagrammatic sign did not enhance driver performance at the exit direction sign.

The significant difference between the groups for the IID measure at the Germantown exit sign was surprising since this sign remained exactly the same under both the conventional and diagrammatic conditions. These results suggest that the driver in the diagrammatic condition was more uncertain of his decision at this location of the interchange and that he had to rely more on information from the Germantown exit sign than did the driver in the conventional condition. Although he was able to retain comparable velocity control, he apparently had to attend longer to the

Germantown exit sign. By the time the driver reaches the vicinity of the Germantown exit sign he has approached a critical point in the decision making process for this interchange. It is at this point that the driver must irrevocably commit himself and finalize his exit decision. Once beyond this point the interchange is very unforgiving of a decision error.

The increase in driver velocity noise in the zone between the Germantown exit sign and Damascus exit sign further suggests that more driver uncertainty was also translated into the gore vicinities under the diagrammatic condition. Normally velocity noise is relatively high in this zone compared to the other zones. There are a variety of reasons for this including the fact that entering traffic from the southbound entrance ramp merges into the traffic stream within this zone. But the important point is that it is apparent from the velocity noise data in Table 4-2 that the diagrammatic signing sequence significantly increased velocity noise beyond what perhaps might be considered as practical tolerance limits.

The results of this study are in basic agreement with work reported elsewhere. Based on his findings in the laboratory, Berger (1970) stated, "The data for the cloverleaf interchange indicates the difficulty of effectively conveying a cloverleaf interchange through the use of graphic guide signs. Performance wise, the modified conventional appears the best." The measure of performance in that study was the percentage of drivers making the proper lane choice. Similar results were obtained by Gordon (1971), reported in Chapter III of this report. In Gordon's study, the subject's response time was measured, as well as his percentage correct lane choices. The response times for the diagrammatic signs at a cloverleaf interchange were significantly longer than the conventional signs. "Implied crossover" graphic designs were used in both the Gordon and Berger studies.

The results of this study coupled with the laboratory findings failed to support the hypothesis that diagrammatic signs enhance driver performance in the vicinity of cloverleaf interchanges. In fact, the evidence suggests that there was an impairment in performance with the graphic information display. It must be pointed out, however, that the results reported here should not be construed as evidence against all types of diagrammatic signs. This study was specifically concerned with a cloverleaf interchange that had excellent site distance using a graphic component described as an "implied crossover." In addition, this study examined the driver's initial response to diagrammatic signs. It may be argued that prolonged exposure and experience with graphic guide signs at a cloverleaf interchange could mitigate the performance degradation. However, laboratory work reported by Gordon (1971) suggests that in spite of a large number of practice trials with diagrammatic signs, subjects in the laboratory always perform better under the conventional signing conditions.

Summary

The study was designed to assess the individual driver's initial response to diagrammatic signs at a cloverleaf interchange. An instrumented vehicle was used to measure the driver's vehicular velocity noise and information interpretation distance under field conditions. The graphic component used in the diagrammatic information display was an "implied crossover." The results suggest that on the initial encounter with diagrammatic signs there is a degradation in information processing and vehicular velocity control. Not only was there impairment in information processing and velocity control at the advance sign, but more driver uncertainty was translated into critical decision commitment points located in the vicinity of the exit gore areas. No difference was found between the diagrammatic and conventional signing conditions in driver's responses to three questions on confidence in exit choice, signing adequacy and availability of reading time. Similarly, driver preference for conventional versus diagrammatic signs were equally divided between the two sign types.

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Chapter V

INSTRUMENTED VEHICLE EVALUATION OF DIAGRAMMATIC GUIDE SIGNS USING AN IN-VEHICLE SIGN SIMULATION TECHNIQUE

One of the primary purposes of this investigation was to study the in-vehicle sign simulation technique as a means of evaluating highway guide signs. An in-vehicle information display system was used to present sign images to drivers as they drove an instrumented vehicle under real traffic conditions. Presentation of sign stimulus material was projected on a display screen located in the upper portion of the vehicle's front windshield. Sign presentations were programmed to the test driver inside the vehicle much in the same way real signs mounted on the road are normally programmed to the motorist. Drivers were required to negotiate real interchanges open to normal traffic operations in order to seek out prescribed destinations.

At the time this study was initiated, it was unknown whether or not drivers would be able to carry out route guidance tasks using guide signs presented on an in-vehicle display. Previous work using in-vehicle information displays had not attempted to simulate the presentation of actual highway guide signs inside an instrumented vehicle. Much of the work in the past had used in-vehicle displays to present command instructions or auxiliary types of preparatory signals to the driver. The ERGS display (Eberhard, 1969) as well as the display used by Mace, Hostetter, and Seguin (1967) are examples where command inputs were given to the driver by means of an in-vehicle display. No previous attempts had been made to simulate overhead or shoulder mounted signing inside a vehicle moving on the highway.

In order to evaluate the in-vehicle sign simulation technique, it was necessary to compare instrumented vehicle results using regular road mounted signs with results obtained using signs presented on a display inside the vehicle. To do this, an interchange was selected which was similar to the one used in previous instrumented vehicle research conducted at Germantown as reported in Chapter IV of this report. The same sign designs employed in the Germantown study were used again in conjunction with the in-vehicle information display technique, thus permitting a direct comparison between "on-road" and "in-vehicle" sign evaluation techniques.

In all, two types of interchanges were negotiated by test drivers as they sought prescribed destinations. In addition to a cloverleaf interchange, subject drivers were required to make an exiting decision at a single right hand exit, similar to the type encountered at diamond interchanges. Therefore, another primary objective in the investigation was to evaluate diagrammatic sign designs that might be used for diamond interchanges. At the time this study was conducted, diagrammatic signs for diamond interchanges had not before been evaluated in the field in an instrumented vehicle study.

The measures recorded in the study included, (1) driver information interpretation time (IIT) which was comparable to the driver information interpretation distance (IID) measure used in the Germantown study, (2) average vehicular velocity, (3) velocity noise (velocity variance) recorded during sign influence periods, (4) accelerator pedal movement during sign influence periods, and (5) driver exiting errors.

It was conceptualized that diagrammatic guide signs would have an influence on driver performance as measured in an instrumented vehicle using an in-vehicle sign simulation technique. The experimental hypothesis was that diagrammatic signs serving cloverleaf and diamond interchanges would affect driver information interpretation time, average driver velocity, velocity noise, accelerator pedal movement, and driver exiting errors.

Method

Subjects

A total of 58 subjects, 35 males and 23 females, were tested in the study. Subjects were randomly assigned to either the diagrammatic or conventional signing condition. The 16 males and 13 females assigned to the diagrammatic signing group ranged in age from 18 to 28 years and had a mean age of 21 years. Subjects in the conventional signing group had a mean age of 20 years and ranged in age from 18 to 23 years. There were 19 males and 10 females in this group. The average number of years driving experience was 4 and 5 for the conventional and diagrammatic signing groups respectively. All the subjects tested possessed valid drivers licenses and consisted of volunteers from the metropolitan Washington, D.C. area. Most of the volunteers were students attending area colleges and universities and each was paid $10 to participate in the study.

Instrumented Vehicle

A 1966, 8-cylinder Chevrolet was instrumented and used in the investigation. A picture of this vehicle was presented in Chapter IV in Figure 4-3. The vehicle was equipped with steel belted 4-ply radial tires, power steering, automatic transmission, air conditioning, and power brakes. Instrumentation components were mounted in both the back and front seat area of the vehicle. Mounted on the dash board on the passenger side was a velocity/distance measuring device manufactured by Zeronic Engineering Company (Figure 5-1). It measured the velocity of the test vehicle in 1/10ths of a mile per hour and the distance traversed to the nearest 1/100ths of a mile. An experimenter's control box was positioned on the front seat between the test driver and the experimenter (Figure 5-1). Buttons on the control box were used to present experimental test signs to the driver as well as to record the subject's response latencies or information interpretation times (IIT). A digital readout of subject IIT times was displayed to the experimenter on the front of the control box panel. Also mounted in the front seat area of the vehicle was a small 3.5 x 8 inch screen which was positioned along the upper edge of the front windshield next to the rear view mirror (Figure 5-1). This screen was used for the projection of sign stimuli to the driver. The image of a diagrammatic sign can be seen on the screen in Figure 5-1.

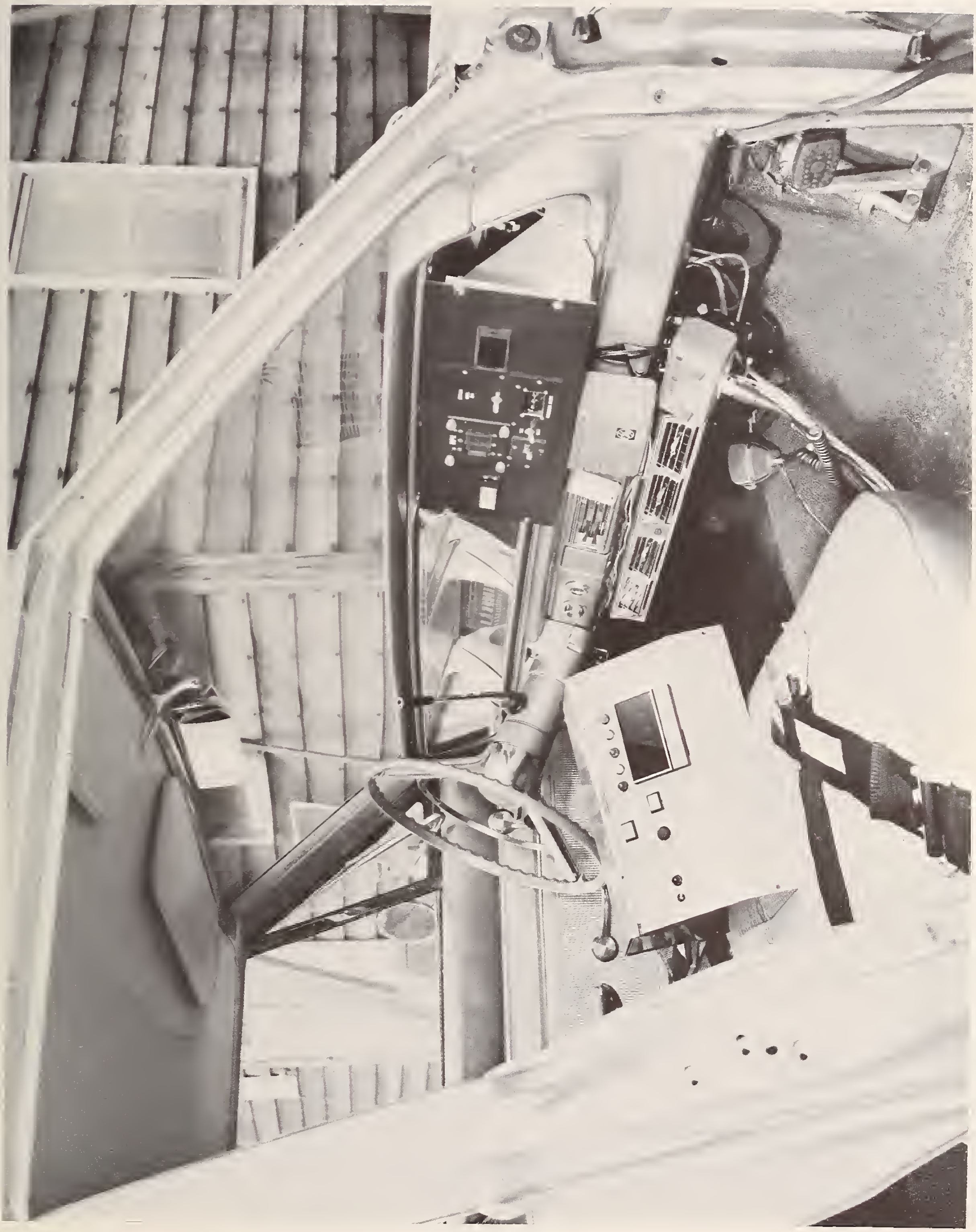

Figure 5-1. Picture of front seat area of instrumented vehicle.

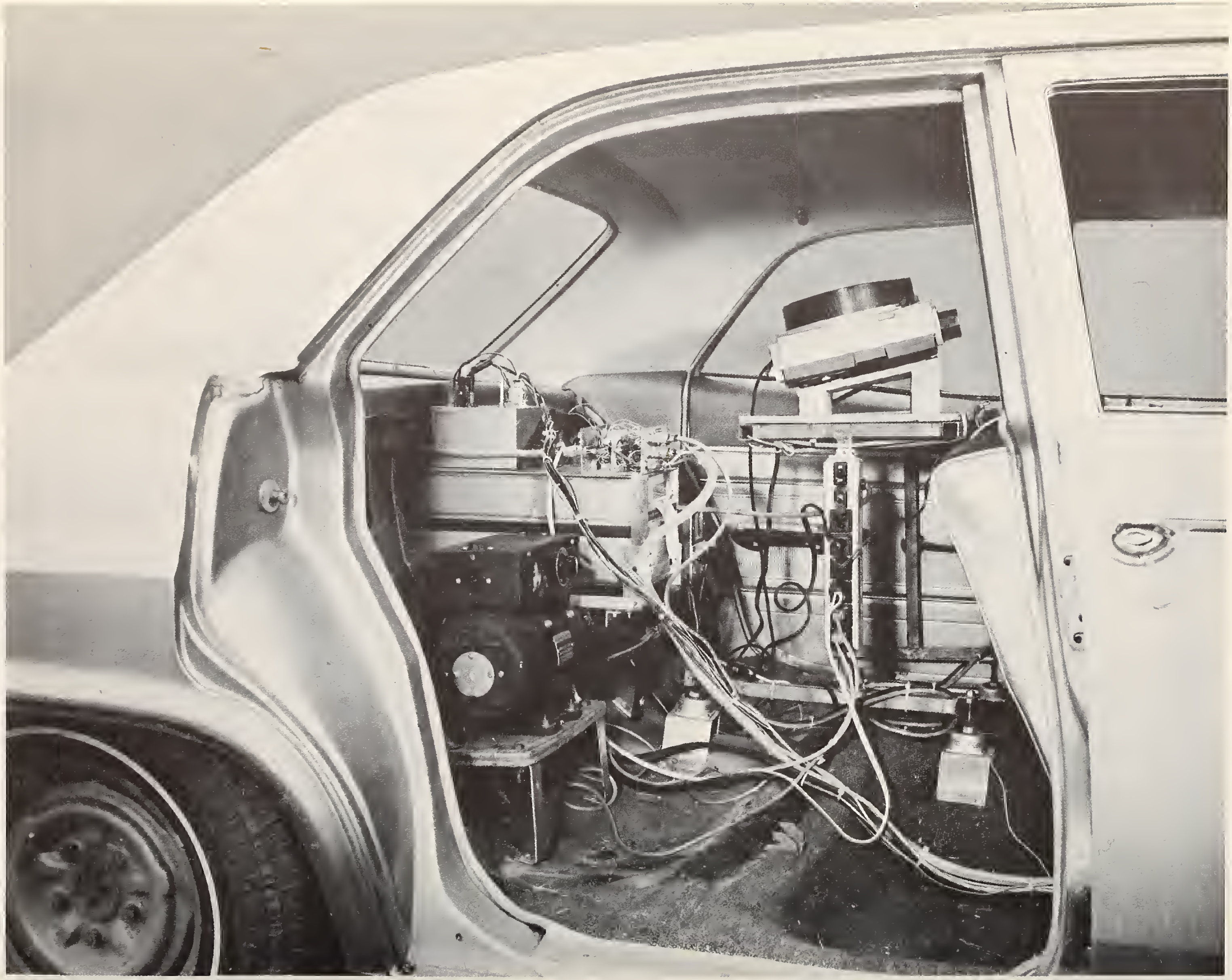

Figure 5-2. View of back seat area of test vehicle.

Figure 5-3. View of Projector and Sign Image

Presented in Figure 5-2 is a view of the back seat area of the test vehicle. A 35 mm Kodak Carousal projector was mounted on a stand in back and to the right of the driver. It was used to present sign images to the driver. The platform was shock mounted so that there was a minimum amount of vibration in the sign image when the car was in motion. The inverter and digital recorder can be seen on the left of this figure. The inverter was manufactured by Carter Company and provided 115 volts at 60 cycles per second. It was the source of power for the recorder, Zeronic velocity/distance equipment, and 35 mm projector. The digital recorder was a 10 channel, paper print output, Systron-Donner model. A view of the projector and projected sign image are presented in Figure 5-3. Also, a front view of the Zeronic velocity/distance measuring device can be seen on the right of this figure.

Procedure

Data were gathered during the months of December 1971 and January and February 1972. Subjects reported to Fairbank Highway Research Station and filled out a brief biographical data sheet before they were dispatched on the test drive. The first part of the test procedure consisted of a familiarization drive where the subject drove the vehicle around the research station compound area, testing the brakes and acceleration characteristics of the vehicle. As soon as the driver indicated that he felt comfortable with the vehicle, the experimenter asked the subject to stop the car. Then he gave the following oral instructions:

> "I am going to present some slides of highway guide signs on this small screen (experimenter pointed to screen). Can you clearly see the signs? Ordinarily the driver seeks his destination by using the guide signs mounted along the highway. In this experiment I would like for you to drive me to different destinations, using the guide signs presented on the screen. Since your destinations will be fictitious places, information pertaining to them will not be available on the signs along the road. Your only source of information will be what I present to you on the screen. In other words, you will ignore the guide signs along the highway that you commonly use and you will rely on the route guidance information that I present to you in the car. Let me give you an example. (Experimenter put a sign on the screen). Let's assume that you have been instructed to drive me to Banning. Since Banning doesn't really exist you will have to use signs like the one now on the screen. As you approach the Banning interchange a 1 mile advance sign will be presented on the screen. When you have read and understand the information on the sign, I want you to push the horn rim button (experimenter pointed to horn rim button). When you press the button, the image of the sign will be removed from the screen. You may leave the slide on as long as it takes you to understand the information. However, as soon as you understand the

information, I want you to press the button. When you arrive at the interchange I also want you to drive through the interchange as if the fictitious destination really exists and you are going there. In other words, if it is appropriate for you to make an exit in order to reach your destination, I want you to perform the exit maneuver. Do you have any questions? You will now have an opportunity to practice using the display. The first interchange you drive through will be a practice interchange so if at any time you have questions concerning what you are supposed to do at the first interchange, feel free to ask them."

Presented in Figures 5-4 and 5-5 is a map of the test route with locations of the interchanges and presentation points for the experimental test signs. The test route was located on a portion of the George Washington Memorial Parkway in Virginia near Fairbank Highway Research Station. Test drivers were dispatched from the grounds of the research station and first negotiated what was designated as a practice interchange. This was a single exit to the right into the Turkey Run recreation area shown on the upper portion of the map.

Practice Interchange. After the experimenter gave the subject the instructions above, he directed him to the northbound portion of the G. W. Parkway and informed him that his destination was a place called Banning. Soon after the vehicle was traveling northbound on the Parkway, the experimenter presented the practice test sign shown in either Figure 5-4 or Figure 5-5, Picture A, depending upon which experimental group the driver had been assigned. The subject was told that his proper response was to exit.

Upon entering the Turkey Run recreation area, the subject was asked to bring the vehicle to a stop. At this time, the experimenter again answered any questions, turned on the recorder and directed the driver to the southbound portion of the G.W. Parkway. He informed the subject that his destination was still Banning and that he would be traveling on fictitious Interstate 34 to get there.

Cloverleaf Interchange. After leaving the Turkey Run recreation area, the driver proceeded past the exit to the research station and continued southbound on the parkway. Approximately 1 mile prior to the McLean cloverleaf interchange, the 1 mile advance sign shown in Picture C in either Figure 5-4 or Figure 5-5 was presented. The experimenter used painted stakes unobtrusively positioned along the edge of the highway as cues for the sign presentations. As soon as the subject pressed his horn button, removing the sign from the screen, the experimenter recorded the subject's information interpretation time (IIT) displayed on the front of the control box. Approximately 1/2 mile in advance of the interchange, the exit direction sign shown in Picture D of the figures was presented using the same procedure.

No exit signs were presented to the driver on the in-vehicle display. In other words the driver was forced to base his exiting decision at the interchange on information that was made available to him on the 1 mile and 1/2 mile signs.

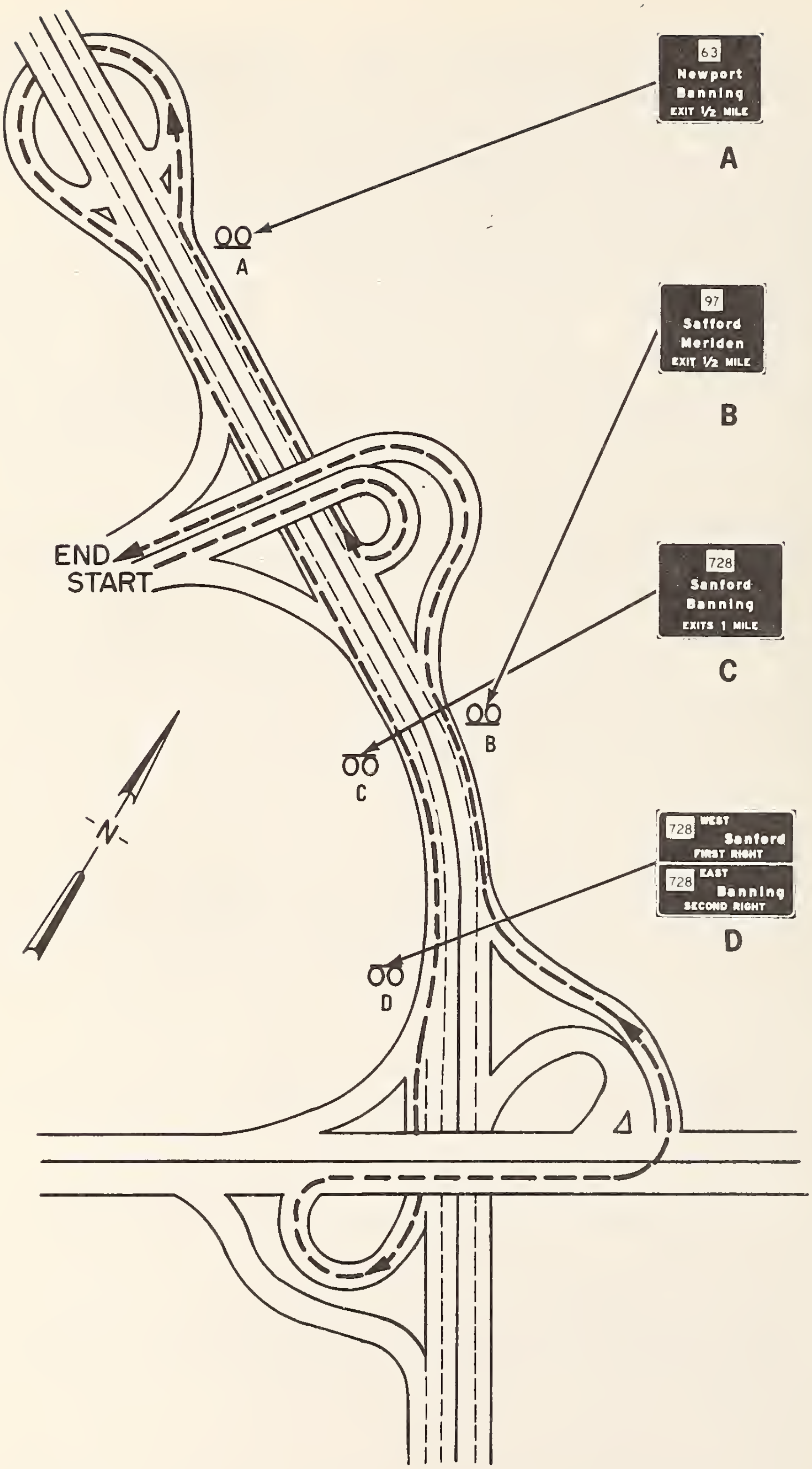

Figure 5-4. Test route interchanges and signs for conventional signing conditions.

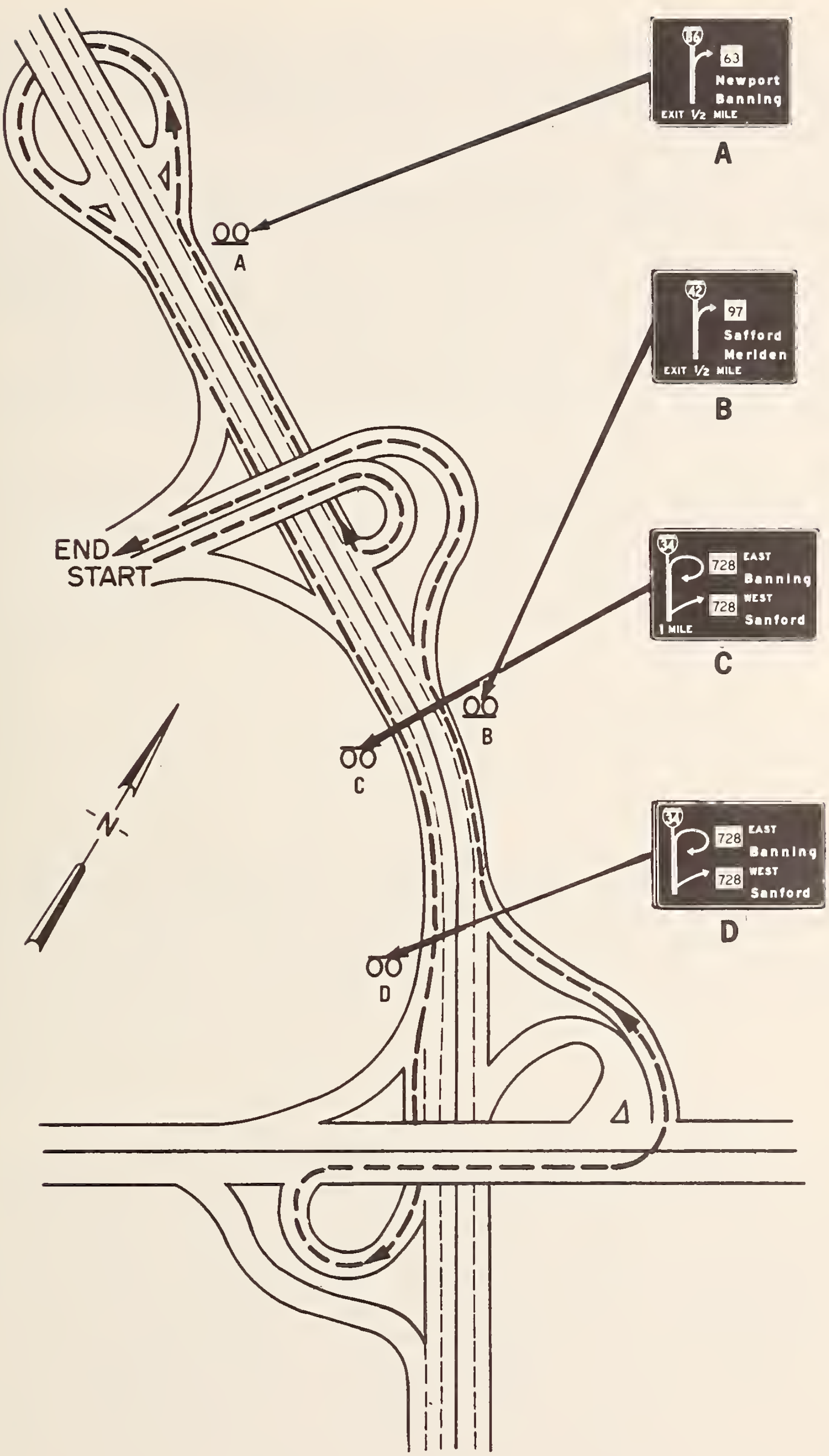

Figure 5-5. Test route interchanges and signs for diagrammatic signing conditions.

His experience at the practice interchange prepared him for this procedure. It should also be noted that the sight distance was restricted for this interchange. Drivers were unable to view the second exit ramp prior to the interchange's choice point.

It can be seen in Figure 5-5 that the graphic design chosen for diagrammatic signs was the "implied crossover" type. The same design was used in the Germantown study reported in Chapter IV. As in the Germantown study the diagrammatic exit direction sign differed from the diagrammatic 1 mile advance sign only in that the word "1 mile" was missing from the exit direction sign. These graphic designs also denote a lane drop situation at the second exit. Physically there were two lanes available to through traveling motorists, but the pavement markings indicated a lane drop.

Diamond Interchange. Upon exiting at the cloverleaf interchange, the correct exit being at the second ramp, the driver was then instructed to turn around and drive northbound on the G.W. Parkway. He was informed that his next destination was a place called Safford and that he was traveling on fictitious Interstate 42. The next sign presentation was approximately 1/2 mile in advance of the exit to the research station. The sign presented to the drivers at this point is shown in Picture B of the figures. Again, the driver was not presented an exit sign at this interchange. If the subject performed properly, he took the exit and returned to the research station.

Measures

The information interpretation time (IIT) measure was defined as the length of time required by the driver to read and interpret guide sign information presented on the display. It was measured directly by a timer which was activated by the onset of the projector and deactivated by the subject's response button. The experimenter read and recorded the IIT values from the control box digital display after each sign presentation.

An average vehicular velocity score and velocity noise score were determined for each subject for each of the three sign influence periods as well as for two baseline periods. The sign influence period was arbitrarily defined as the 14 second period immediately following the presentation of the test sign. It was designated at 14 seconds so that it would include the IIT period for most drivers as well as any changes in driver performance that might take place immediately following the IIT period. Two baseline periods, free from the influence of guide signs, were similarly defined. One baseline period was located prior to the cloverleaf 1 mile advance sign and the other was located prior to the diamond 1/2 mile advance sign. A velocity noise score was computed for each subject for each of the sign influence and baseline periods. Velocity noise was defined as the standard deviation about the average vehicular velocity score.

Accelerator pedal movement was recorded for each subject for each of the sign influence and baseline periods. It was measured on an interval scale ranging from 02 to 80 with 80 representing the maximum displacement of the accelerator pedal and 02 representing zero pedal displacement. Driver exiting errors were recorded when subjects failed to take the second exit at the cloverleaf or continued driving beyond the exit ramp at the diamond interchange.

Data Recording

Velocity of the vehicle, distance traversed, and accelerator pedal movement data were continuously recorded and printed on paper tape at a sampling rate of 1 per second. In addition, the experimenter marked the tape by means of a button on the control box when sign presentations were made to the driver. He also marked the tape when the moving vehicle was aligned with important physical land marks along the test route such as gore areas or yield signs. The tape was also marked when the subject depressed his response button mounted in the rim of the steering wheel. He used this button to indicate when he had completed processing the information on the sign.

Results

There were significant differences between the conventional and the diagrammatic test signs on the driver information interpretation time (IIT) measure. Shown in Table 5-1 are the means and standard deviations for IIT values for each of the test signs employed in the study. It can be seen from the table that the mean IIT value for the diagrammatic one-mile advance sign was almost twice as long as that for the conventional sign at the cloverleaf interchange. This result was significant beyond the .05 level. On the other hand, the difference between the experimental signing conditions at the cloverleaf 1/2 mile exit direction sign was not significant. The results for the diamond advance sign, however, indicated that there was again a significant increase in mean IIT values under the diagrammatic condition.

Presented in Table 5-2 are the means, standard deviations, and T ratios for the average vehicular velocity scores recorded during sign influence and base line periods. Comparison between the signing conditions for each of the base line and sign periods indicate that there were no significant differences between conditions in the average vehicular velocity maintained by the driver. It is apparent from the table that the average velocity maintained throughout the test drive during the base line periods as well as during the sign influence periods was extremely stable. The magnitude of the overall range for the values in the table is only 6.3 miles per hour.

Vehicular velocity noise scores were also computed for each driver during each of the sign influence and base line periods. These data are

Table 5-1

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR DRIVER

INFORMATION INTERPRETATION TIME (IIT) FOR EACH SIGNING CONDITION

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
	N	Mean (Sec.)	SD (Sec.)	N	Mean (Sec.)	SD (Sec.)	T Ratio	Sign Level
Cloverleaf Advance Sign	26	4.4	1.8	29	8.8	3.7	5.768	$P < .05$
Cloverleaf Exit Dir. Sign	28	6.0	2.2	27	7.3	4.8	1.362	NS
Diamond Advance Sign	29	3.9	1.2	26	5.8	2.4	3.589	$P < .05$

Table 5-2

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR AVERAGE

VEHICULAR VELOCITY RECORDED DURING SIGN INFLUENCE PERIODS

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	T Ratio	Sign Level
Cloverleaf Baseline	19	46.5	3.4	18	48.1	4.3	1.281	NS
Cloverleaf Advance Sign	17	49.3	3.6	17	50.0	4.3	0.554	NS
Cloverleaf Exit Dir. Sign	17	46.9	3.5	16	46.4	4.1	0.347	NS
Diamond Baseline	15	52.7	3.8	17	52.2	3.9	0.368	NS
Diamond Advance Sign	14	50.9	3.7	14	51.6	3.7	0.536	NS

presented on Table 5-3. Again, none of the differences between signing conditions were statistically significant. Another measure that was recorded in the study was accelerator pedal movement. As can be seen in Table 5-4. the comparison between conventional and diagrammatic signs indicated that there was only one comparison which reached statistical significance and that was for the cloverleaf 1 mile advance sign. The mean values indicate that there was a decrease in accelerator pedal displacement while drivers processed information on the diagrammatic sign. The frequency of exiting errors was too small in number for statistical analysis.

Discussion

Overall, the most significant differences between the conventional and diagrammatic signs were found for the driver information interpretation time (IIT) measure. These results are consistent with the findings in the previous experiment conducted at Germantown, reported in Chapter IV, using similar signs mounted on the highway. Results at Germantown were based upon the information interpretation distance (IID) measure which was defined as the distance in front of a sign where the driver indicated he understood the information display. The average IIT signing difference values were derived from the average IID signing difference quantities recorded in the Germantown study since the average vehicular velocities were known. An examination of the 1 mile advance sign and exit direction sign IIT values for the cloverleaf interchange presented in Figure 5-6 reveals that the on-road and in-vehicle difference was on the order of .61 seconds at the 1 mile advance sign. This difference was not statistically significant based upon the Cochran and Cox approximate T test with alpha set at the .05 level. The comparison between the in-vehicle and on-road findings for the exit direction sign shows a difference magnitude of .70 seconds. Again this difference was not significant based upon the T test. The in-vehicle IIT values were consistently longer than the on-road values. However, these values were extremely close and would be almost identical if the lag time between projector activation and the appearance of a sign image on the screen was taken into consideration. This lag time was approximately 0.5 seconds. Since IIT values for signs displayed on the road are practically equivalent to IIT values for identical signs displayed inside the vehicle, it is concluded that the in-vehicle information display technique can be used effectively to evaluate highway guide signs.

The in-vehicle sign simulation technique used in this study provides a research tool not previously available to sign researchers. In the past the sign researcher has had two basic techniques available to him, the before-after type field study and the laboratory study. Both of these have limitations and virtues. Although field studies by definition are conducted under realistic conditions which serves to enhance the researcher's confidence in the applicability of the findings, never-the-less they have serious limitations. These limitations include lack of experimental control over confounding

Table 5-3

MEANS, STANDARD DEVIATIONS AND T RATIOS FOR VEHICULAR

VELOCITY NOISE VALUES RECORDED DURING SIGN INFLUENCE PERIODS

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	T Ratio	Sign Level
Cloverleaf Baseline	19	1.9	2.3	18	1.2	0.8	1.186	NS
Cloverleaf Advance Sign	17	1.6	1.1	17	1.4	0.8	0.462	NS
Cloverleaf Exit Dir. Sign	17	1.2	0.5	16	1.6	1.3	1.084	NS
Diamond Baseline	15	1.7	1.5	17	1.6	0.7	0.388	NS
Diamond Advance Sign	14	1.7	1.6	14	1.2	0.6	1.149	NS

Table 5-4

MEANS, STANDARD DEVIATIONS AND T RATIOS FOR ACCELERATOR

PEDAL MOVEMENT VALUES RECORDED DURING SIGN INFLUENCE PERIODS

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
	N	Mean	SD	N	Mean	SD	T Ratio	Sign Level
Cloverleaf Baseline	16	23.2	3.0	10	25.4	6.5	0.969	NS
Cloverleaf Advance Sign	20	17.2	3.5	19	14.3	4.9	2.132	P <.05
Cloverleaf Exit Dir. Sign	18	16.9	3.4	16	16.0	3.5	0.740	NS
Diamond Baseline	16	12.6	3.9	18	11.9	3.2	0.525	NS
Diamond Advance Sign	17	8.5	2.4	19	7.4	2.3	1.315	NS

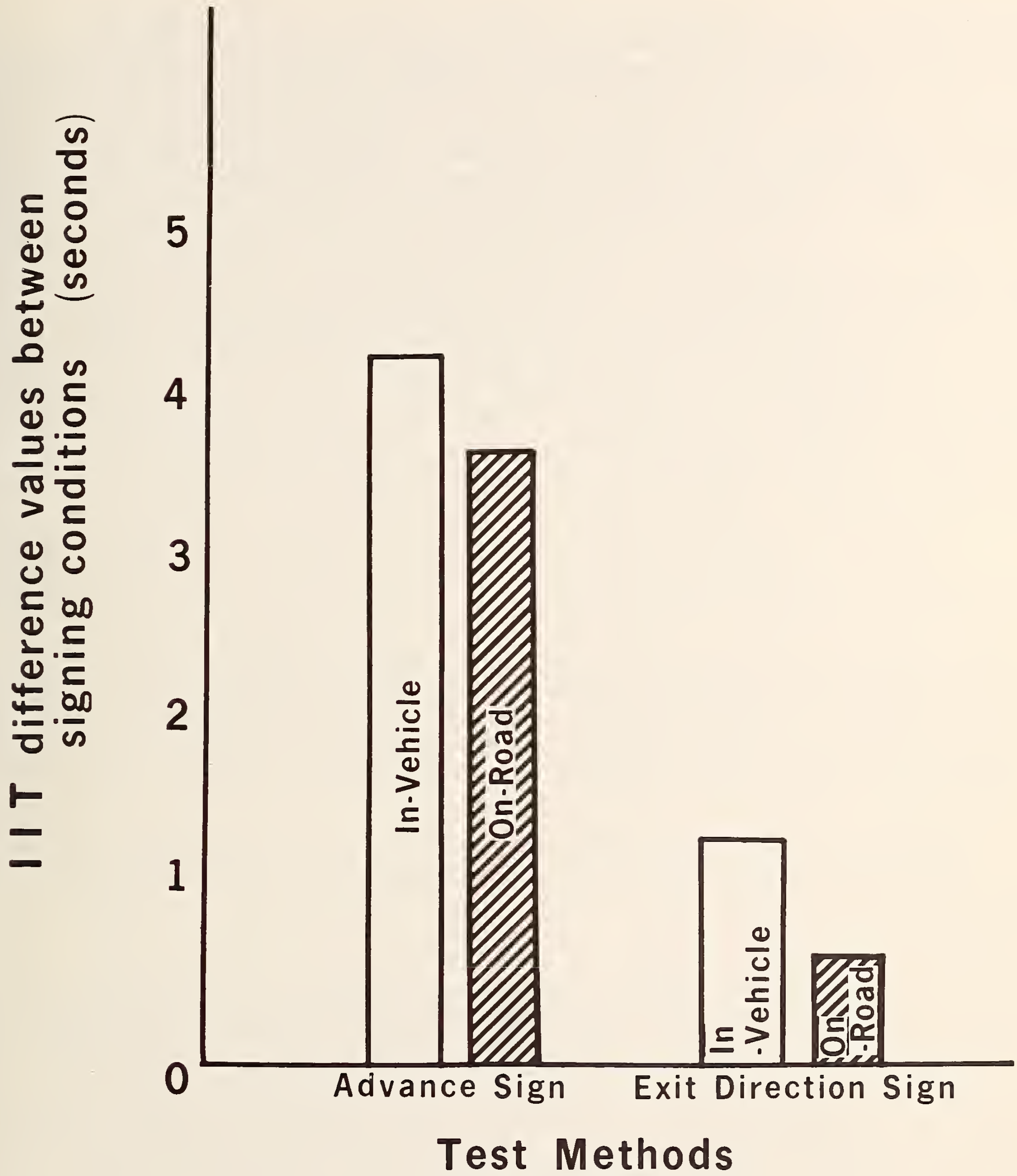

Figure 5-6. Differences between experimental signing conditions as a function of test methods.

variables and loss of freedom in the number and types of sign variables that can be investigated. Moreover, cost and logistic problems make them inefficient and difficult to conduct. Laboratory studies, on the other hand, also have limitations. The most serious one being the problem of validity. It is not always clear what laboratory results can be generalized to the highway environment. But laboratory studies do permit precise experimental control over confounding variables and, moreover, a large number of different types of sign variables can be quickly and efficiently investigated.

The in-vehicle sign simulation technique has proven to be a very effective guide sign research tool. Of course it will have to be scrutinized and further validated before its potential can be fully assessed. However, at this point in time it is clear that this technique exhibits the virtues of both the field and laboratory techniques while at the same time it excludes many of their limitations. With the in-vehicle sign simulation technique the researcher has control over possible confounding variables and can efficiently investigate many types of sign variables. At the same time, he is afforded the reality of the normal driving environment, since test drivers drive the instrumented vehicle through real interchanges, seeking out destination.

In general the drivers tested in the study were able to use the in-vehicle information display with little difficulty. It should be pointed out, however, that most of the test drivers were young adults and probably above average in their ability to adapt to novel situations. This technique may not be suitable for testing drivers from advanced age groups. For one thing, it would be expected that aged drivers would have visual accommodation problems with the in-vehicle display. That is, they would have difficulty shifting their visual focus from the display to events on the road. Moreover, the advanced age driver may find it difficult to adapt to the novel testing situation.

Examination of the velocity data in Tables 5-2 and 5-3 indicates that none of the signing differences were statistically significant. This was true for both average velocity and velocity noise measures recorded during the sign influence periods. The findings for average vehicular velocity were consistent with the data recorded in the Germantown study reported in Chapter IV (see Table 4-1). However, velocity noise was a sensitive measure in the Germantown study using signs mounted on the road in that it revealed significant differences between the signing conditions (see Table 4-2). In the study reported here, however, velocity noise was not a discriminating measure. The most reasonable explanation for this is that the in-vehicle display permits the driver to maintain control over information processing time by means of a push button. In the Germantown study or in normal roadway situations the driver maintains control over information processing time by manipulating the velocity of his vehicle.

The data for the accelerator pedal movement measure presented in Table 5-4 indicated statistical significance between experimental signs for the cloverleaf advance sign. There was a reduction in displacement of the pedal with the diagrammatic sign. This measure was used because it appeared reasonable that low levels of driver uncertainty in the presence of information that was difficult to interpret might not be translated into vehicular velocity changes but would be reflected in driver accelerator pedal movement. However, in view of the independent relationship between information presentation time and vehicular velocity in this study, the accelerator pedal results are probably due to the driver's stereotyped response to let up on the pedal in the face of uncertainty associated with the diagrammatic sign.

The number of discrete exiting errors committed by the test drivers does not appear to be significant across signing conditions. However, since a statistical analysis was not possible because of the limited amount of data, it cannot be determined whether or not the differences were due to random variation or the influence of the signing conditions. The number of errors committed by drivers in this study was almost double the number of errors committed in the Germantown study reported in Chapter IV. This is no doubt due to the fact that drivers in this study were not afforded the opportunity to use exit signs. The driver had to base his exit decision only on information gleaned from the advance signs. This was of course not the case in the Germantown study where drivers were able to use exit signs mounted in close proximity to the exit ramps.

In conclusion, the results of this study suggest that the diagrammatic guide signs did not facilitate driver information processing at the cloverleaf and diamond advance guide signs. In fact the data indicate some impairment in driver performance with the diagrammatic sign. These findings were consistent with previous work where test signs serving a cloverleaf interchange were mounted on the road and evaluated with an instrumented vehicle. Furthermore, the results indicated that the in-vehicle sign simulation technique can be effectively employed with young adult test drivers and that it offers the researcher several advantages in comparison to other methodological approaches.

Summary

The objective of this investigation was to evaluate diagrammatic guide signs for use at cloverleaf and diamond interchanges and to study the in-vehicle sign simulation technique as a means for evaluating guide signs. An in-vehicle display was used to present conventional and diagrammatic guide signs to test drivers as they negotiated highway interchanges seeking out destinations. Measures of driver performance consisted of information interpretation time, average vehicular velocity, velocity noise, accelerator pedal movement, and driver exiting errors. The results indicated that there was a significant increase in driver information interpretation time at the cloverleaf and diamond advance signs under the diagrammatic condition. There was a decrease in accelerator pedal displacement for the diagrammatic advance sign at the cloverleaf interchange. The other measures, average velocity, velocity noise and number of exiting errors, did not discriminate between signing conditions. It was

concluded that the diagrammatic guide signs did not facilitate driver information processing at the interchanges tested in the study and that the in-vehicle sign simulation technique is an effective sign research tool.

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Chapter VI

DIAGRAMMATIC GUIDE SIGNS AND DRIVER PERFORMANCE AT COMPLEX INTERCHANGES

The research reported here was the final and most extensive investigation conducted in the series of controlled field or instrumented vehicle studies under the diagrammatic signing research program. Its purpose was to examine the influence of diagrammatic versus conventional highway guide signs on driver performance at complex interchanges. Within this context, questions pertaining to the efficacy of diagrammatic signs at interchanges with considerable variation in geometrics were addressed. In addition, questions concerning sign deployment were also considered.

The scope of the study, however, was restricted in terms of the number and types of diagrammatic sign design variables and deployment variables investigated. Diagrammatic sign formats were developed on the basis of results from previous work. Prior research indicated that simple graphic designs were superior to complex designs and that designs with intersecting components or implied crossover elements were confusing to many motorists. Therefore, an effort was made to design diagrammatic signs which depicted simple graphic components. No graphic designs employing crossing elements or implied crossing components were used in the study. Moreover, sign deployment conditions were limited to those commensurate with the current signing standards as outlined in the Manual on Uniform Traffic Control Devices (MUTCD).

The study employed an independent groups research design using three groups. One group of drivers was tested with conventional signs and two groups were tested with diagrammatic signs. The two diagrammatic sign conditions differed in that one group used only diagrammatic signs deployed at the exit direction sign location whereas the other group used diagrammatic signs deployed at both the advance and exit direction sign locations. Also, the second diagrammatic group used diagrammatic exit signs at some test interchanges.

The investigative method employed the in-vehicle sign simulation technique described in Chapter V. Drivers were tested individually and were required to drive the instrumented vehicle under real traffic conditions while they searched out prescribed destinations. Test signs were programmed to the driver on the instrumented vehicle's in-vehicle display. Drivers negotiated 10 test interchanges, 5 of which required an exiting maneuver. The interchanges requiring an exiting maneuver exhibited a variety of geometrics consisting of (1) single exit right, (2) double lane drop with a split ramp (multiple split ramp), (3) collector distributor, (4) left exit, and (5) cloverleaf. The test route was located in northern Virginia and involved the use of Capital Beltway Exit 4 (I-495 and I-95) and its surrounding interchanges.

The independent variables, sign type (conventional versus diagrammatic), type of interchange geometry, and sign deployment location, were studied as a function of driver performance. There were four kinds of driver performance measures: (1) information interpretation time (IIT) which was measured directly for each sign, (2) velocity control as measured in terms of average vehicular velocity and velocity variability or velocity noise, (3) vehicular maneuvers consisting of lane changes and erratic maneuvers (erratic maneuvers were defined as vehicular excursions across physical or theoretical gore areas), and (4) driver exiting errors based upon driver success or failure to exit properly in order to reach designated target destinations. The primary conceptual hypothesis was that diagrammatic versus conventional guide signs would influence driver exiting performance at interchanges varying in geometri complexity. Furthermore, it was hypothesized that diagrammatic sign deployment at the exit direction sign location versus deployment at both the advance and exit direction sign locations would affect driver exiting performance. The only directional experimental hypothesis in the study concerned the IIT measure. Here it was hypothesized that diagrammatic guide signs would increase driver information interpretation time.

Method

Subjects

Test drivers were male and female volunteers who possessed valid drivers' licenses and had prior driving experience on the Interstate highway system. Each subject was paid to participate in the study. Most of the volunteers were students attending the University of Maryland in College Park, Maryland. Non-student participants either worked or lived in the College Park vicinity. Volunteers were recruited from Maryland so that there would be small likelihood that they would be familiar with the test route and interchanges.

The sample of test subjects was divided into three groups. One group was tested under conventional signing conditions whereas the other two groups were tested with diagrammatic guide signs. There were 26 subjects tested in the Conventional group, 29 in the Diagrammatic I group and 33 in the Diagrammatic II group. The age means and standard deviations for subjects in the Conventional, Diagrammatic I, and Diagrammatic II groups were 26 (SD = 4.7), 24 (SD = 3.3), and 24 (SD = 3.1) years, respectively. It can be seen in Table 6-1 that there was a high proportion of males compared to females in each of the three groups. However, Z values for the comparisons between groups on the basis of relative proportions of males and females indicated that there were no statistical differences between the three groups. Also presented in Table 6-1 are the relative proportions of subjects exhibiting different levels of familiarity with the test route and interchanges. Subjects were categorized into four levels of familiarity. Levels ranged from subjects who had never driven the test route before to those who had driven it more than five times in the past month. It is apparent from Table 6-1 that the three groups were well matched on the route familiarity characteristic.

Experimental Design

The experimental design employed three independent groups. Groups were defined in terms of the types of signs used by the drivers along the test route. The Conventional signing group utilized only conventional type

Table 6-1

SUMMARY OF SUBJECT SAMPLE SEX AND TEST ROUTE FAMILIARITY CHARACTERISTICS

Sample Characteristics	(A) Conv. N	(A) Conv. (Prop)	(B) Diag. I N	(B) Diag. I (Prop)	(C) Diag. II N	(C) Diag. II (Prop)	Z Value A-B	Z Value A-C	Z Value B-C
Females	3	.115	7	.241	10	.303	1.210	1.726	0.543
Males	23	.885	22	.759	23	.697	1.210	1.726	0.543
Familiarity: Never	11	.423	14	.483	17	.515	0.696	0.703	0.026
Familiarity: 1-2 Past Year	9	.346	11	.379	9	.273	0.351	0.711	1.101
Familiarity: 1 Past Month	4	.154	2	.069	6	.182	0.969	0.218	1.221
Familiarity: 5 Past Month	2	.077	2	.069	1	.030	0.113	0.809	0.708

signs throughout the test drive. Subjects in the Diagrammatic I group were required to use diagrammatic signs presented only at the exit direction location, one-half mile prior to the interchange proper. The Diagrammatic II group used diagrammatic signs presented at both the 1 mile advance sign and the 1/2 mile exit direction signs. In addition, diagrammatic exit signs were presented at some of the interchanges used by the Diagrammatic II group.

Instrumented Vehicle

The 1966, 8-cylinder Chevrolet used in the previous work reported in Chapters IV and V was used in this investigation. However several changes were made to the instrumentation package in order to meet the requirements of the study reported here. A picture of the vehicle's exterior was presented in Chapter IV in Figure 4-3. The vehicle was equipped with steel belted 4-ply radial tires, power steering, automatic transmission, air conditioning, and power brakes. Instrumentation components were mounted in both the back and front seat area of the vehicle. Mounted on the dashboard on the passenger side was the Zeronic velocity/distance measuring device (Figure 6-1). It measured the velocity of the vehicle to the nearest 0.1 of a mile per hour and the distance traversed to the nearest .01 of a mile at a sampling rate of 1 per second.

The experimenter's control box was a small hand held unit with two push buttons. It is shown resting on the front seat in Figure 6-1. One button on the control box was used to present the experimental test signs to the driver. A 1 kc tone, clearly audible to the driver, sounded each time a test sign was presented. The other button was used to override the subject's response button to remove a sign image from the screen, should this become necessary. The subject's response button was contained in the horn rim on the steering wheel. Depression of the horn rim by the subject removed the sign image from the screen without sounding the horn.

Also mounted in the front seat area of the vehicle was the screen for the sign display. It was 3.0 inches in height and 11.25 inches in width. It was made of white cardboard and was positioned along the upper edge of the front windshield next to the driver's side of the rear view mirror. A 2.5 inch light shroud extended over the top of the screen. The screen was used for the projection of test signs to the driver. The image of a conventional sign can be seen on the screen in Figure 6-2. The distance between the driver's eye and screen was approximately 19-20 inches. Capital letters on the sign images subtended a visual angle of approximately 48-50 minutes of arc.

Presented in Figure 6-3 is a view of the back seat area of the test vehicle. The sign images were projected by a 35 mm Kodak Ektagraphic AF2 slide projector. The projector's optical system utilized a 300 watt, 24 volt dc lamp and Buehl 4.0 inch f/2.8 lens. The projector was positioned on a shock mounted stand in back and to the right of the driver. The shocks on the stand minimized the vibration of the sign image when the vehicle was in motion.

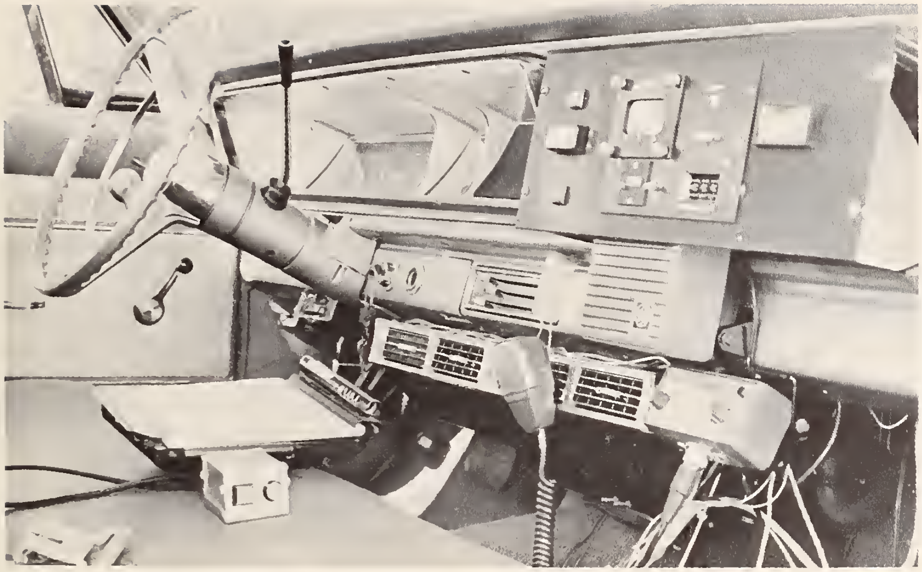

Figure 6-1. Picture of front seat of instrumented vehicle.

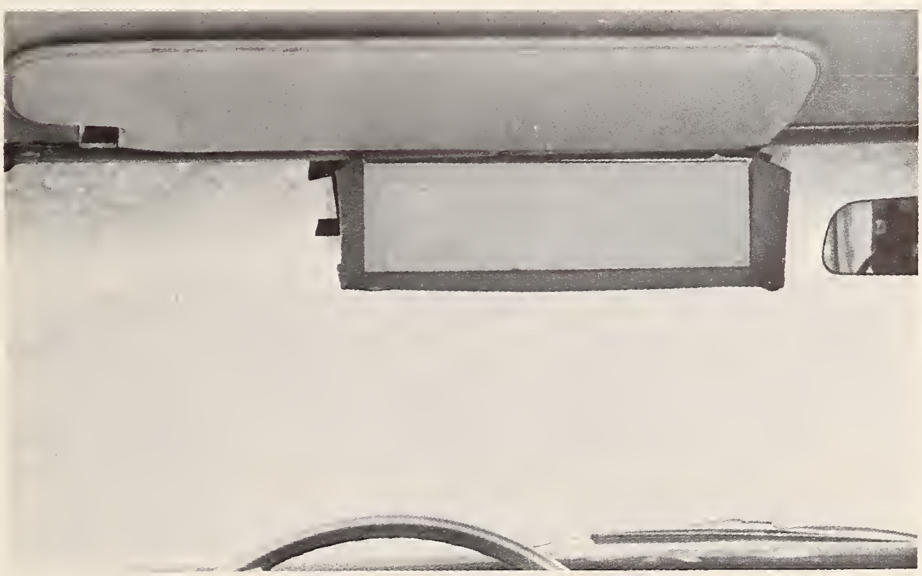

Figure 6-2. Picture of sign display screen showing the image of a conventional sign.

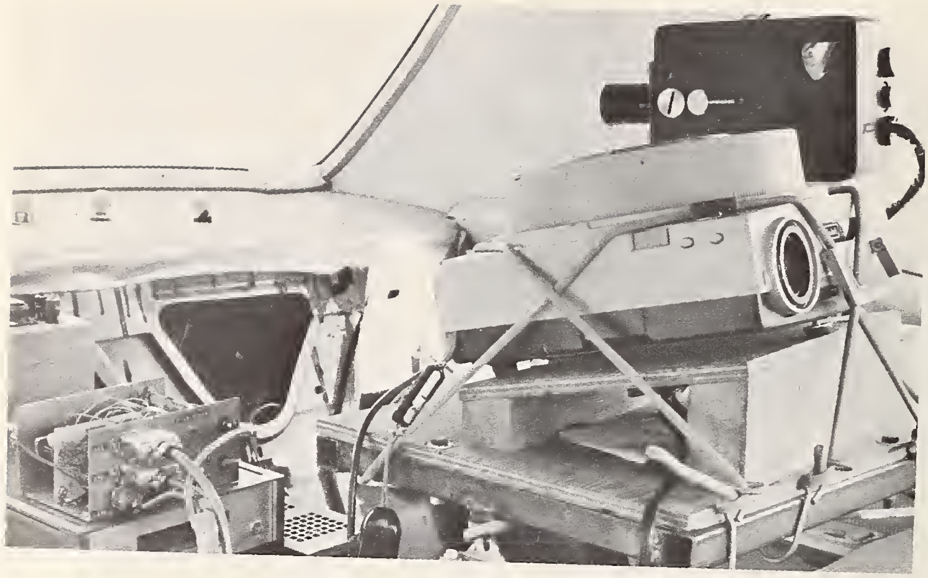

Figure 6-3. View of the back seat of test vehicle

Figure 6-4. View of projector, camera, and stimulus response lamps.

Also mounted on the stand was a 16 mm motion picture camera (Figure 6-4). It was located in back of the driver's head with its field of view to the rear of the vehicle. The camera was used to record vehicular maneuvers including lane changes and gore crosses. Camera aim was preserved through film changes by means of a Samson 7201 tripod head with positive location pins. The camera was a KB 21B Instrumentation Camera manufactured by Teledyne Camera Systems. Film was exposed at 3 frames per second through a 9 mm, f 1.5 lens; Kodak Tri-X, 7278, film was used. Power for camera operation as well as the 35 mm projector lamp was provided by two, 12 volt, dc automobile batteries connected in series to obtain 24 volts.

A digital recorder was used to record vehicular velocity, distance traversed and driver information interpretation time. It was a 10 channel, paper print output, Systron-Donner model. The digital recorder was powered by an inverter which supplied 115 volts at 60 cycles per second. A Zeronic model 351 control device provided the control circuitry for signal inputs to the digital recorder and stimulus response lamps. The three stimulus response lamps were mounted in front of the camera next to the rear view window. They can be seen in Figure 6-4. Two of the lamps were activated by the two buttons on the experimenter's control box and one was activated by the subject's response button. These lamps enabled the investigator to correlate events on the film record with sign presentations and subject responses. The Zeronic control device also supplied the circuitry for the information interpretation time measure. A timing circuit recorded the latency between experimenter activation of the slide projector and depression of the subject's response button.

Velocity of the vehicle and distance traversed were continuously recorded and printed on the paper tape at a sampling rate of 1 per second. In addition, subject IIT values were printed on the tape after each subject response. The tape was marked when the experimenter pushed either of the two buttons on his control box.

Test Route and Interchanges

The test interchange and connecting route were located in the vicinity of the connection between I-495 and I-95 (Capital Beltway Exit 4) in Northern Virginia. The test route was approximately 20 miles long and required the driver to negotiate six different interchanges. A schematic representation of the test route and interchanges is presented in Figure 6-5. The interchanges are represented as circles in the figure and are designated A through F. The lines connecting the circles indicate the test route and sequence of travel through the interchanges. Drivers correctly negotiating the test route entered the route at interchange A and traveled southbound through interchanges B through F. They reversed direction at interchange F and traveled northbound through interchange E to interchange C at which point they changed direction and drove westbound to interchange D. After reversing direction at interchange D they traveled eastbound to interchange C. Here they again changed direction and traveled northbound through interchange B, exiting from the test route at interchange A. Diagrams depicting the geometrics of the test

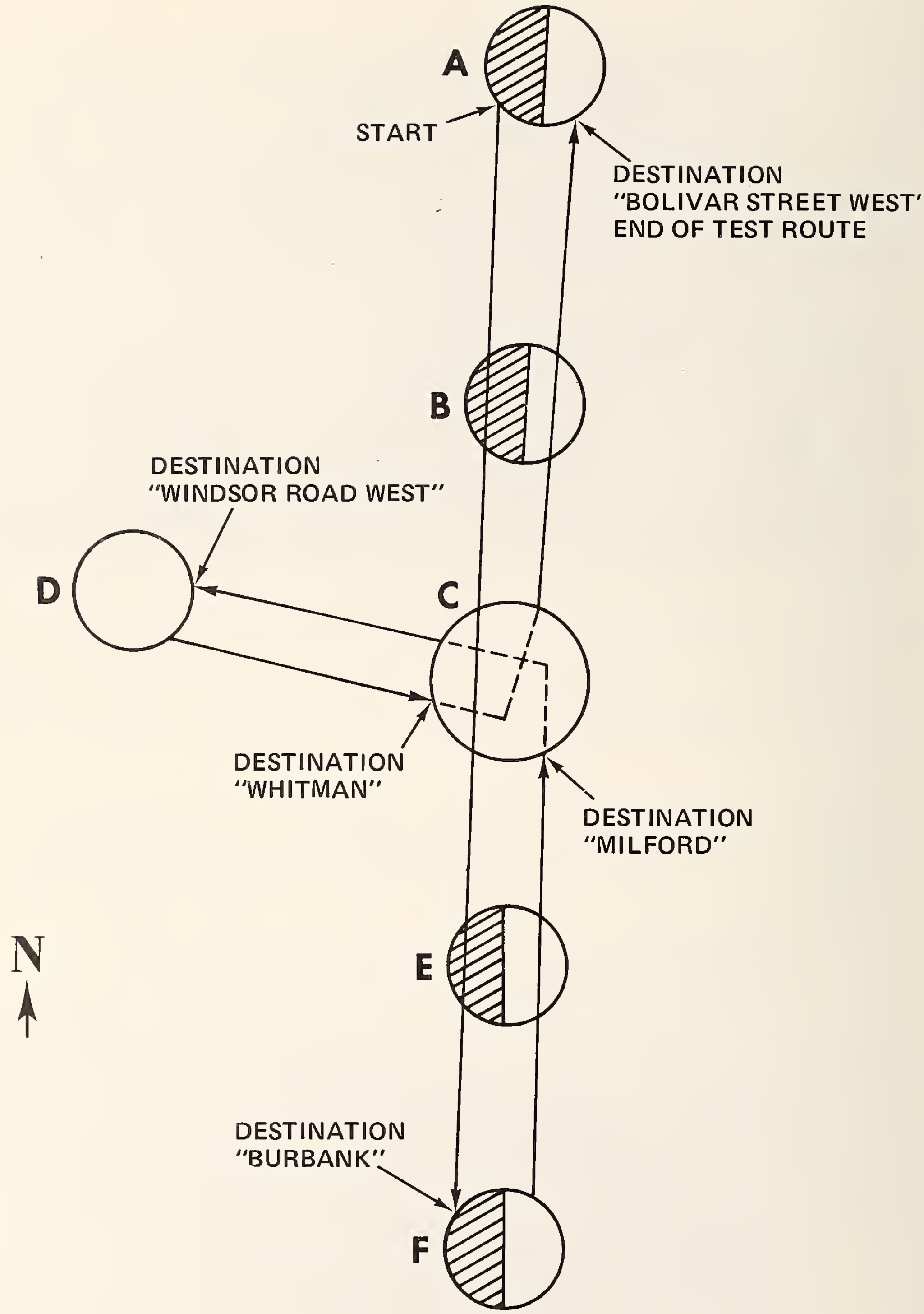

Figure 6-5. Schematic representation of test route and interchanges.

Table 6-2

INTERCHANGE TRAVEL SEQUENCE, VIRGINIA LOCATIONS, APPROACH GEOMETRICS, EXPERIMENTAL DESIGNATIONS, DRIVER DESTINATIONS, AND CORRECT NAVIGATION MANEUVERS

Inter-Change*	Approach Direction	Virginia Location	Experimental Designation	Driver Destination	Correct Navigation Maneuver	Approach Geometrics
B	Southbound	I-95/648	I-17/228	Burbank	Through	Partial Cloverleaf
C	Southbound	I-95/I-495	I-17/121	Burbank	Through	Partial Cloverleaf
E	Southbound	I-95/644	I-17/358	Burbank	Through	Full Cloverleaf
F	Southbound	I-95/617	I-17/---	Burbank	Exit	Single Right Exit
E	Northbound	I-95/644	I-81/413	Milford	Through	Partial Cloverleaf
C	Northbound	I-95/I-495	I-81/I-267	Milford	Exit	Multiple Split Ramp
D	Westbound	I-495/62	I-267/547	Windsor Rd "West"	Exit	Collector Distributor
C	Eastbound	I-495/I-95	I-988/I-42	Whitman	Exit	Left Exit
B	Northbound	I-95/648	I-42/435	Bolivar St "West"	Through	Northbound
A	Northbound	I-95/236	I-42/592	Bolivar St "West"	Exit	Northbound

* Listed in sequence of travel

interchanges are presented in Figures 6-6 through 6-35 in the results section. These figures also show the correct travel paths required of the test drivers from each direction of approach as well as the test signs used under the experimental conditions.

The test interchange approach geometrics, navigation maneuvers, locations in Virginia, experimental designations, and prescribed driver destinations are given in Table 6-2. Experimental designations refer to the fictitious route identification numbers used in the study. Both fictitious route numbers and place names were displayed on the signs employed in the investigation.

Test Signs

All of the test signs employed in the study were presented to the driver in the form of 35 mm colored slides. Sign panel layouts were developed as hard copy art work which was later photographed under controlled conditions. Consequently, sign image brightness and contrast between image figure and ground were held constant across experimental conditions. Sign contrast ratios ranged from 0.56 to 1.0 depending on ambient light conditions. Under direct sunlight, overcast, and cloudy conditions, the contrast ratios were 0.56, 0.84, and 1.0, respectively. These ratios were determined from sign brightness measurements made with a Pritchard Photometer supplied by the National Bureau of Standards.

Sign panels were designed to simulate overhead signing arrays. Therefore, lane assignment arrows and yellow "exit only" panels were used where it was appropriate. In general, sign layouts were designed in accordance with the guidelines outlined in the Manual on Uniform Traffic Control Devices.

Several sign variables were held constant across experimental conditions. These variables included sign panel size, capital and small letter styles and heights, interstate and State shield dimensions, and quantity of printed destination information. All of the place names on the test signs were seven letters long. Moreover, complex graphic components for the diagrammatic signs were avoided as much as possible. No crossing elements or implied crossover components were used in the diagrammatic sign formats.

Procedure

Data for the study were gathered during the summer of 1972. Volunteer test subjects were transported from Maryland to the research base station located at Cameron Military Station in Virginia. The military facility was located proximal to the origin of the test route. The research base station was housed in an 8 x 25 foot air conditioned trailer which served as a center of operations during the data gathering period.

As soon as drivers reported to the test area they were first screened for visual defects by means of an orthorater. Then they were asked to complete a brief biographical form. Questions on the form pertained to age, driving experience, and accident experience. After the subjects completed the forms, they waited in the trailer to be dispatched on the test drive. Care was taken to keep the subjects naive as to the exact purpose and details of the study. Subjects who had completed the test drive were not allowed to discuss the details of the experiment with subjects not yet tested.

The first part of the test drive consisted of a familiarization phase. At this point, the driver was simply instructed to become familiar with the test vehicle. He was told to drive the vehicle around Cameron Military Station and to test the brakes, steering, and acceleration characteristics of the vehicle. An experimenter accompanied the test subject throughout the familiarization phase as well as during the actual test drive. The experimenter rode on the passenger's side of the front seat during all test drives. The preliminary drive permitted the subject to adapt to the instrumented vehicle but it also gave the experimenter an opportunity to assess the subject's general driving performance and ability to function in the test situation. Out of the total sample of volunteers, six drivers were rejected because of visual defects or because their driving performance during the preliminary drive was substandard.

When the driver indicated that he felt comfortable with the vehicle, the experimenter gave the following oral instructions:

"I am going to present some slides of highway guide signs on this small screen (experimenter presented a test sign and pointed to screen). Can you clearly see the signs? Ordinarily the driver seeks out his destination by using the guide signs mounted along the highway. In this experiment I want you to drive me to different destinations, using the guide signs presented on the screen. The destinations I will give you are fictitious places. Fictitious in the sense that they don't exist around here. Although the destinations are fictitious, you will be driving the car under real traffic conditions over a predetermined test route with real interchanges. Because the destinations are fictitious, your only source of information regarding them will be the signs I present to you on the screen. Since the guide signs along the highway will not be of help to you, you may ignore them and rely solely on the route guidance information given to you in the car. Signs will be programmed to you on the screen in the same way they are ordinarily presented to you on the road. That is, as you approach a given interchange, one or more advance signs will be presented to you at least 1/2 mile prior to the interchange. Similarly, an exit sign will appear on the screen as you approach the interchange's exit ramp. When you arrive at a given interchange, I want you to drive through the interchange as if the fictitious destinations really exist and you are traveling to them. In other words, if the information on the signs indicate that you should exit at a given interchange in order to reach your destination, I want you to perform the exiting maneuver. You will control the length of time each sign is displayed on the screen. You will do this by means of the horn rim button. When you have read and understand the information on the sign, I want you to push this button (experimenter pushed the horn rim button). This will remove the image of the sign from the screen. You may leave the slide on the screen as long as it takes you to understand the information. However, as soon as you understand the information, I want you to press the button. I will now present some practice signs so that you can practice pushing the horn button (experimenter presented three practice slides). Do you have any questions?"

After the above instructions were given to the driver, the experimenter directed him to the test route. On the test route entrance ramp the subject was told that his destination was "Burbank" and that as soon as he entered the traffic stream, he would be traveling southbound on fictitious I-17. He was informed that he should stay on I-17 until he located the exit to Burbank.

At this point the experimenter activated the recording equipment in the vehicle. Soon after the vehicle was traveling southbound, the experimenter presented the 1 mile advance sign shown in either Figure 6-22, 6-23, or 6-24 (see pages 133, 134, 135), depending on which experimental group the driver had been assigned. The experimenter used red flags unobtrusively positioned along the edge of the highway as cues for the sign presentations. Presentation points for signs were located approximately where signs should first become readable when positioned according to MUTCD standards. As soon as the subject pressed the horn rim button, the subject's information interpretation time (IIT) was automatically recorded by the digital recorder.

After the subject negotiated test interchange F, the experimenter informed the subject whether he had exited correctly or incorrectly. Then he gave him instructions for turning around and his target destination for the next segment of the test route. This same procedure was used throughout the test drive. Upon completing the test route, the experimenter asked the subject to indicate his familiarity with the test route and to comment on the test signs, his route navigation problems, if any, and the in-vehicle sign display technique. This concluded the experimental test procedure.

Measures

Information Interpretation Time (IIT). The IIT measure was defined as the length of time required by the driver to read and interpret guide sign information presented on the display. It was measured directly by a timing circuit which was activated by the experimenter when he presented the test signs and deactivated by the subject's response button. It was automatically recorded by the digital recorder and printed on paper tape.

Average Vehicular Velocity. An average vehicular velocity score was determined for each subject for each of the sign influence periods as well as for baseline or control portions along the test route. The sign influence period was arbitrarily defined as the 10 second period immediately following each presentation of a test sign. Average velocity during baseline or control periods were also recorded. These were 10 second periods recorded prior to the signing sequences at the exiting interchanges. They provided a sample of the driver's average velocity during a period which was free from the influence of guide signs.

Vehicular Velocity Noise. A velocity noise score was computed for each subject for each of the sign influence and baseline periods. Velocity noise was defined as the standard deviation around the average vehicular velocity score. The velocity noise as well as average velocity measures were scored from the digital recorder output.

Preparatory Lane Changes. Two types of preparatory lane changes were defined in the study. These consisted of correct and incorrect preparatory lane changes. A correct preparatory lane change was defined as a lane change into the lane from which a correct exiting maneuver could be executed. For example, at a single right exit where the driver's destination required an exit maneuver, movement into the right most lane within the signing sequence constituted a correct lane change. By the same token, movement out of the right most lane within the signing sequence by an exiting driver was defined as an incorrect lane change. Movements out of the right lane for the purposes of overtaking and passing slow moving vehicles were not scored as incorrect lane changes. The geometric and exiting requirements at each interchange defined what specifically constituted correct and incorrect lane changes.

Erratic Maneuvers. Only one type of erratic maneuver was scored in this study. This was defined as a gore cross over the physical or theoretical gore. The painted gore with its solid extension line was considered to be the theoretical gore. Erratic maneuver and lane change data were scored from the 16 mm film record.

Exiting Errors. Exiting errors were scored on the basis of the driver's success or failure to perform the appropriate exiting maneuver based on his target destination. The experimenter recorded the exiting error on the subject's biographical data sheet.

Results

The study results for interchanges where exiting maneuvers were required will be presented first. These results will be followed by findings at interchanges where the driver was required to make a through maneuver. Exiting interchange results will be presented in the order of the interchange travel requirement.

A t-test statistical model designed to test populations with unequal variances (Dixon and Massey, 1951, p. 104-105) was used to test the group differences on the IIT and velocity control measures. Since the hypothesis concerning the IIT measure was directional, a 1 tail test was used. All other statistical comparisons in the study employed 2 tail tests. The proportional differences between groups on the lane change, erratic maneuver, and exiting error measures were tested by means of a 2 tail test (Walker and Lev, 1953, pp. 77-79). The significance level was set at the .025 level for all of the statistical tests used in the investigation.

In this study, three paired comparisons were made, A vs B, A vs C, and B vs C, where A, B, and C represented the experimental results from the Conventional, Diagrammatic I, and Diagrammatic II conditions, respectively.

Since the three paired comparisons utilize the same set of data, they are not independent. Therefore, because of this lack of independence, the joint significance level was in fact closer to .05 than .025.

Single Right Exit (Interchange F, Southbound)

Presented in Figures 6-6, 6-7, and 6-8, are diagrams for Interchange F showing the geometry, correct travel path, and signing conditions for the Conventional, Diagrammatic I, and Diagrammatic II groups. It can be seen from these figures that only one sign change was made at this interchange. The 1 mile advance sign was changed to a diagrammatic format for the Diagrammatic II group. Otherwise, the rest of the signs remained the same throughout the study.

The sign information interpretation time (IIT) results for this interchange are in Table 6-3. It can be seen that the mean IIT value for the diagrammatic 1 mile advance sign was 1.26 seconds longer than the IIT value for the conventional sign. However, this difference only reached statistical significance for the B-C comparison and just missed it for the A-C comparison.

The diagrammatic sign at this interchange had no effect on the driver's velocity control during the advance and exit sign influence periods. This was true for both the average velocity and velocity noise measures (Tables 6-4 and 6-5). The values for these measures remained virtually constant across the experimental conditions. All three groups exhibited a reduction in velocity during the exit sign influence period. This reduction amounted to approximately 8 miles per hour.

There were no differences between groups in the proportion of correct and incorrect lane changes within the interchange approach area. In this study, the interchange approach area was defined as the area between the first advance sign and the gore. For the analysis of driver lane change behavior, this approach area was further subdivided into zones. The delineation of each of these zones was marked on the basis of sign presentation location.

Lane change results are presented in Table 6-6. It is apparent from the correct preparatory lane change findings that the greatest proportion of drivers moved into the exiting preparatory lane, the extreme right lane, between the advance sign and the exit sign. Very few drivers made the exiting lane change between the exit sign and the gore. Furthermore, no incorrect lane changes were recorded for any of the drivers tested in the study at this interchange.

No erratic maneuvers, i.e., vehicular traverses across the gore, were observed for the entire sample of drivers at this interchange (Table 6-24, page 131). There was a slight increase in the proportion of exiting errors under the diagrammatic condition, but it was not statistically significant.

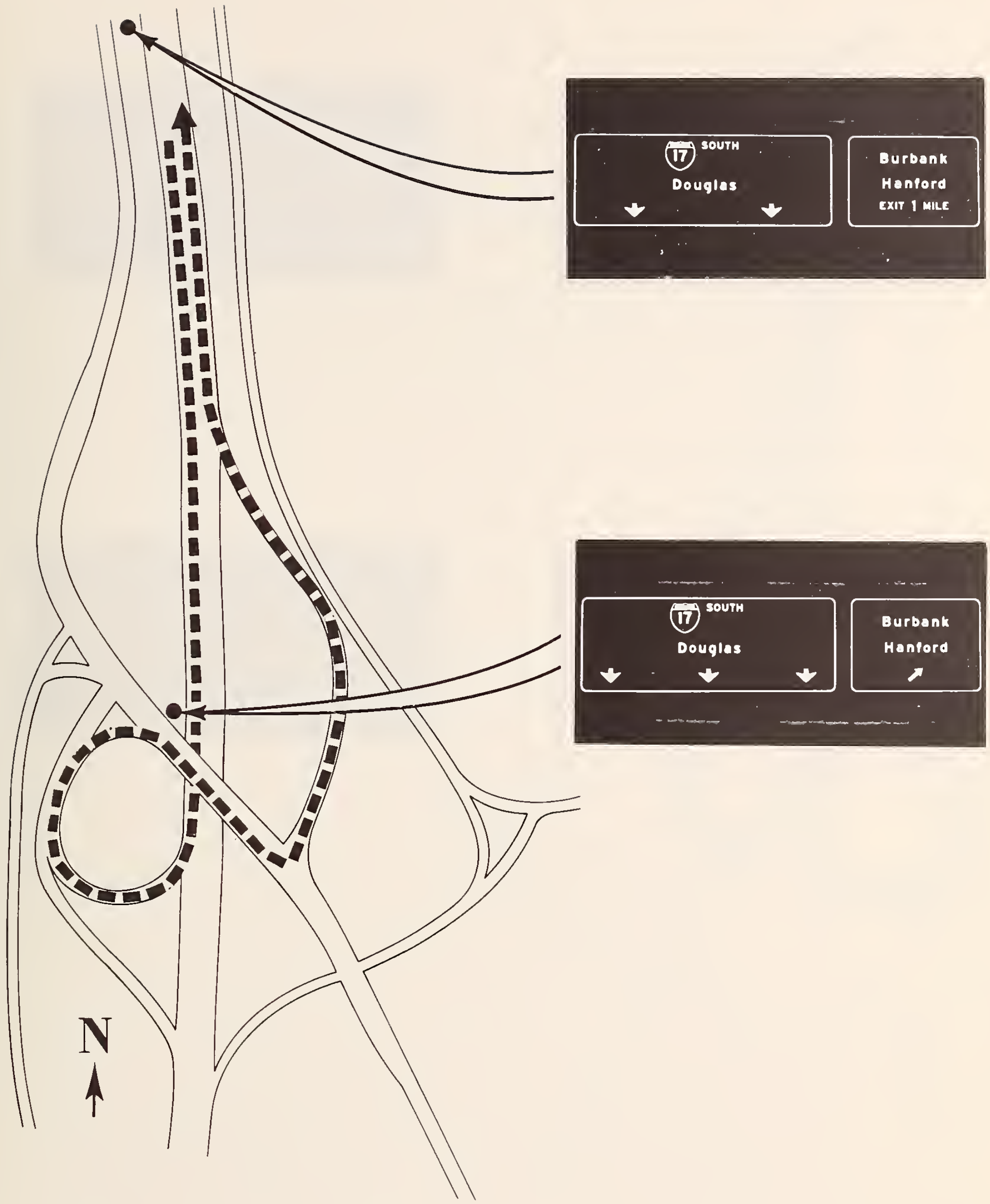

Figure 6-6. Southbound approach to Interchange F (conventional signing).

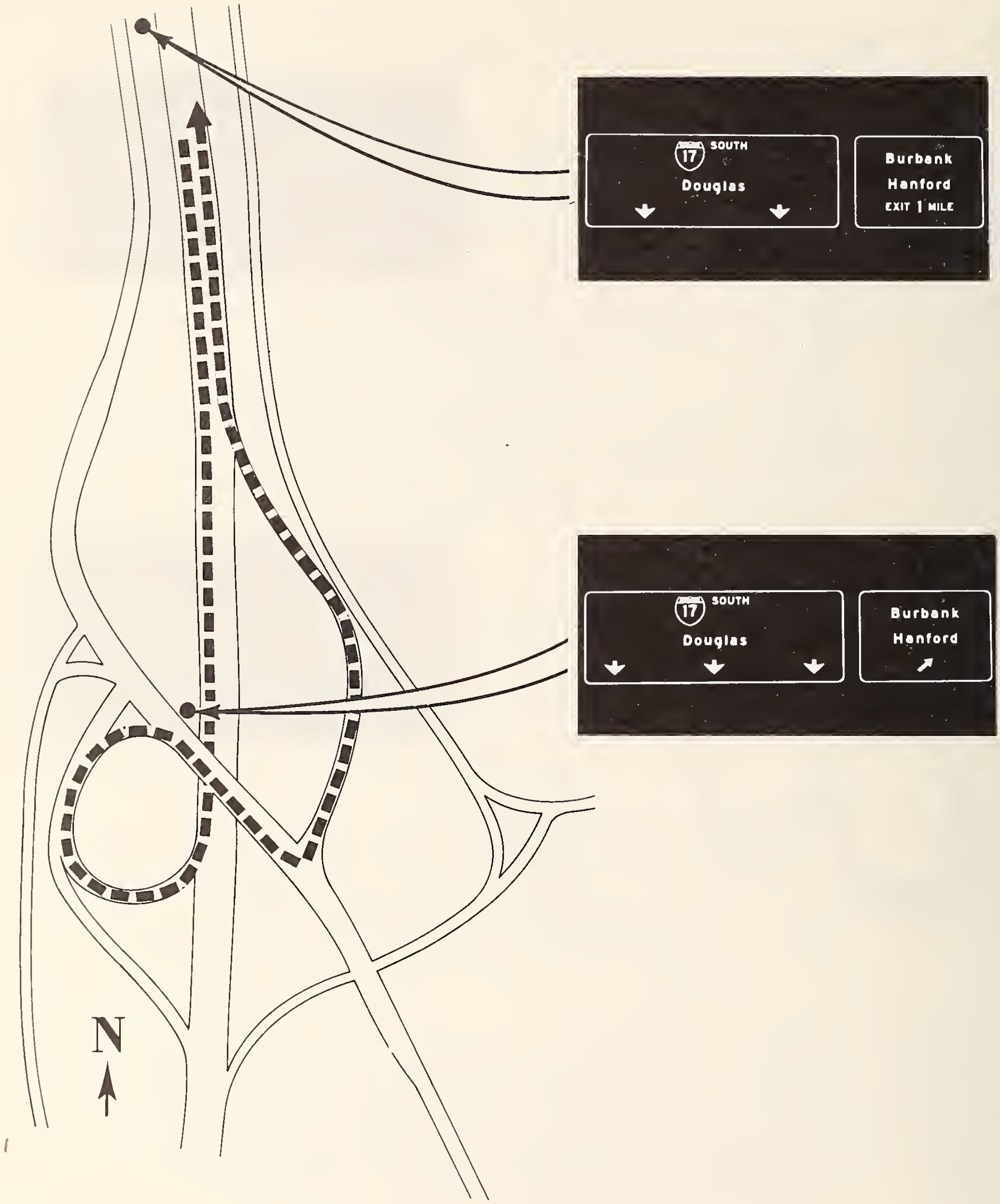

Figure 6-7. Southbound approach to Interchange F (Diagrammatic I signing).

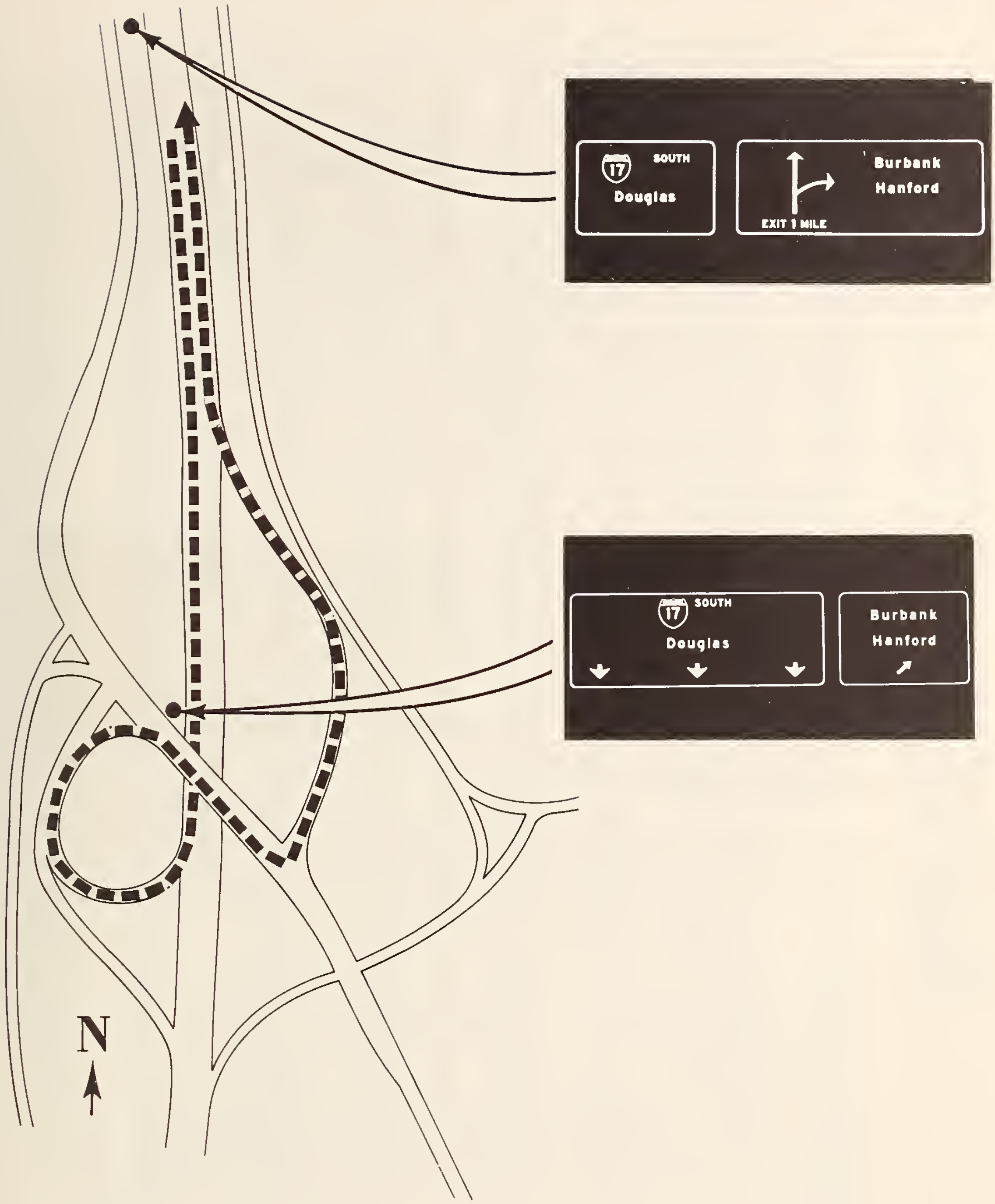

Figure 6-8. Southbound approach to Interchange F (Diagrammatic II signing).

Table 6-3

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT SOUTHBOUND APPROACH TO INTERCHANGE F (SINGLE RIGHT EXIT)

	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Sign Type	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	23	4.27	1.81	26	4.27	1.37	28	5.53	2.71	0.005	1.982	2.178*
Exit	21	3.93	2.21	26	3.90	2.36	26	4.72	2.45	1.041	1.165	1.228

* $P < .025$ (1 tail test)

Table 6-4

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR AVERAGE VEHICULAR VELOCITY WITHIN SIGN INFLUENCE PERIODS
AT SOUTHBOUND APPROACH TO INTERCHANGE F (SINGLE RIGHT EXIT)

Condition	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Southbound Baseline	25	57.7	9.9	27	58.5	8.2	28	57.4	7.7	0.330	0.103	0.508
Advance Sign	25	57.7	8.0	27	57.5	8.6	28	57.3	7.6	0.093	0.177	0.076
Exit Sign	24	49.1	8.2	26	50.4	8.8	27	48.9	7.9	0.501	0.144	0.663

Table 6-5

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR VEHICULAR VELOCITY NOISE WITHIN SIGN INFLUENCE PERIODS
AT SOUTHBOUND APPROACH TO INTERCHANGE F (SINGLE RIGHT EXIT)

Condition	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Southbound Baseline	25	2.0	2.3	27	1.8	1.6	28	2.1	2.3	0.507	0.139	0.692
Advance Sign	25	2.6	2.3	27	2.6	2.2	28	2.3	2.3	0.023	0.500	0.539
Exit Sign	24	3.0	2.5	26	3.1	2.3	27	2.8	2.2	0.097	0.287	0.420

Table 6-6

PROPORTION OF CORRECT AND INCORRECT LANE CHANGES AND Z VALUES AT SOUTHBOUND APPROACH TO INTERCHANGE F (SINGLE RIGHT EXIT)

Interchange Approach Zone	(A) Conv.		(B) Diag. I		(C) Diag. II		Z Value		
	N	Lane Change (Prop)	N	Lane Change (Prop)	N	Lane Change (Prop)	A-B	A-C	B-C
Preparatory Lane Change Required	22	.957	24	.960	30	.968	0.062	0.216	0.155
Correct Preparatory Lane Change									
Advance Sign -- Exit Sign	18	.783	21	.840	27	.871	0.509	0.862	0.329
Exit Sign -- Gore	4	.174	3	.120	1	.032	0.529	1.776	1.267
Incorrect Preparatory Lane Change									
Advance Sign -- Exit Sign	0	.000	0	.000	0	.000	---	---	---
Exit Sign -- Gore	0	.000	0	.000	0	.000	---	---	---

Double Lane Drop With Split Ramp (Interchange C, Northbound)

Presented in Figures 6-9 through 6-11 are diagrams of the second interchange where drivers were required to perform an exiting maneuver. Included on the diagrams are the interchange geometry, correct travel path for the northbound approach, and test signs used under each of the experimental conditions. Since interchanges C and E were 3/4 mile apart, the 3/4 mile advance sign for Interchange C, Northbound, was presented with the exit sign for Interchange E, Northbound (see pages 145 - 147). The 3/4 mile advance sign remained conventional throughout this study. In addition, the last sign in the signing sequence also remained conventional throughout the study. Only the two exit direction signs were changed to diagrammatic formats for the Diagrammatic I and II conditions. It should also be noted that the diagrammatic format stayed the same for both of the two exit direction signs in the Diagrammatic II condition. However, in the Diagrammatic I condition, the two exit direction signs were different. The first exit direction sign showed just the two lane drop whereas the second exit direction sign depicted the two lane drop plus the split ramp. The latter type sign was used for both exit direction signs in the Diagrammatic II condition.

The information interpretation time results (Table 6-7) indicated that average IIT at the first exit direction sign location for the diagrammatic sign showing both the double lane drop and the split ramp was approximately 2 seconds longer than the conventional sign or the diagrammatic sign showing just the two lane drop. This was also true when it was presented as the second exit direction sign. The average IIT values for this sign were very constant, ranging between 7.1 and 7.5 seconds. All the statistical comparisons involving this sign were significant. But there was no difference between the conventional exit direction sign and the diagrammatic sign showing just the two lane drop on this measure.

Although the last sign in the sequence was not changed, the results indicated that there was an increase in IIT time for this sign under both of the diagrammatic signing conditions. However, only the comparison between the Conventional and the Diagrammatic II groups showed a significant difference. The magnitude of this increase was approximately 2 seconds.

An examination of the average velocity results in Table 6-8 indicates that none of the comparisons between groups reached statistical significance. Although there was a tendency for a reduction in average velocity during the first exit direction sign influence period, none of the group differences were significant on the velocity noise measure (Table 6-9).

The lane change results in Table 6-10 reveals a number of differences between the conditions. It should be noted that any movement into the correct preparatory lane for purposes of exiting was scored as a correct preparatory lane change. This was true even if it occurred very near the gore and may also have been scored as an erratic maneuver. It is apparent in Table 6-10 that there was an increase in correct preparatory lane changes between the exit sign and the gore under the Diagrammatic I condition. Also, the incorrect preparatory lane change results in the same table indicate that there was a

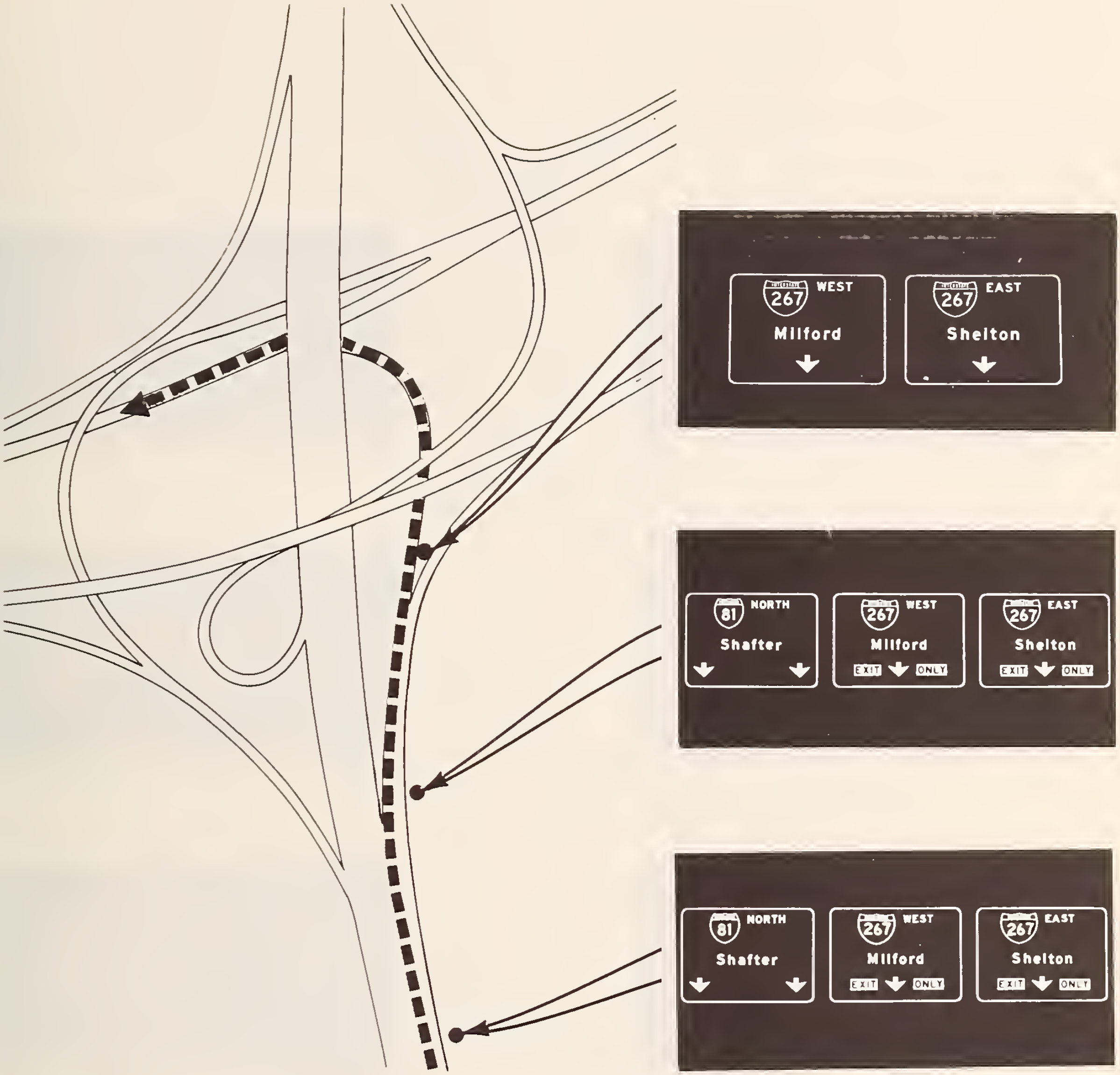

Figure 6-9. Northbound approach to Interchange C (conventional signing).

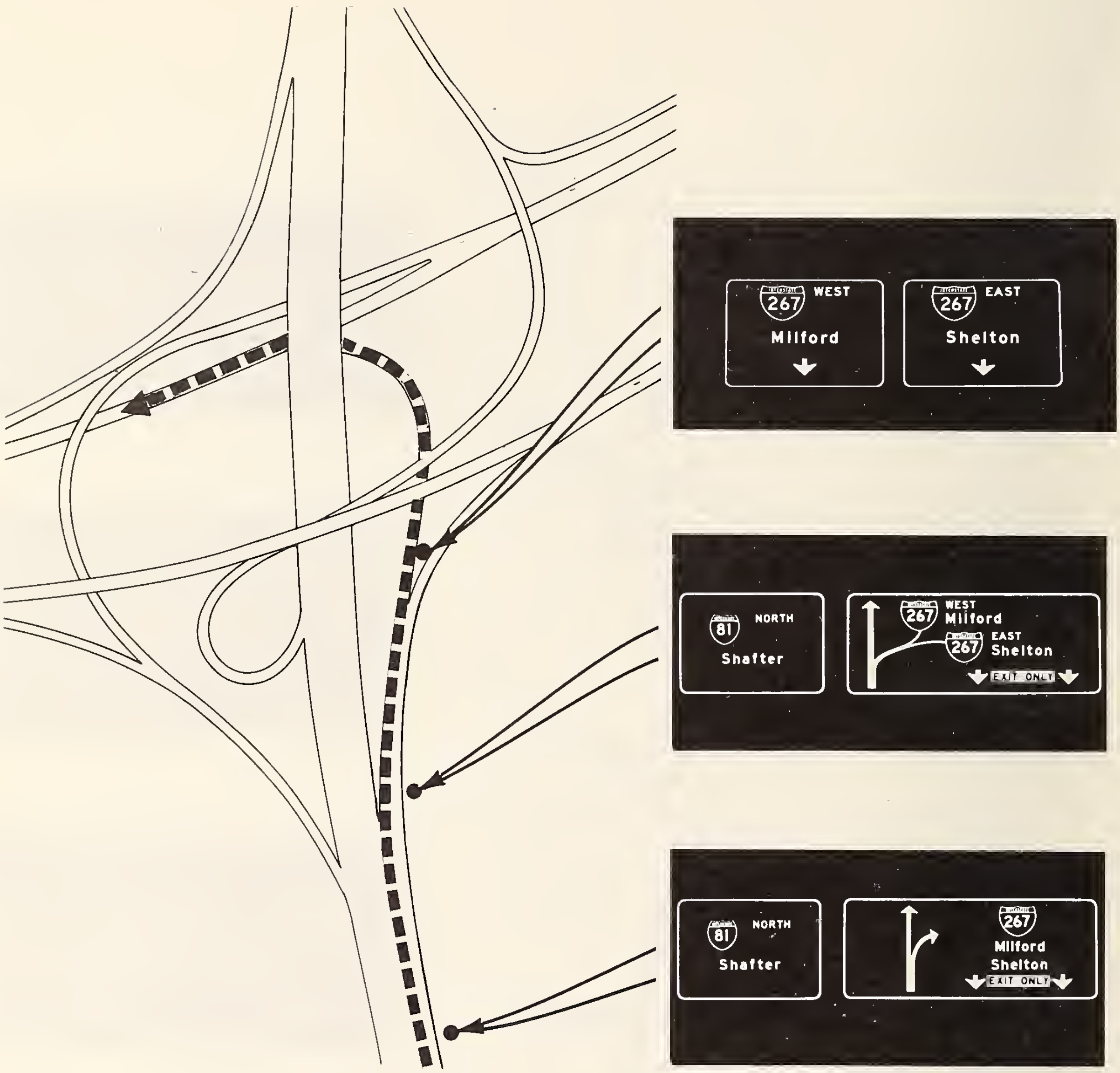

Figure 6-10. Northbound approach to Interchange C (Diagrammatic I signing).

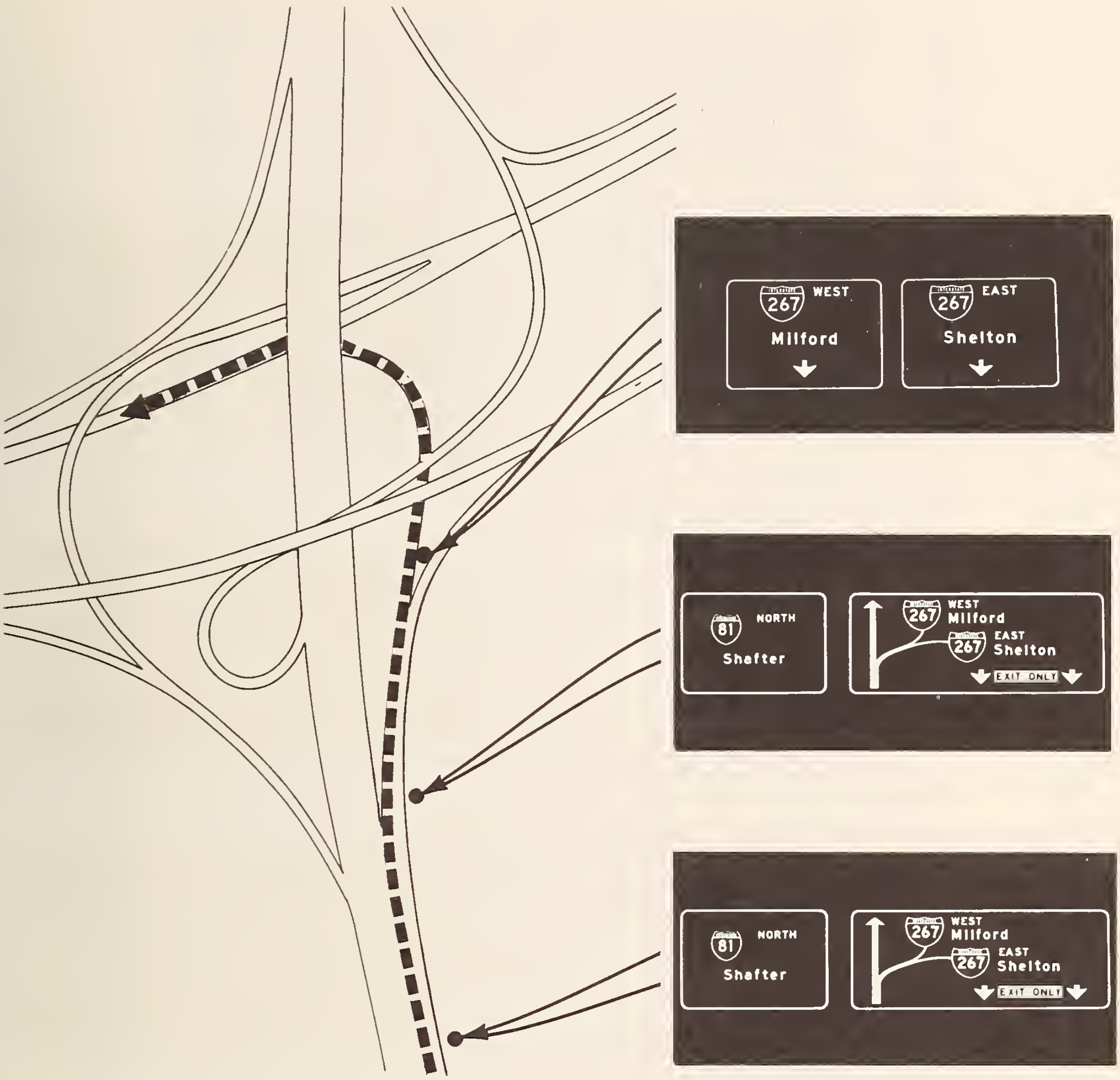

Figure 6-11. Northbound approach to Interchange C
(Diagrammatic II signing).

Table 6-7

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT NORTHBOUND APPROACH TO INTERCHANGE C (SPLIT RAMP)

	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Sign Type	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	25	4.44	1.94	27	5.17	2.49	28	4.99	1.87	1.185	1.045	0.305
First Exit Direction	25	5.70	3.22	25	5.20	2.41	28	7.54	2.96	0.625	2.158*	3.172*
Second Exit Direction	25	5.07	2.96	26	7.47	3.22	26	7.15	4.08	2.776*	2.067*	0.310
Exit	25	3.34	1.33	23	4.11	2.44	22	5.30	3.18	1.336	2.677*	1.398

* $P < .025$ (1 tail test)

Table 6-8

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR AVERAGE VEHICULAR VELOCITY WITHIN SIGN INFLUENCE PERIODS
AT NORTHBOUND APPROACH TO INTERCHANGE C (SPLIT RAMP)

Condition	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Northbound Baseline	25	54.4	8.4	27	51.6	9.2	27	54.6	9.2	1.175	0.078	1.224
First Exit Direction Sign	25	48.0	7.6	27	44.4	6.1	28	45.6	7.2	1.933	1.235	0.666
Second Exit Direction Sign	25	45.6	5.0	27	43.4	4.0	27	43.6	5.6	1.776	1.427	0.121
Exit Sign	25	39.9	6.7	26	41.0	5.2	27	42.8	1.9	0.664	2.101	1.642

Table 6-9

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR VEHICULAR VELOCITY NOISE WITHIN SIGN INFLUENCE PERIODS
AT NORTHBOUND APPROACH TO INTERCHANGE C (SPLIT RAMP)

	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Condition	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Northbound Baseline	25	2.0	2.1	27	2.2	1.8	27	1.9	1.9	0.345	0.072	0.455
First Exit Direction Sign	25	2.8	2.2	27	3.3	2.5	28	2.4	1.6	0.654	0.899	1.589
Second Exit Direction Sign	25	3.4	2.4	27	2.4	2.1	27	2.8	2.0	1.489	0.893	0.685
Exit Sign	25	3.2	1.8	26	3.2	2.0	27	2.7	1.6	0.031	0.973	0.949

Table 6-10

PROPORTION OF CORRECT AND INCORRECT LANE CHANGES AND Z VALUES AT NORTHBOUND APPROACH TO INTERCHANGE C (SPLIT RAMP)

Interchange Approach Zone	(A) Conv.		(B) Diag. I		(C) Diag. II		Z Value		
	N	Lane Change (Prop)	N	Lane Change (Prop)	N	Lane Change (Prop)	A-B	A-C	B-C
Preparatory Lane Change Required	24	1.000	21	.875	28	.903	1.789	1.567	0.333
Correct Preparatory Lane Change									
Advance Sign -- 1st Exit Direction	15	.625	17	.708	20	.645	0.612	0.154	0.495
1st Exit Direction -- 2nd Exit Direction	6	.250	5	.208	3	.097	0.343	1.523	1.164
2nd Exit Direction -- Exit Sign	6	.250	4	.167	8	.258	0.711	0.068	0.814
Exit Sign -- Gore	0	.000	14	.583	5	.161	4.446*	2.064	3.264*
Incorrect Preparatory Lane Change									
Advance Sign -- 1st Exit Direction	0	.000	1	.042	2	.065	1.010	1.268	0.370
1st Exit Direction -- 2nd Exit Direction	24	.125	13	.542	4	.129	3.062*	0.044	3.284*
2nd Exit Direction -- Exit Sign	0	.000	6	.250	5	.161	2.619*	2.064	0.816
Exit Sign -- Gore	0	.000	0	.000	0	.000	--	--	--

* P < .025 (2 tail test)

significant increase in incorrect lane changes between the first exit direction sign and the exit sign under the Diagrammatic I condition.

There was a tendency for the number of exiting errors to increase under the diagrammatic signing conditions. However, the Z values in Table 6-23 indicate that none of the statistical comparisons reached significance. The erratic maneuver results in Table 6-24 show a significant increase in the proportion of erratic maneuvers under the diagrammatic signing conditions. It is apparent that the largest contributor of these maneuvers was the Diagrammatic I group. Moreover, by far the largest proportion of these gore crosses occured at the mainstream exit gore.

Cloverleaf With Collector Distributor (Interchange D, Westbound)

Presented in Figures 6-12 through 6-14 are diagrams of test interchange D under the conditions of the experiment. Two diagrammatic sign deployment conditions were evaluated at this interchange. Under the Diagrammatic I condition, a diagrammatic sign was deployed at the exit direction sign only, whereas under the Diagrammatic II condition, a diagrammatic sign was deployed at the advance sign only. The rest of the signs in the sequence remained the same for all three test conditions. No diagrammatic signs were presented on the collector ramp.

Table 6-11 presents the results at this interchange for the IIT measure. The diagrammatic advance sign used by the Diagrammatic II group required approximately 1.28 seconds longer to interpret than the conventional sign. This difference was statistically significant. There was no difference in average IIT between conditions at the exit direction sign location, however. Similarily, none of the other statistical comparisons reached significance on this measure.

Examination of the T ratios for average vehicular velocity during the sign influence periods indicates that none reached significance (Table 6-12). Although there was a trend for drivers in the Diagrammatic II group to maintain a lower average velocity, this was reflected in the control or baseline period as well as during the advance and exit direction sign influence periods.

There was only one statistical difference in velocity noise shown in Table 6-13. It was for the difference between the diagrammatic groups for the exit direction sign influence period. There were no differences between experimental conditions on the proportion of correct or incorrect preparatory lane changes (Table 6-14) nor in the incidence of erratic maneuvers or number of exiting errors (See Table 6-23 and 6-24 on pages 130 - 131).

Left Exit Preceded by a Right Exit (Interchange C, Eastbound)

Presented in Figures 6-15 through 6-17 are diagrams for interchange C. There were 5 signs used in the signing sequence at the eastbound approach to interchange C. At the 1 mile advance sign only the Diagrammatic II group was presented with a diagrammatic sign. Both diagrammatic groups viewed a

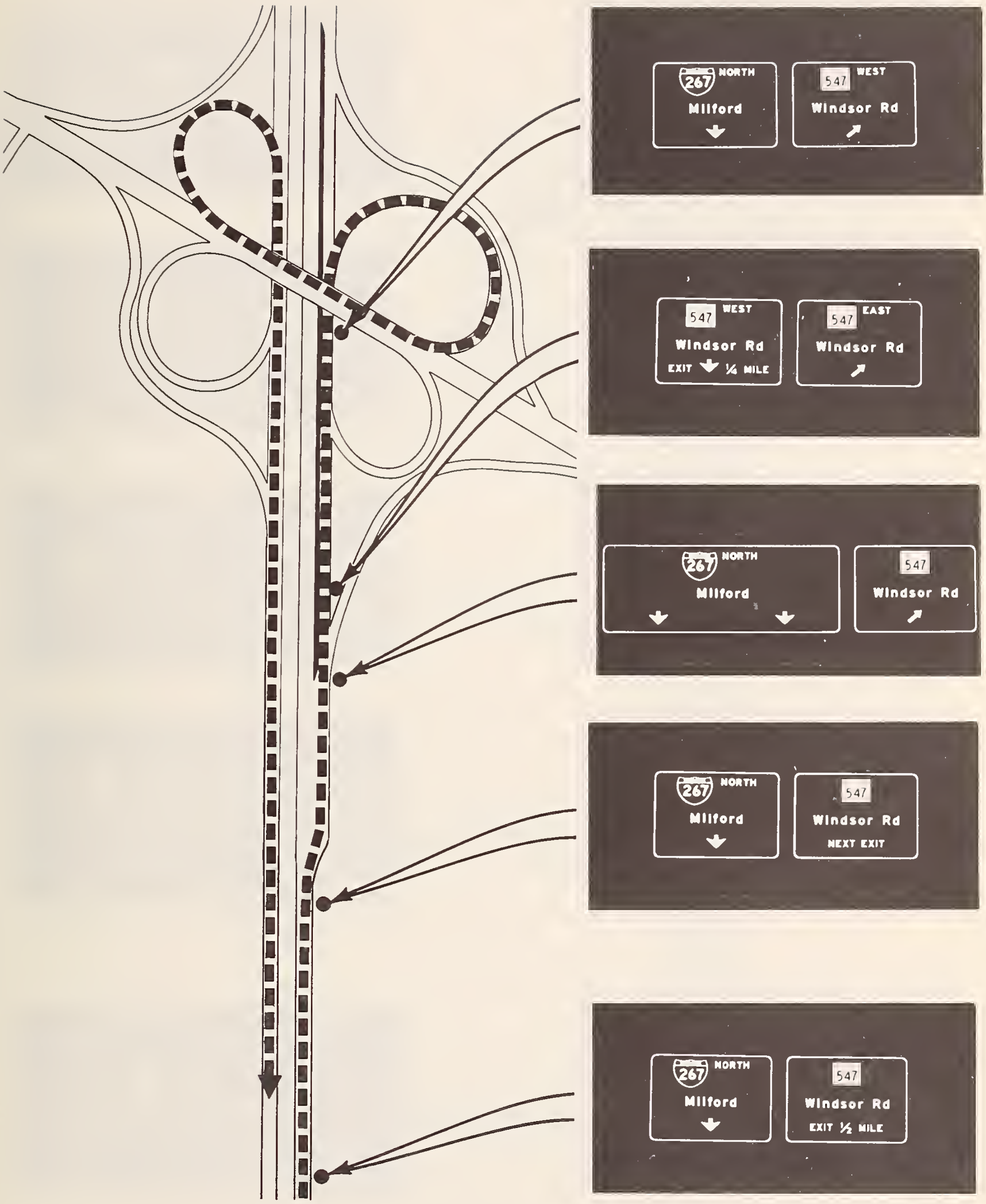

Figure 6-12. Westbound approach to Interchange D (conventional signing).

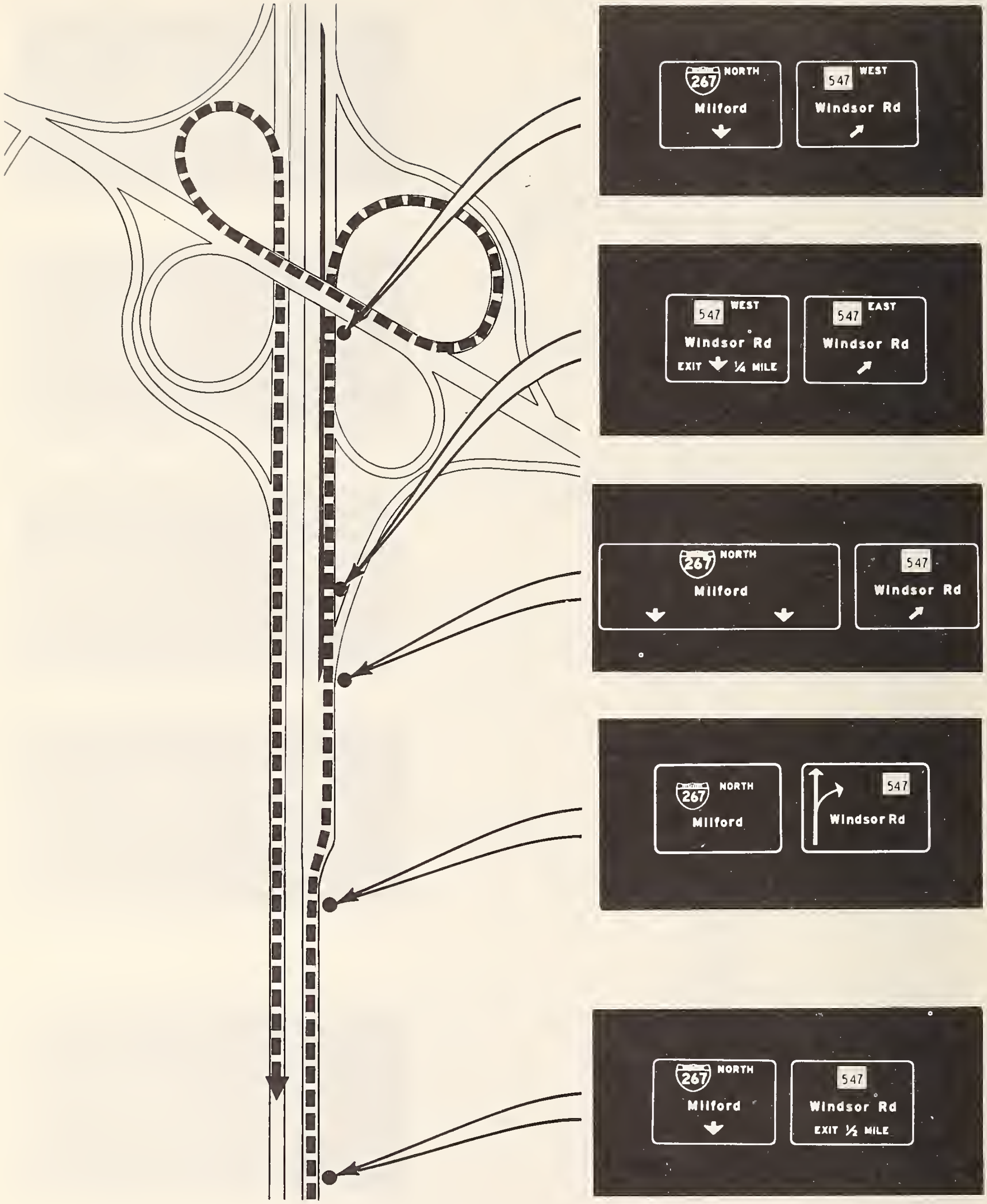

Figure 6-13. Westbound approach to Interchange D (Diagrammatic I signing).

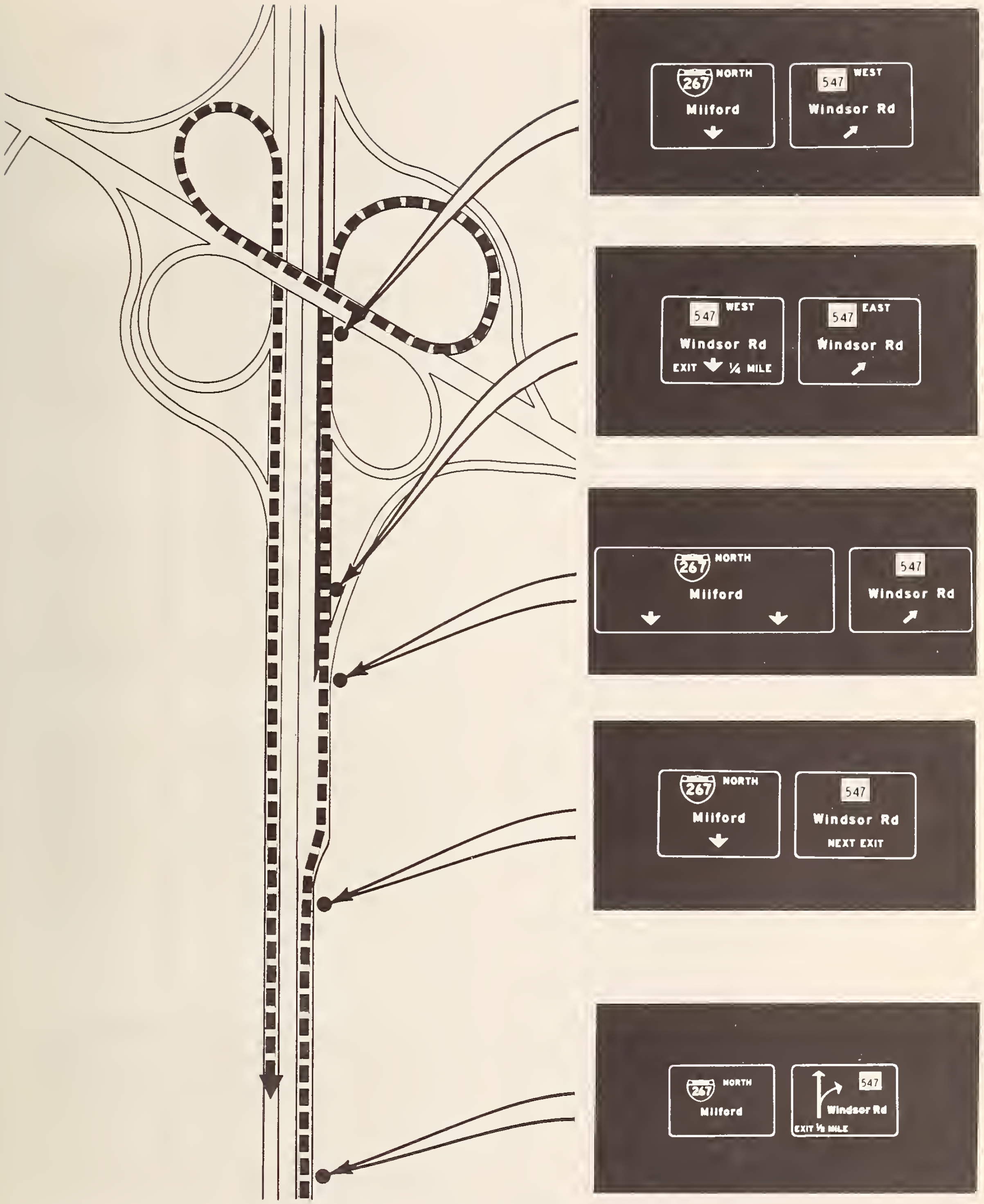

Figure 6-14. Westbound approach to Interchange D (Diagrammatic II signing).

Table 6-11

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT WESTBOUND APPROACH TO INTERCHANGE D (COLLECTOR DISTRIBUTOR)

Sign Type	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	23	3.83	1.42	27	4.09	1.83	27	5.24	2.17	0.549	2.753*	2.119*
Exit Direction	23	3.54	1.55	27	4.17	1.90	28	4.18	1.82	1.305	1.352	0.004
Mainstream Exit	24	2.95	1.30	25	2.99	1.04	27	3.24	1.42	0.122	0.756	0.720
Exit East	23	3.84	2.55	25	3.12	1.26	28	3.90	2.48	1.228	0.085	1.472
Exit West	20	3.09	1.78	22	3.20	1.43	25	4.44	2.82	0.218	1.961	1.944

* P < .025 (1 tail test)

Table 6-12

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR AVERAGE VEHICULAR VELOCITY WITHIN SIGN INFLUENCE PERIODS
AT WESTBOUND APPROACH TO INTERCHANGE D (COLLECTOR DISTRIBUTOR)

	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Condition	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Westbound Baseline	25	49.8	8.8	27	44.7	9.4	27	47.8	9.0	2.043	0.808	1.264
Advance Sign	25	49.3	8.3	27	45.0	7.5	27	46.4	8.2	1.936	1.260	0.634
Exit Direction Sign	24	46.1	6.1	27	43.4	4.5	26	44.3	6.2	1.789	1.032	0.615
Main Stream Exit Sign	24	44.4	4.7	26	44.0	4.2	27	43.4	5.7	0.330	0.696	0.431

Table 6-13

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR VEHICULAR VELOCITY NOISE WITHIN SIGN INFLUENCE PERIODS
AT WESTBOUND APPROACH TO INTERCHANGE D (COLLECTOR DISTRIBUTOR)

	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Condition	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Westbound Baseline	25	2.8	2.2	27	1.8	1.8	27	2.6	2.4	1.832	0.258	1.475
Advance Sign	25	2.6	2.3	27	2.6	2.2	27	3.7	3.1	0.029	1.412	1.435
Exit Direction Sign	24	2.1	1.7	27	1.6	1.4	26	2.5	1.4	1.166	0.907	2.402*
Mainstream Exit Sign	24	2.1	1.7	26	2.2	1.7	27	1.9	1.5	0.263	0.483	0.786

* $P < .025$ (2 tail test)

Table 6-14

PROPORTION OF CORRECT AND INCORRECT LANE CHANGES AND Z VALUES AT WESTBOUND APPROACH TO INTERCHANGE D (COLLECTOR DISTRIBUTOR)

	(A) Conv.		(B) Diag. I		(C) Diag. II		Z Value		
Interchange Approach Zone	N	(Prop)	N	(Prop)	N	(Prop)	A-B	A-C	B-C
Preparatory Lane Change Required	11	.478	14	.583	2	.690	0.576	1.543	0.803
Correct Preparatory Lane Change									
Advance Sign -- Exit Direction	11	.478	13	.542	20	.690	0.435	1.543	1.106
Exit Direction -- Exit Sign	0	.000	1	.042	0	.000	0.990	---	1.110
Exit Sign -- Gore	0	.000	0	.000	0	.000	---	---	---
Incorrect Preparatory Lane Change									
Advance Sign -- Exit Direction	0	.000	0	.000	0	.000	---	---	---
Exit Direction -- Exit Sign	0	.000	0	.000	0	.000	---	---	---
Exit Sign -- Gore	0	.000	0	.000	0	.000	---	---	---

diagrammatic sign at the exit direction sign location. However, only the Diagrammatic II group was presented a diagrammatic sign at the right exit ramp location. Furthermore, only the Diagrammatic II signing condition employed diagrammatic signs at the two exit signs at the left exit.

There were a number of significant differences between the experimental groups on the IIT measure. The results for this measure are shown in Table 6-15. It took drivers in the Diagrammatic II group approximately 3.1 seconds longer to interpret the information on the 1 mile advance sign. On the other hand, there were no significant differences between the groups at the exit direction sign. The diagrammatic signs at the right ramp, however, required approximately 1.3 seconds longer on the average to interpret in comparison to the conventional sign. Furthermore, the sign at this location for the Diagrammatic I group showed the same increase in average IIT even though this sign exhibited a conventional format. The results of the first left exit sign again showed an increase on the IIT measure under the two diagrammatic conditions. None of the statistical comparisons were significant, however, at the second left exit sign.

There were also significant differences between signing conditions on the average velocity control measure. These results are presented in Table 6-16. There were no differences between the signing conditions in average velocity at the advance sign. However, at the exit direction sign there was a significant increase in average velocity under the Diagrammatic II condition. The results also indicated an increase in average velocity for this group at the right exit sign and first left exit sign. None of the differences between groups were significant for the second left exit sign. As far as the velocity noise measure was concerned, none of the statistical comparisons reached significance (Table 6-17).

The proportion of correct and incorrect preparatory lane change results in Table 6-18 did reveal significant differences between the signing conditions, however. There was a dramatic increase in the proportion of correct preparatory lane changes at the advance sign under the Diagrammatic II condition. There was a corresponding decrease in proportion of incorrect preparatory lane changes between the advance sign and exit direction sign under this condition. Figure 6-18 shows the pattern of lane change movement in the interchange approach area. It is apparent that the Diagrammatic II group exhibited optimal lane change behavior, but the conventional and Diagrammatic I groups demonstrated counter-productive lange change behavior.

There were no differences between the signing conditions in recorded proportions of erratic maneuvers and driver exiting errors at this interchange approach (see Tables 6-23 and 6-24 on pages 130 - 131).

Partial Cloverleaf (Interchange A, Northbound)

Presented in Figures 6-19 through 6-21 are diagrams of the partial cloverleaf interchange where drivers exited under the experimental signing conditions. A conventional 1 mile advance sign was presented for all three groups. The Diagrammatic I condition had a diagrammatic sign at only

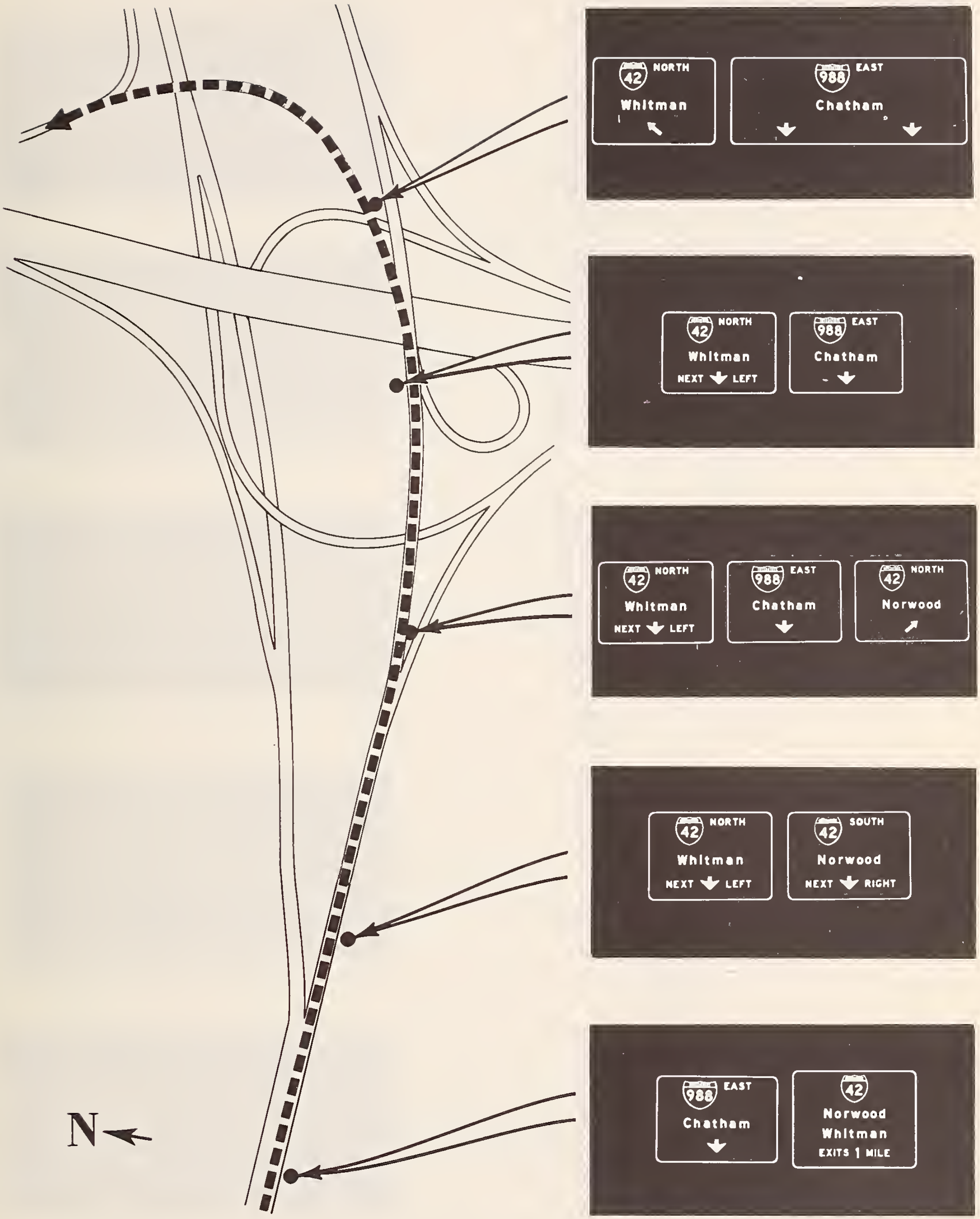

Figure 6-15. Eastbound approach to Interchange C (conventional signing).

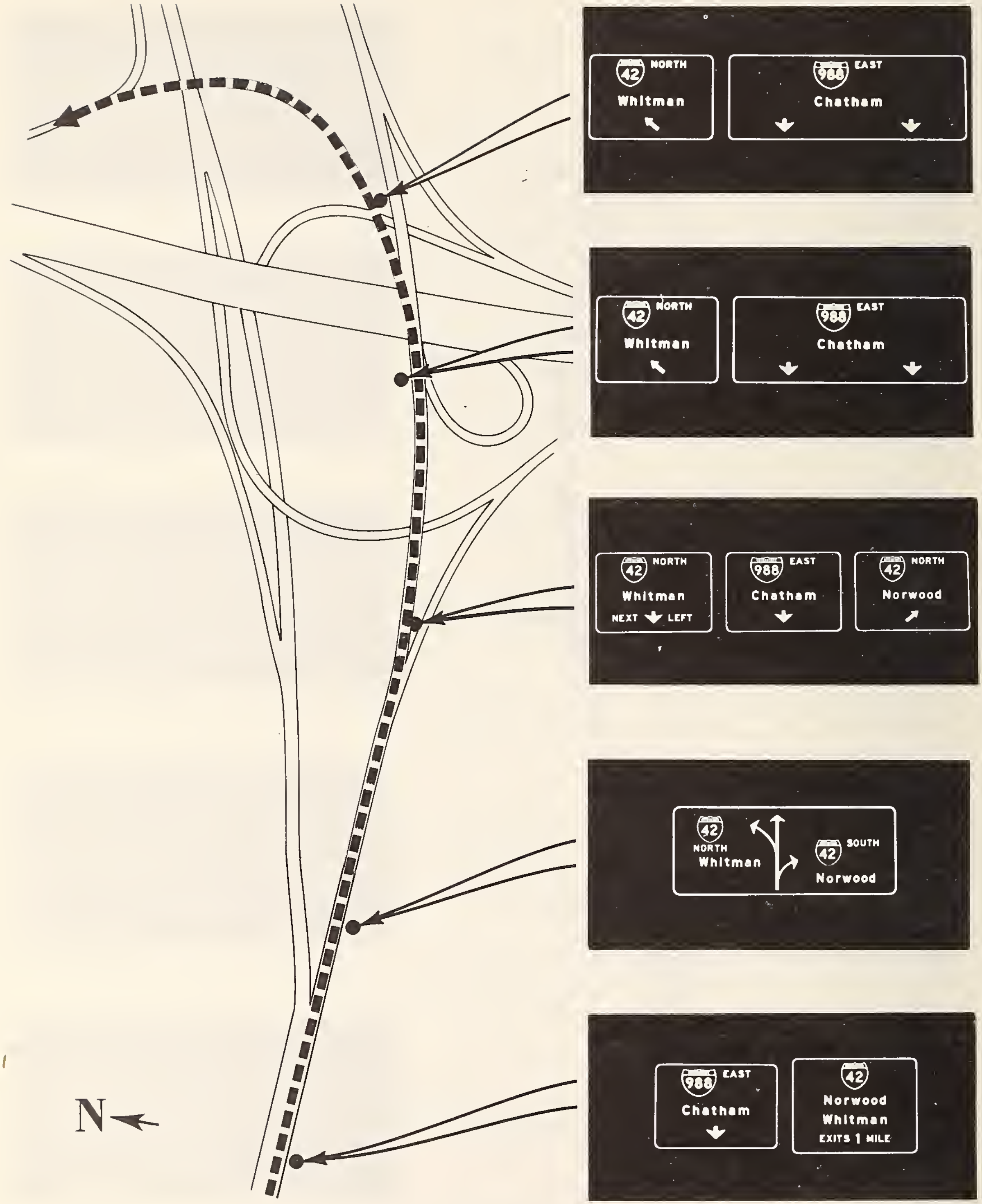

Figure 6-16. Eastbound approach to Interchange C (Diagrammatic I signing).

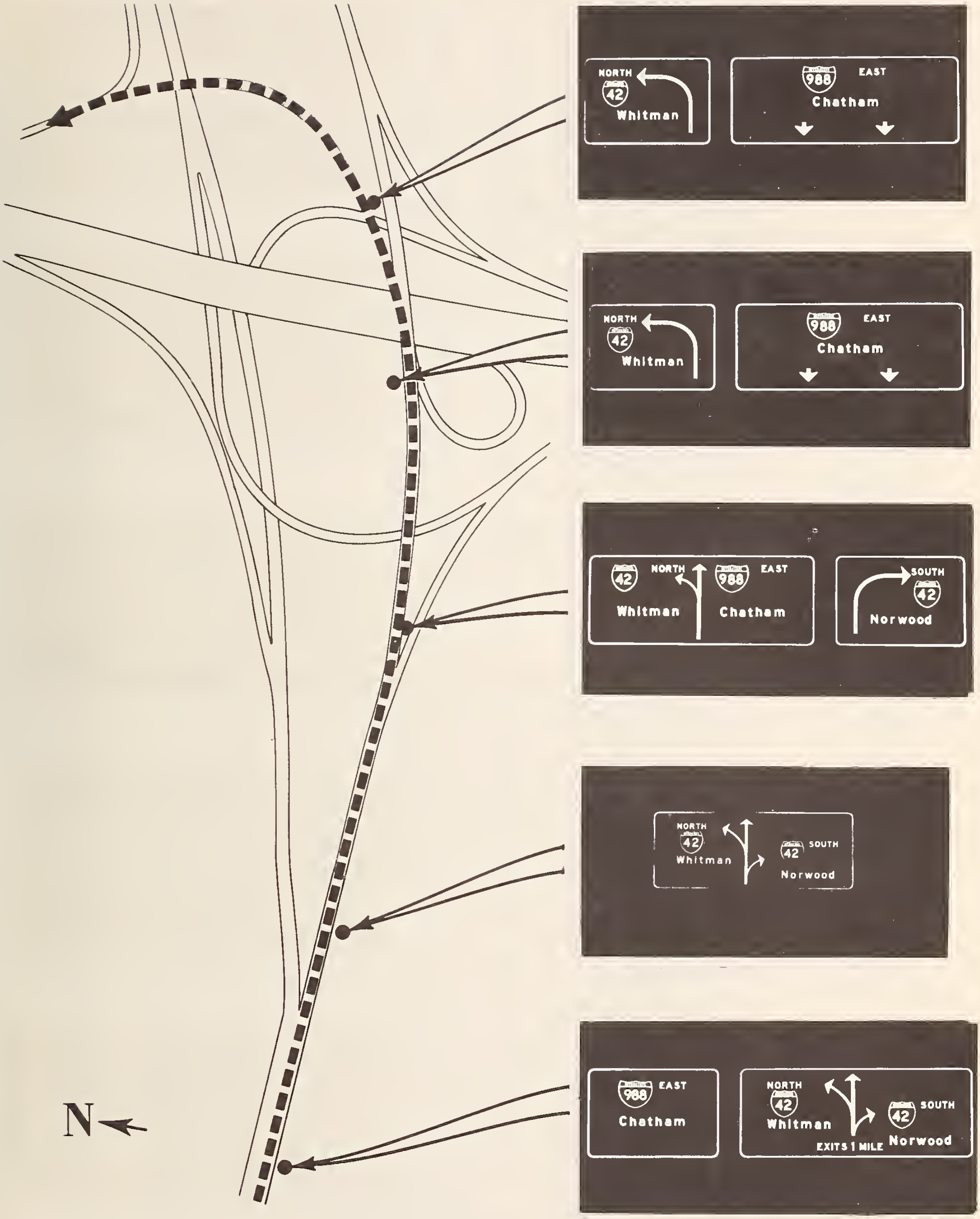

Figure 6-17. Eastbound approach to Interchange C (Diagrammatic II signing).

Table 6-15

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT EASTBOUND APPROACH TO INTERCHANGE C (LEFT EXIT)

	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Sign Type	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	23	3.96	1.33	26	3.82	1.10	28	6.98	3.00	0.378	4.796*	5.208*
Exit Direction	21	5.77	3.73	27	6.23	3.56	28	5.33	2.37	0.435	0.471	1.100
Right Exit	23	3.45	1.16	27	4.70	2.32	28	4.80	2.23	2.458*	2.787*	0.172
First Left Exit	23	2.82	0.83	27	4.13	1.92	28	3.18	1.12	3.224*	1.336	2.234*
Second Left Exit	23	2.65	1.09	26	3.29	1.59	28	3.19	1.51	1.654	1.428	0.227

* $P < .025$ (1 tail test)

Table 6-16

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR AVERAGE VEHICULAR VELOCITY WITHIN SIGN INFLUENCE PERIODS
AT EASTBOUND APPROACH TO INTERCHANGE C (LEFT EXIT)

Condition	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Eastbound Baseline	25	50.8	9.6	27	45.7	7.5	28	50.7	13.0	2.132*	0.021	1.772
Advance Sign	25	50.1	8.7	27	46.8	8.0	28	50.7	11.7	1.395	0.238	1.451
Exit Direction Sign	25	43.2	6.3	27	43.4	4.5	28	48.5	7.4	0.081	2.780*	3.109*
Right Exit Direction Sign	25	46.1	5.7	27	43.4	4.5	28	48.0	8.6	1.857	0.983	2.497*
First Exit Sign	24	48.7	7.7	27	44.8	5.3	28	49.5	8.2	2.073*	0.358	2.508*
Second Exit Sign	24	44.6	4.5	26	43.6	5.2	26	45.6	5.2	0.676	0.736	1.342

* $P < .025$ (2 tail test)

Table 6-17

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR VEHICULAR VELOCITY NOISE WITHIN SIGN INFLUENCE PERIODS
AT EASTBOUND APPROACH TO INTERCHANGE C (LEFT EXIT)

	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Condition	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Eastbound Baseline	25	2.9	2.5	27	2.8	3.6	28	2.1	2.1	0.100	1.215	0.865
Advance Sign	25	2.9	2.8	27	2.1	1.8	28	3.7	3.5	1.203	0.959	2.168
Exit Direction Sign	25	3.0	2.2	27	2.5	2.1	28	3.1	2.7	0.815	0.166	0.937
Right Exit	25	2.9	1.8	27	2.3	1.4	28	2.0	1.8	1.348	1.963	0.841
First Left Exit	24	2.5	1.9	27	2.0	2.0	28	2.4	1.6	0.915	0.194	0.811
Second Left Exit	24	2.6	2.3	26	2.9	2.4	26	3.6	2.6	0.449	1.424	0.981

Table 6-18

PROPORTION OF CORRECT AND INCORRECT LANE CHANGES AND Z VALUES AT EASTBOUND APPROACH TO INTERCHANGE C (LEFT EXIT)

Interchange Approach Zone	(A) Conv. N	(A) Conv. Lane Change (Prop)	(B) Diag. I N	(B) Diag. I Lane Change (Prop)	(C) Diag. II N	(C) Diag. II Lane Change (Prop)	Z Value A-B	Z Value A-C	Z Value B-C
Preparatory Lane Change Required	11	.579	16	.800	21	.750	1.495	1.235	0.406
Correct Preparatory Lane Change									
Advance Sign -- Exit Direction	0	.000	1	.050	13	.464	0.987	3.492*	3.113*
Exit Direction -- Right Exit Sign	13	.684	8	.400	5	.178	1.780	3.500*	1.702
Right Exit Sign -- 1st Left Exit	5	.263	6	.300	5	.178	0.256	0.695	0.987
1st Left Exit -- 2nd Left Exit	1	.053	3	.150	0	.000	1.002	1.227	2.117
2nd Left Exit -- Gore	0	.000	0	.000	0	.000	---	---	---
Incorrect Preparatory Lane Change									
Advance Sign -- Exit Direction	19	.421	20	.200	28	.107	1.495	2.494*	0.899
Exit Direction -- Right Exit Sign	0	.000	0	.000	0	.000	---	---	---
Right Exit Sign -- 1st Left Exit Sign	0	.000	0	.000	0	.000	---	---	---
1st Left Exit Sign -- 2nd Left Exit Sign	0	.000	0	.000	0	.000	---	---	---
2nd Left Exit Sign -- Gore	0	.000	0	.000	0	.000	---	---	---

* $P < .05$ (2 tail test)

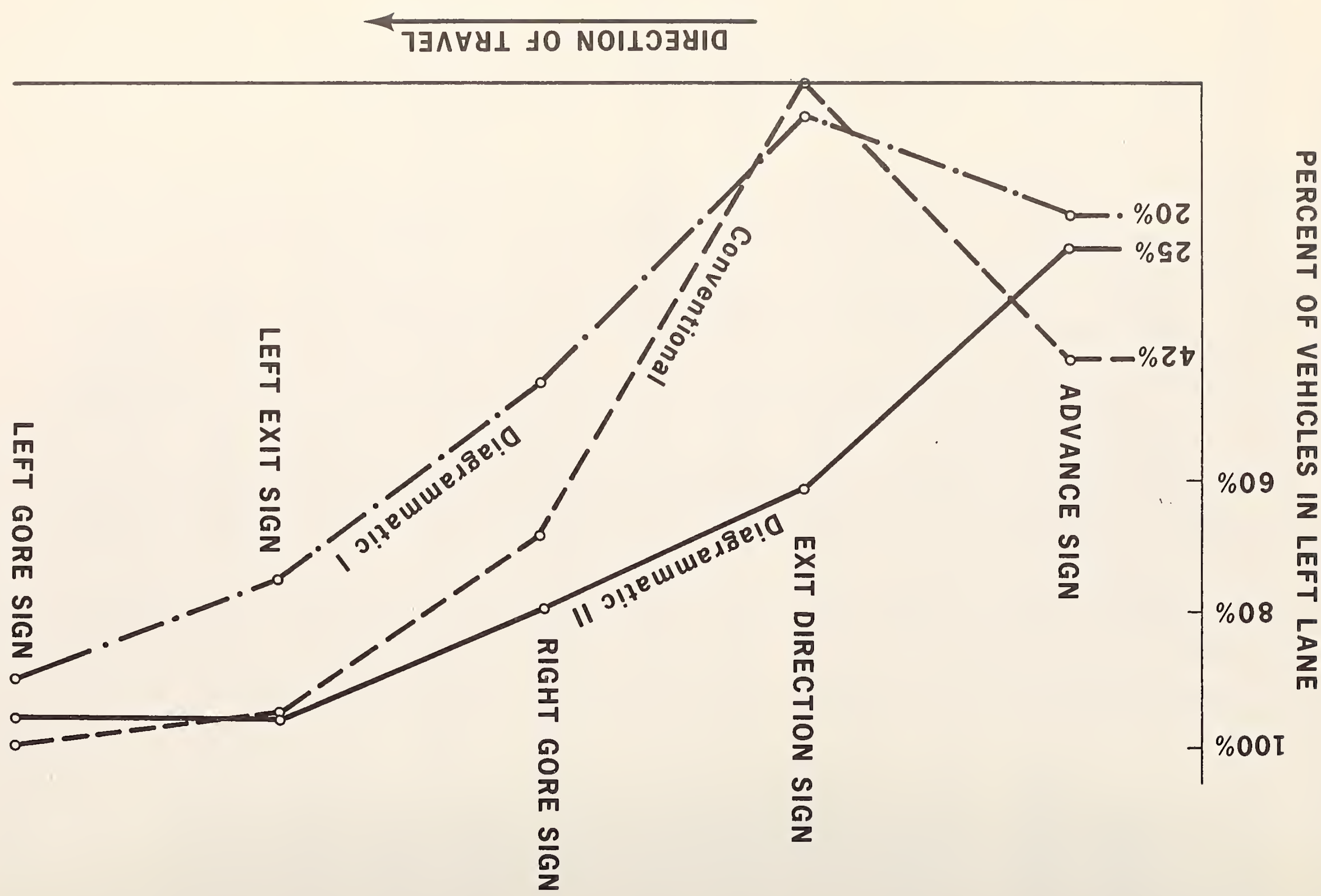

Figure 6-18. Percentage of vehicles in left lane (correct exiting lane) on eastbound approach to Interchange C.

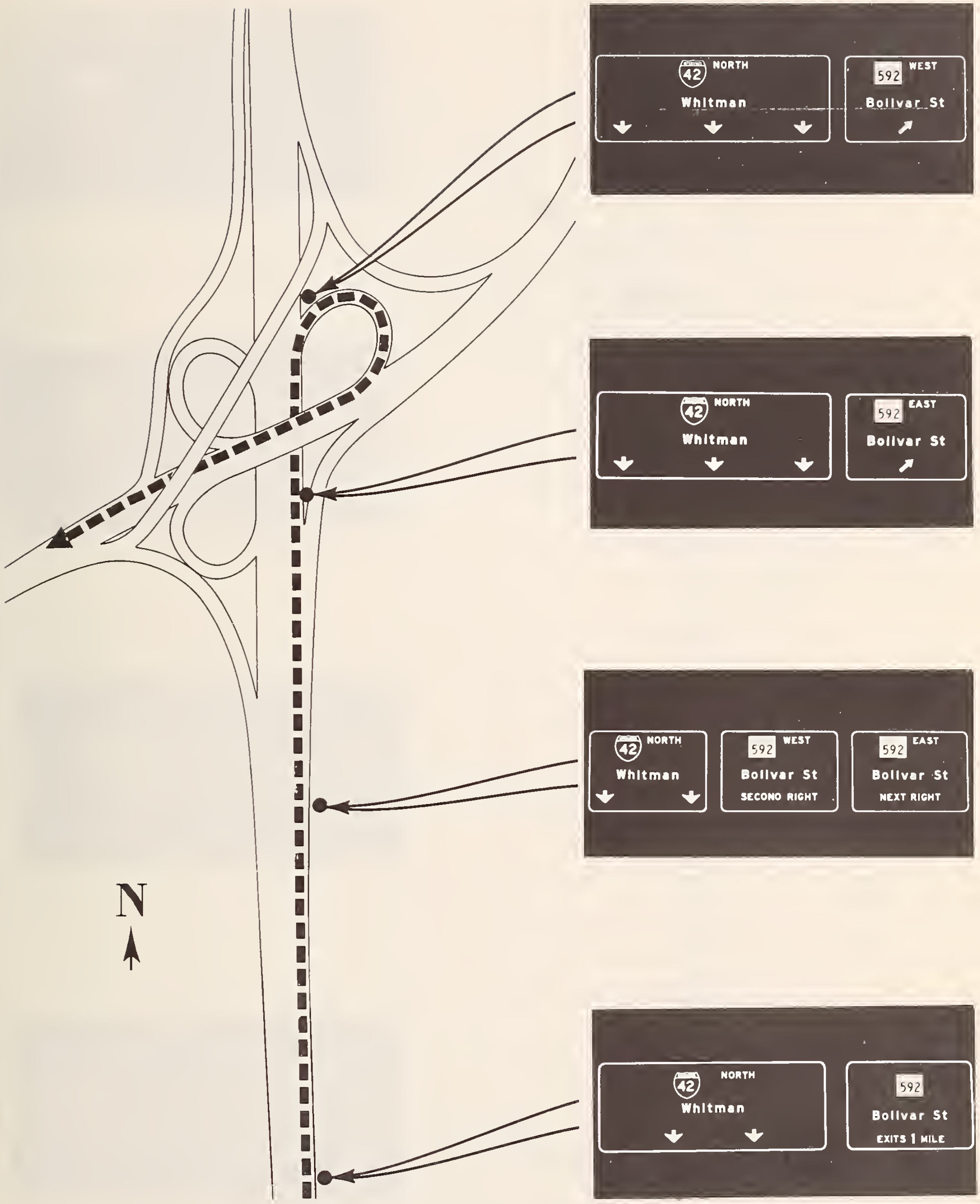

Figure 6-19. Northbound approach to Interchange A (conventional signing).

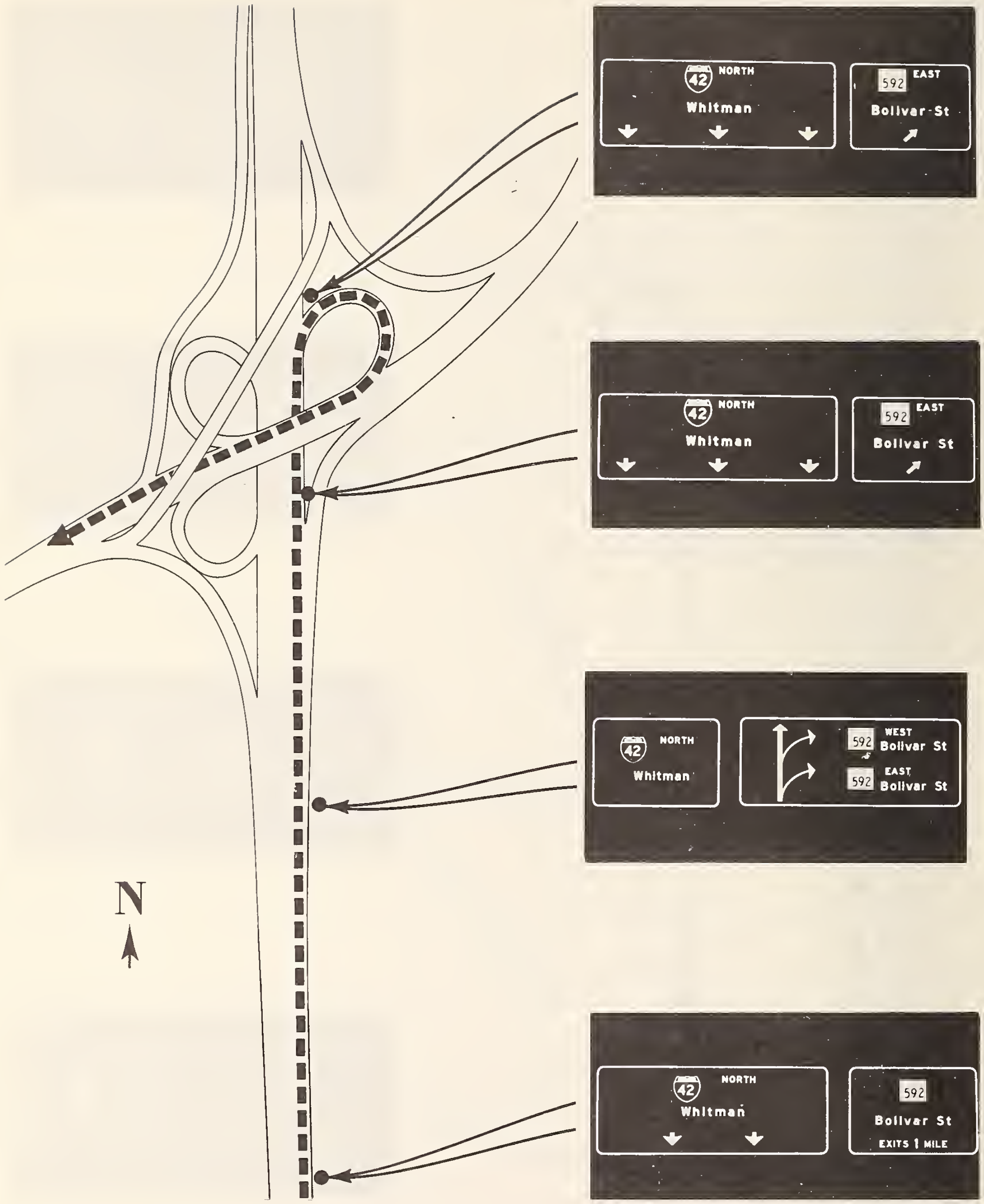

Figure 6-20. Northbound approach to Interchange A (Diagrammatic I signing).

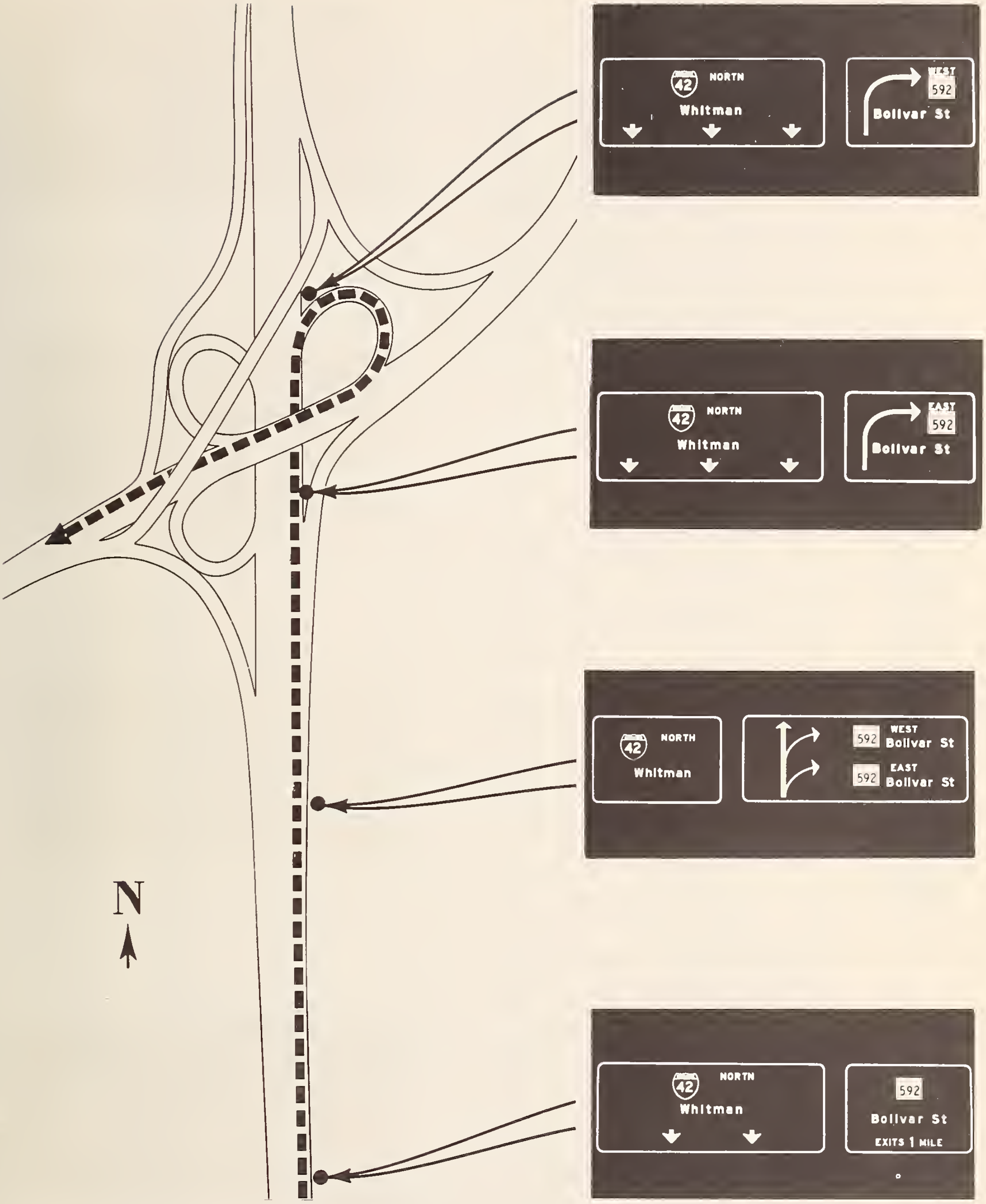

Figure 6-21. Northbound approach to Interchange A (Diagrammatic II signing).

Table 6-19

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT NORTHBOUND APPROACH TO INTERCHANGE A (CLOVERLEAF)

Sign Type	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	24	3.06	1.21	26	3.53	1.57	26	3.63	0.94	1.212	1.851	0.264
Exit Direction	24	4.15	2.18	27	4.75	2.69	27	4.36	2.33	0.884	0.334	0.572
Exit East	24	3.78	2.23	27	4.16	2.72	28	3.37	1.57	0.559	0.746	1.318
Exit West	23	2.50	2.10	27	2.42	0.84	24	2.60	1.87	0.170	0.177	0.438

* P < .025 (1 tail test)

Table 6-20

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR AVERAGE VEHICULAR VELOCITY WITHIN SIGN INFLUENCE PERIODS
AT NORTHBOUND APPROACH TO INTERCHANGE A (CLOVERLEAF)

Condition	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Northbound Baseline	24	58.4	5.2	27	54.2	8.9	28	53.9	9.2	2.080	2.225	0.139
Exit Direction Sign	24	43.6	6.6	27	44.4	6.2	28	43.4	5.6	0.449	0.125	0.637
Exit East Sign	24	42.7	4.6	27	44.9	4.9	28	44.1	3.3	1.654	1.271	0.675
Exit West Sign	23	43.0	1.9	26	43.0	2.4	25	43.3	3.9	0.004	0.315	0.278

Table 6-21

MEANS, STANDARD DEVIATIONS, AND T RATIOS
FOR VEHICULAR VELOCITY NOISE WITHIN SIGN INFLUENCE PERIODS
AT NORTHBOUND APPROACH TO INTERCHANGE A (CLOVERLEAF)

Condition	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	N	Mean (mph)	SD (mph)	A-B	A-C	B-C
Northbound Baseline	24	1.8	2.2	27	2.2	2.3	28	2.2	2.2	0.623	0.550	0.096
Exit Direction Sign	24	3.4	2.7	27	4.1	4.5	28	2.4	1.8	0.716	1.456	1.813
Exit East Sign	24	2.5	2.3	27	2.7	2.2	28	2.6	1.9	0.251	0.125	0.153
Exit West Sign	23	2.6	0.9	26	3.2	2.1	25	3.1	2.1	1.386	1.227	0.112

Table 6-22

PROPORTION OF CORRECT AND INCORRECT LANE CHANGES AND Z VALUES AT NORTHBOUND APPROACH TO INTERCHANGE A (CLOVERLEAF)

Interchange Approach Zone	(A) Conv.		(B) Diag. I		(C) Diag. II		Z Value		
	N	Lane Change (Prop)	N	Lane Change (Prop)	N	Lane Change (Prop)	A-B	A-C	B-C
Preparatory Lane Changes Required	14	.875	16	.842	18	.720	0.277	1.170	0.957
Correct Preparatory Lane Change									
Advance Sign -- Exit Direction	14	.875	12	.632	16	.640	1.641	3.891*	0.070
Exit Direction -- Exit East Sign	0	.000	3	.158	1	.040	1.662	0.810	1.347
Exit East Sign -- Exit West Sign	0	.000	0	.000	1	.040	---	0.810	0.882
Incorrect Preparatory Lane Change									
Advance Sign -- Exit Direction	0	.000	0	.000	0	.000	---	---	---
Exit Direction -- Exit East Sign	0	.000	0	.000	0	.000	---	---	---
Exit East Sign -- Exit West Sign	0	.000	0	.000	0	.000	---	---	---

* P <.025 (2 tail test)

Table 6-23

PROPORTION OF EXITING ERRORS (E E)
AND Z VALUES AT EXITING INTERCHANGES

Interchange	Conv.		Diag. I		Diag. II		Z Value		
	N	E E (Prop)	N	E E (Prop)	N	E E (Prop)	A-B	A-C	B-C
Single Right Exit	0	.000	1	.034	3	.091	0.956	1.578	0.902
Split Ramp Exit	0	.000	2	.069	3	.091	1.364	1.518	0.317
Collector Distributor (Mainstream)	1	.042	3	.103	2	.062	0.848	0.343	0.582
Collector Distributor (Collector Ramp)	3	.125	3	.103	2	.062	0.246	0.812	0.582
Collector Distributor (Total)	4	.167	6	.207	4	.125	0.373	0.441	0.863
Left Exit	0	.000	2	.069	1	.031	1.312	0.874	0.680
Cloverleaf	1	.042	2	.069	2	.064	0.428	0.370	0.690

Table 6-24

PROPORTION OF ERRATIC MANEUVERS (E M) AND Z VALUES AT EXITING INTERCHANGES

Interchange	(A) Conv.		(B) Diag. I		(C) Diag. II		Z Value		
	N	E M (Prop)	N	E M (Prop)	N	E M (Prop)	A-B	A-C	B-C
Single Right Exit	0	.000	0	.000	0	.000	---	---	---
Split Ramp Exit (Mainstream Gore)	0	.000	15	.625	5	.161	4.671*	2.064	3.545*
Split Ramp Exit (Ramp Gore)	5	.208	2	.083	3	.097	1.227	1.164	0.172
Split Ramp Exit (Total)	5	.208	17	.708	8	.258	3.476*	0.430	3.326*
Collector Distributor (Mainstream)	0	.000	0	.000	0	.000	---	---	---
Collector Distributor (Collector Ramp)	1	.045	0	.000	0	.000	1.056	1.140	---
Left Exit	0	.000	1	.053	0	.000	1.039	---	1.227
Cloverleaf	1	.062	0	.000	0	.000	1.047	1.240	---

* P < .025 (2 tail test)

the exit direction sign location. The Diagrammatic II group used diagrammatic signs at the exit direction sign and at the exit sign.

The IIT results are presented in Table 6-19. None of the comparisons reached statistical significance on this measure. Furthermore, none of the comparisons on the two velocity control measures reached statistical significance. These results are shown in Tables 6-20 and 6-21. The lane change results in Table 6-22 show a significant decrease in correct preparatory lane changes between the advance sign and exit direction sign under the two diagrammatic conditions. The proportion of exiting errors and erratic maneuvers remained unchanged under the diagrammatic condition (See Tables 6-23 and 6-24).

Results at Non-Exiting Interchanges

Drivers were required to travel through five interchanges without exiting. The first of these interchanges was interchange B. Figures 6-22 through 6-24 show this interchange's geometrics along with the experimental signing conditions. Presented in Table 6-25 are the results on the IIT measure. One statistical comparison reached significance. It was for the difference between the Diagrammatic groups (B vs C) at the 1 mile advance sign. The diagrammatic sign required approximately 2 seconds longer to interpret than the conventional sign. Because of time constraints, data on driver velocity control, lane changes, erratic and exiting error measure were not analyzed for any of the non-exiting interchanges. Therefore, results on these measures are not included.

Presented in Figures 6-25 through 6-27 are diagrams showing the geometry and test signing for the second interchange where the correct navigational path was through the interchange. The interchange was the southbound approach to interchange C. The IIT results in Table 6-26 indicate that there were no significant differences between the signing conditions in average sign IIT.

Interchange E traveling southbound was the third interchange where test drivers were required to make through maneuvers. Figures 6-28 through 6-30 show the test signs and geometric characteristics for this interchange. An examination of the IIT results in Table 6-27 reveals that none of the statistical comparisons were significant. After the drivers reversed direction at interchange F, they then traveled through interchange E again, this time in the northbound direction. As was the case for the southbound approach, none of the IIT differences between groups were significant (Table 6-28) in the northbound direction. The interchange diagrams and signing conditions are shown in Figures 6-31 through 6-33.

The last interchange where drivers made the through maneuver was interchange B, northbound. Figures 6-34 through 6-36 present the test signs. Table 6-29 has one significant T ratio. This was for the west exit sign. The diagrammatic sign used by the Diagrammatic II group had a slightly higher average IIT value.

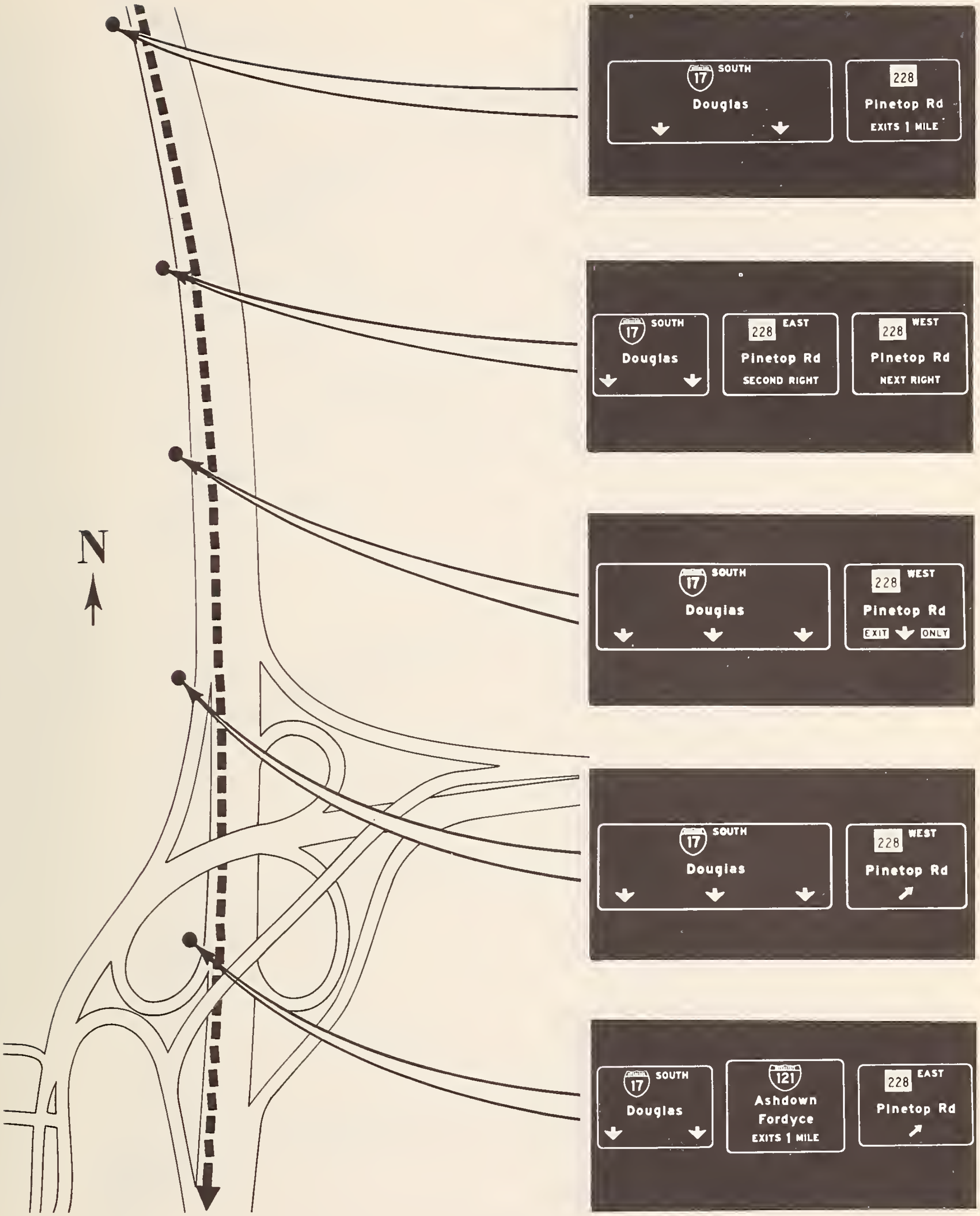

Figure 6-22. Southbound approach to Interchange B (conventional signing).

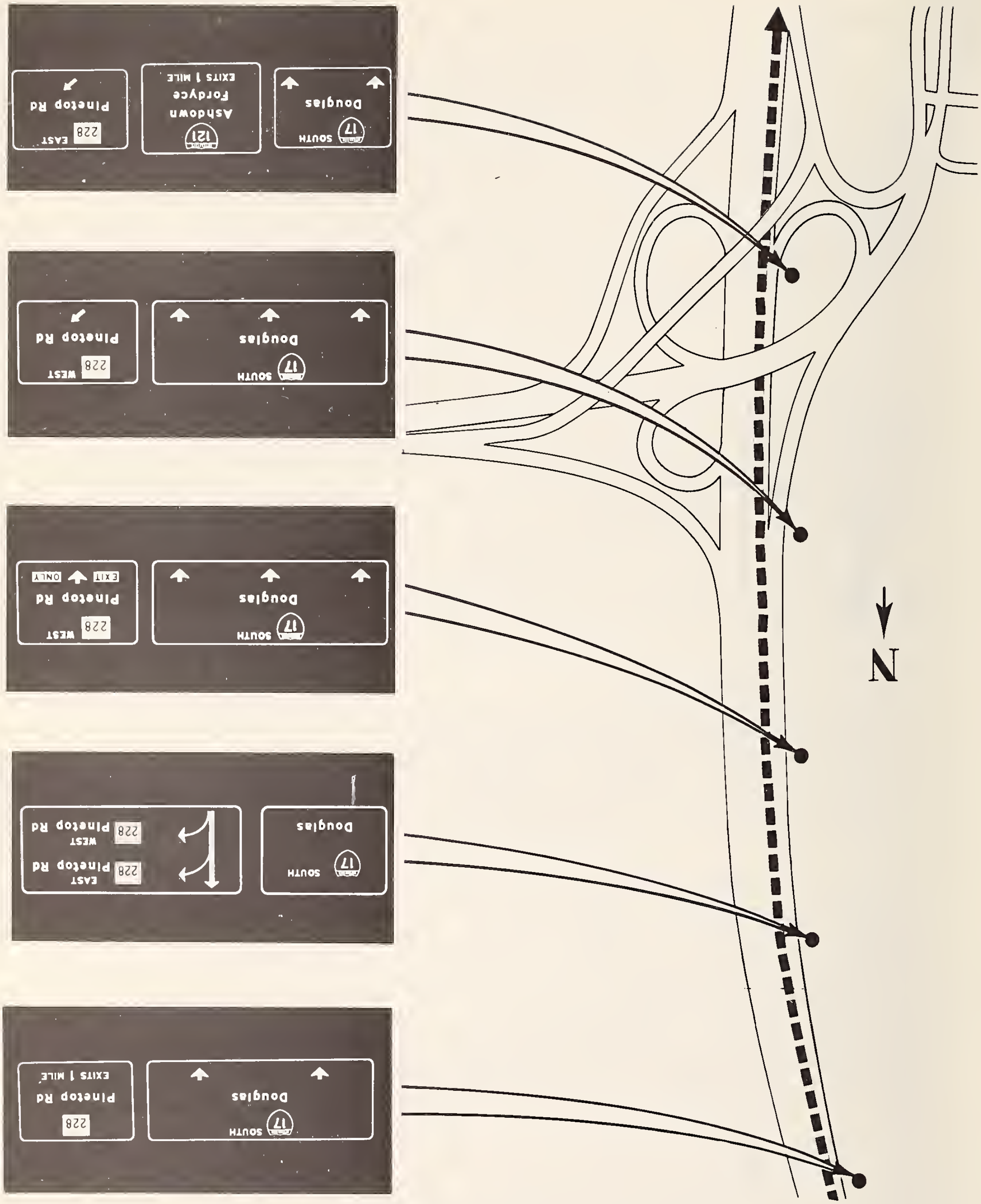

Figure 6-23. Southbound approach to Interchange B (Diagrammatic I signing).

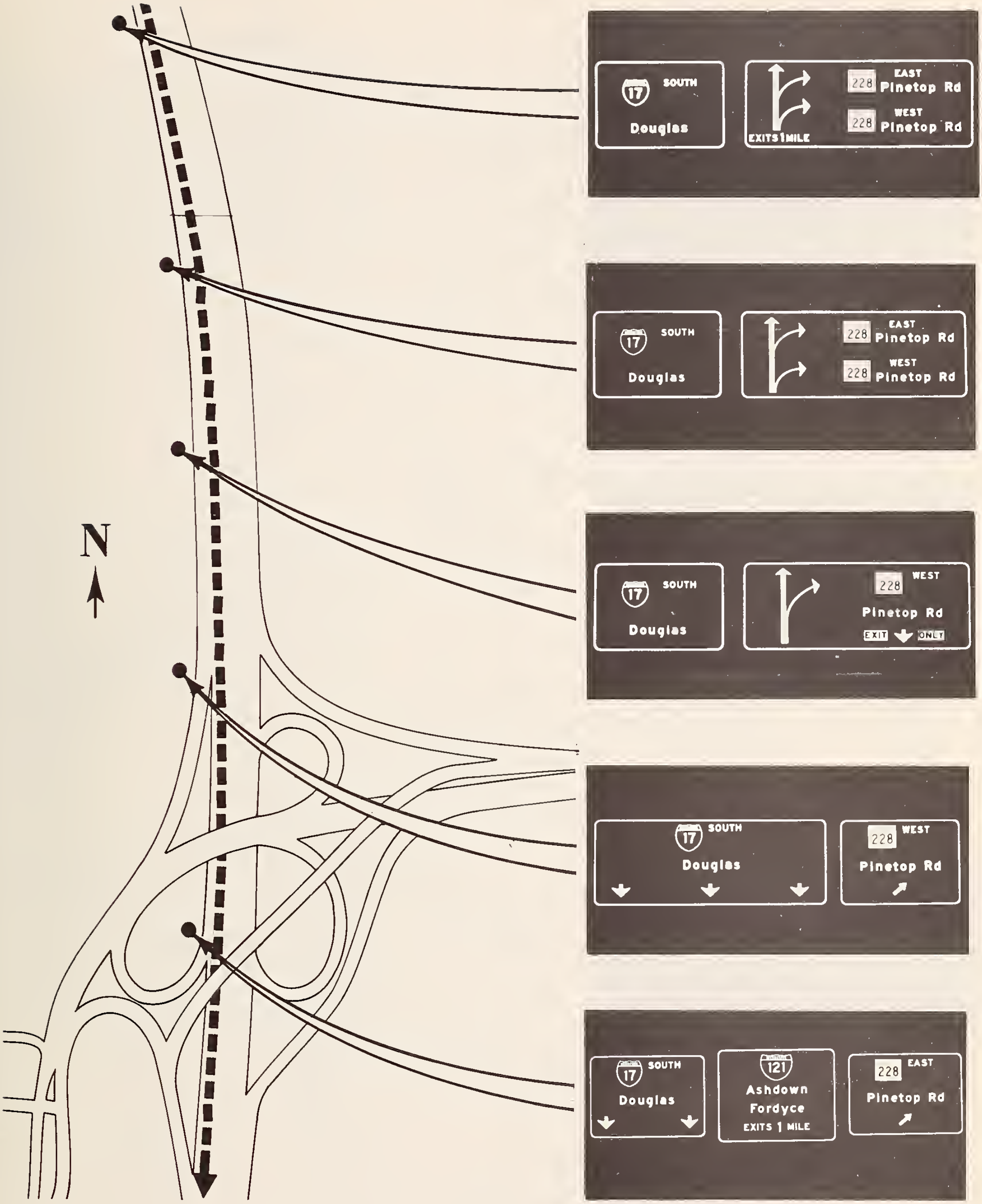

Figure 6-24. Southbound approach to Interchange B (Diagrammatic II signing).

Table 6-25

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT SOUTHBOUND APPROACH TO INTERCHANGE B (CLOVERLEAF)

	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Sign Type	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	20	5.60	2.69	26	5.47	2.85	23	7.62	4.17	0.153	1.913	2.078*
Exit Direction	22	5.28	2.97	27	4.78	2.53	27	4.86	2.98	0.629	0.497	0.105
Exit West (Lane Drop)	23	4.07	2.00	26	3.60	2.13	27	4.51	2.45	0.804	0.690	1.441
Exit West	23	3.51	1.96	27	3.46	1.59	28	3.68	1.28	0.083	0.360	0.547
Exit East	23	4.64	2.21	26	4.31	2.10	28	4.14	1.48	0.530	0.926	0.344

* P<.025 (1 tail test)

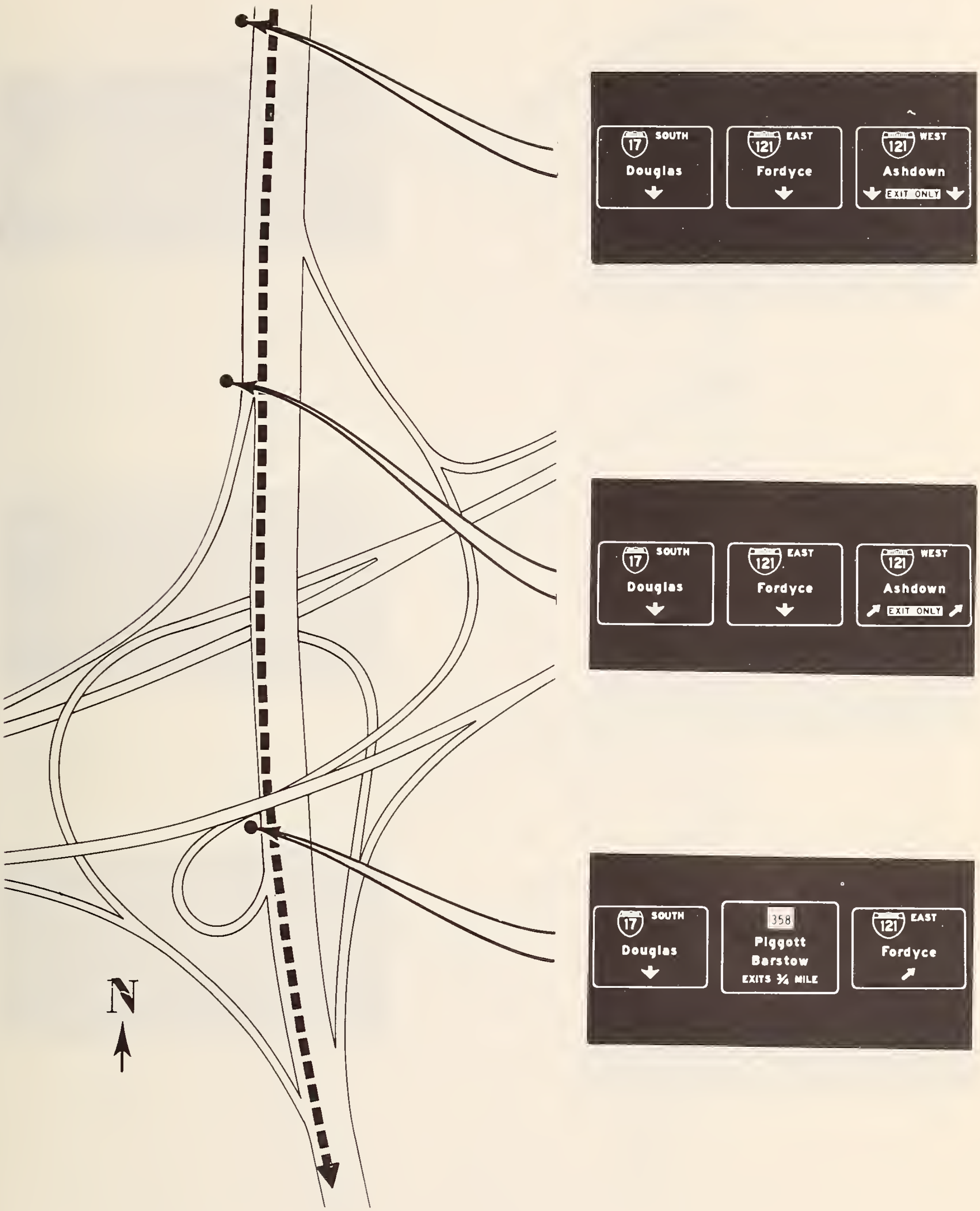

Figure 6-25. Southbound approach to Interchange C (conventional signing).

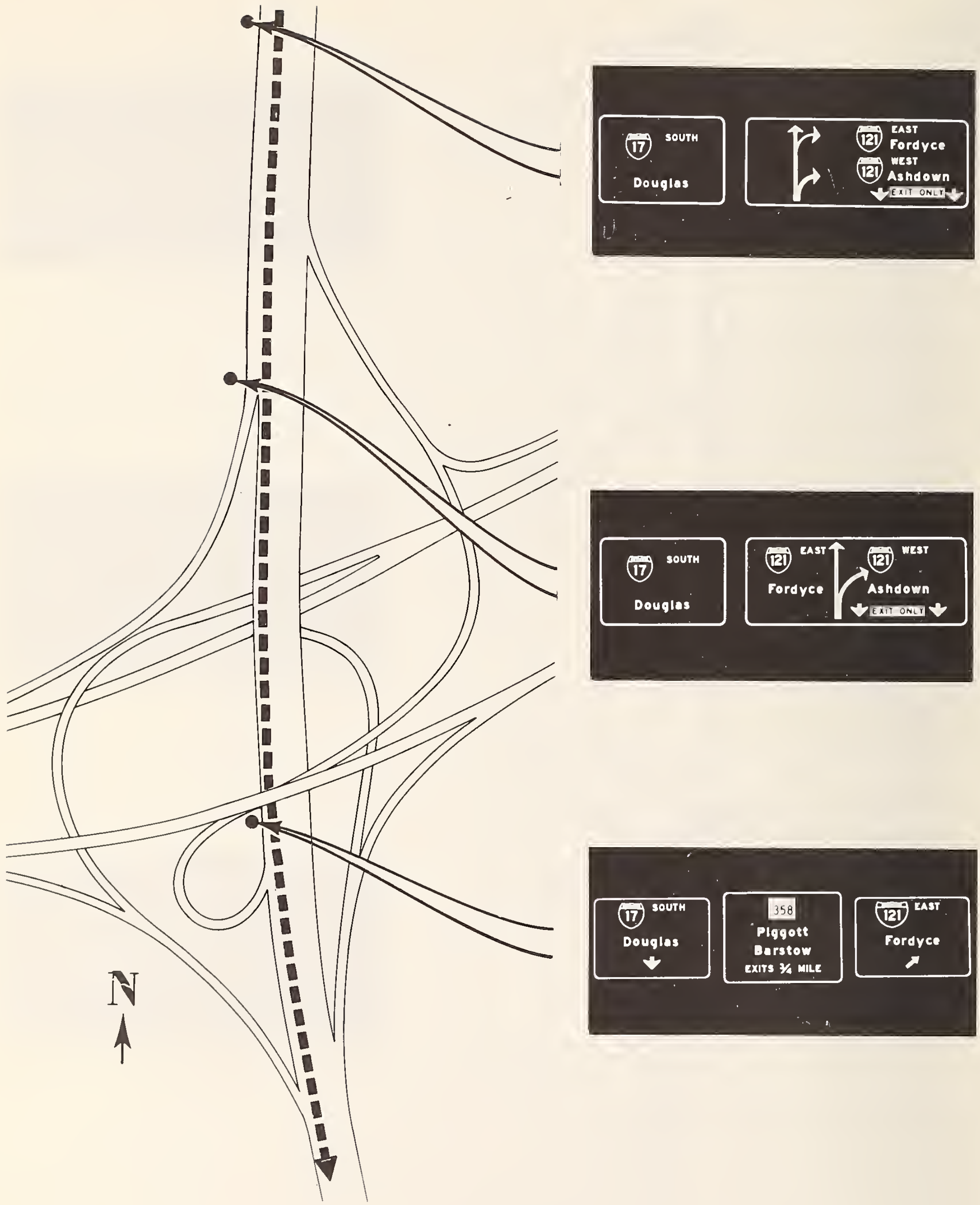

Figure 6-26. Southbound approach to Interchange C (Diagrammatic I signing).

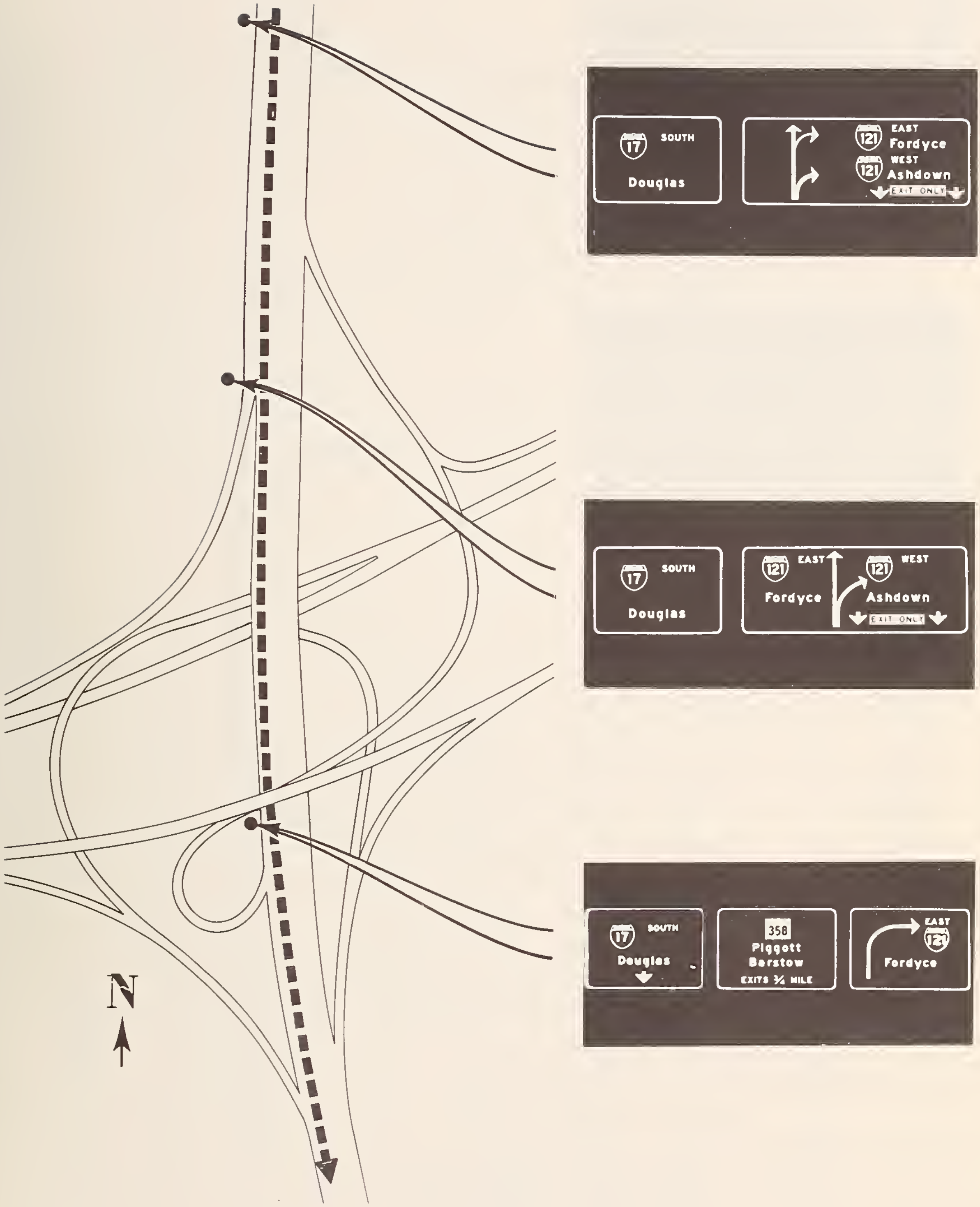

Figure 6-27. Southbound approach to Interchange C (Diagrammatic II signing).

Table 6-26

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT SOUTHBOUND APPROACH TO INTERCHANGE C (CLOVERLEAF)

Sign Type	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	23	4.64	2.21	26	4.31	2.10	28	4.14	1.48	0.530	0.926	0.344
Exit Direction	23	4.33	2.58	26	4.37	2.19	28	4.04	1.43	0.062	0.467	0.638
Exit West (Two Lane Drop)	22	3.81	1.66	26	3.87	1.40	28	3.78	1.50	0.121	0.066	0.214
Exit East	22	4.41	1.83	27	4.11	1.31	28	4.13	1.45	0.643	0.582	0.058

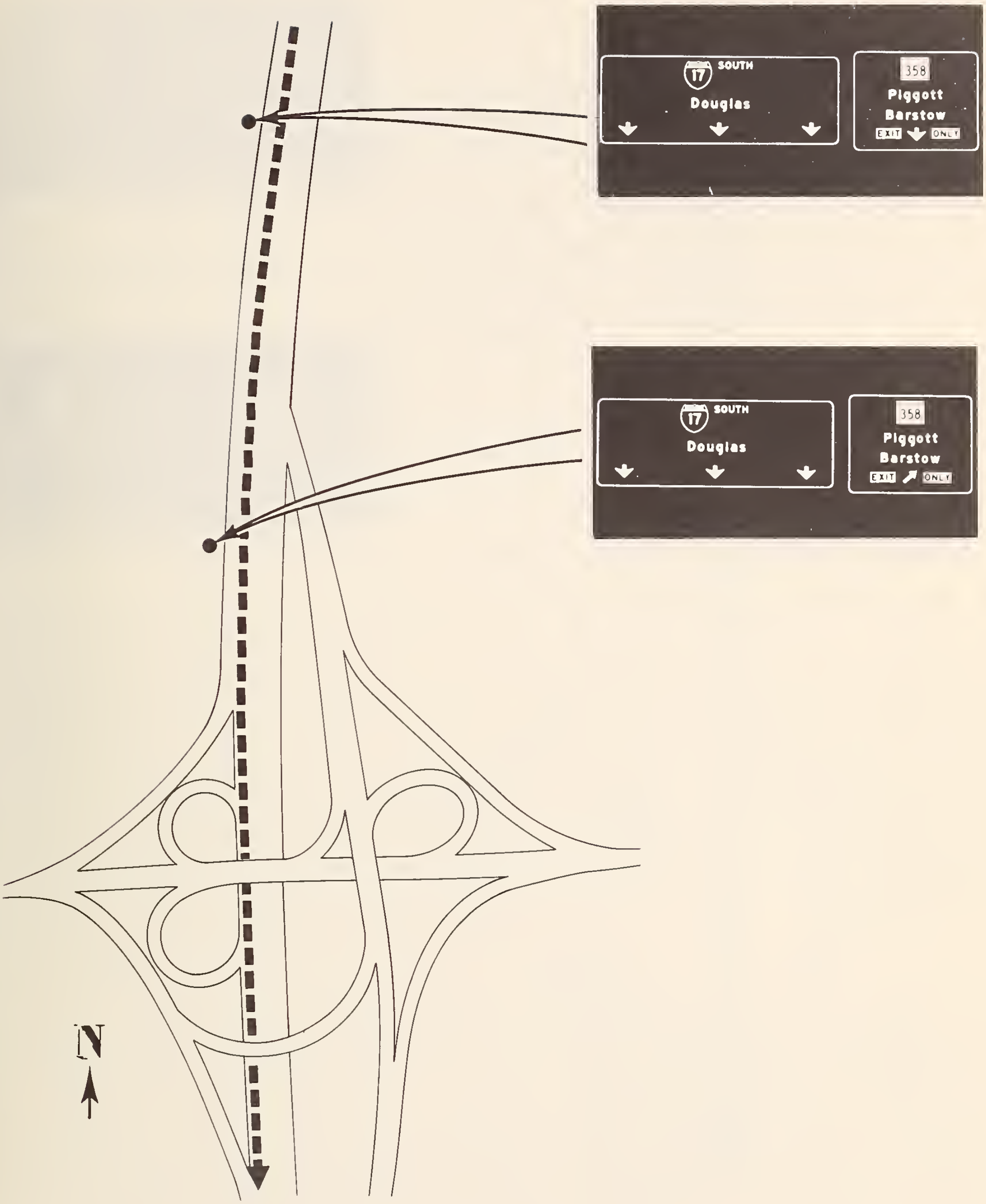

Figure 6-28. Southbound approach to Interchange E (conventional signing).

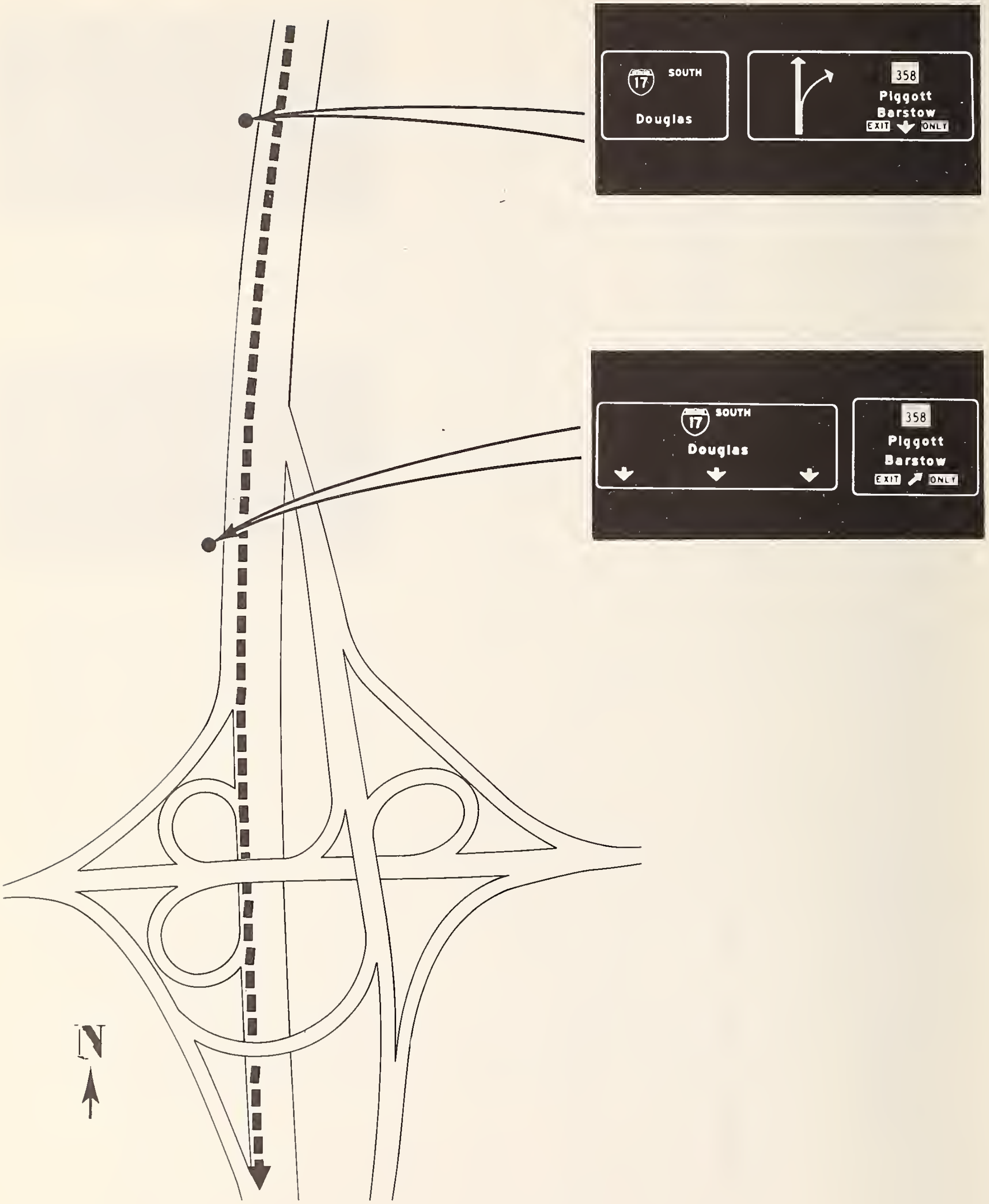

Figure 6-29. Southbound approach to Interchange E (Diagrammatic I signing).

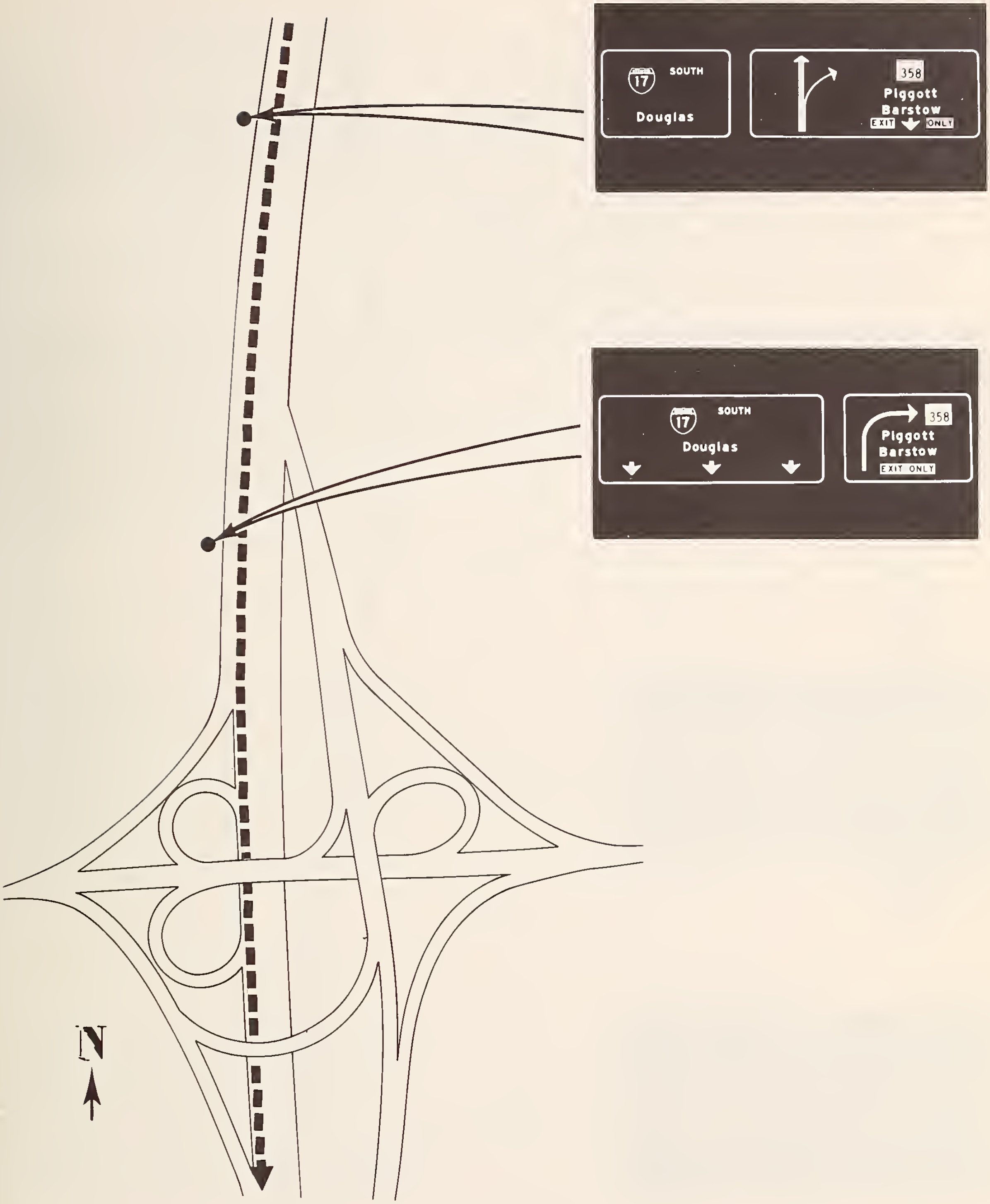

Figure 6-30. Southbound approach to Interchange E (Diagrammatic II signing).

Table 6-27

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT SOUTHBOUND APPROACH TO INTERCHANGE E (SINGLE RIGHT EXIT)

Sign Type	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	22	4.41	1.83	27	4.11	1.31	28	4.13	1.45	0.643	0.582	0.058
Exit (Lane Drop)	23	3.91	1.54	27	3.83	1.22	28	3.54	1.58	0.202	0.850	0.769
Exit	23	3.35	0.92	27	3.22	0.86	28	3.19	0.84	0.517	0.637	0.119

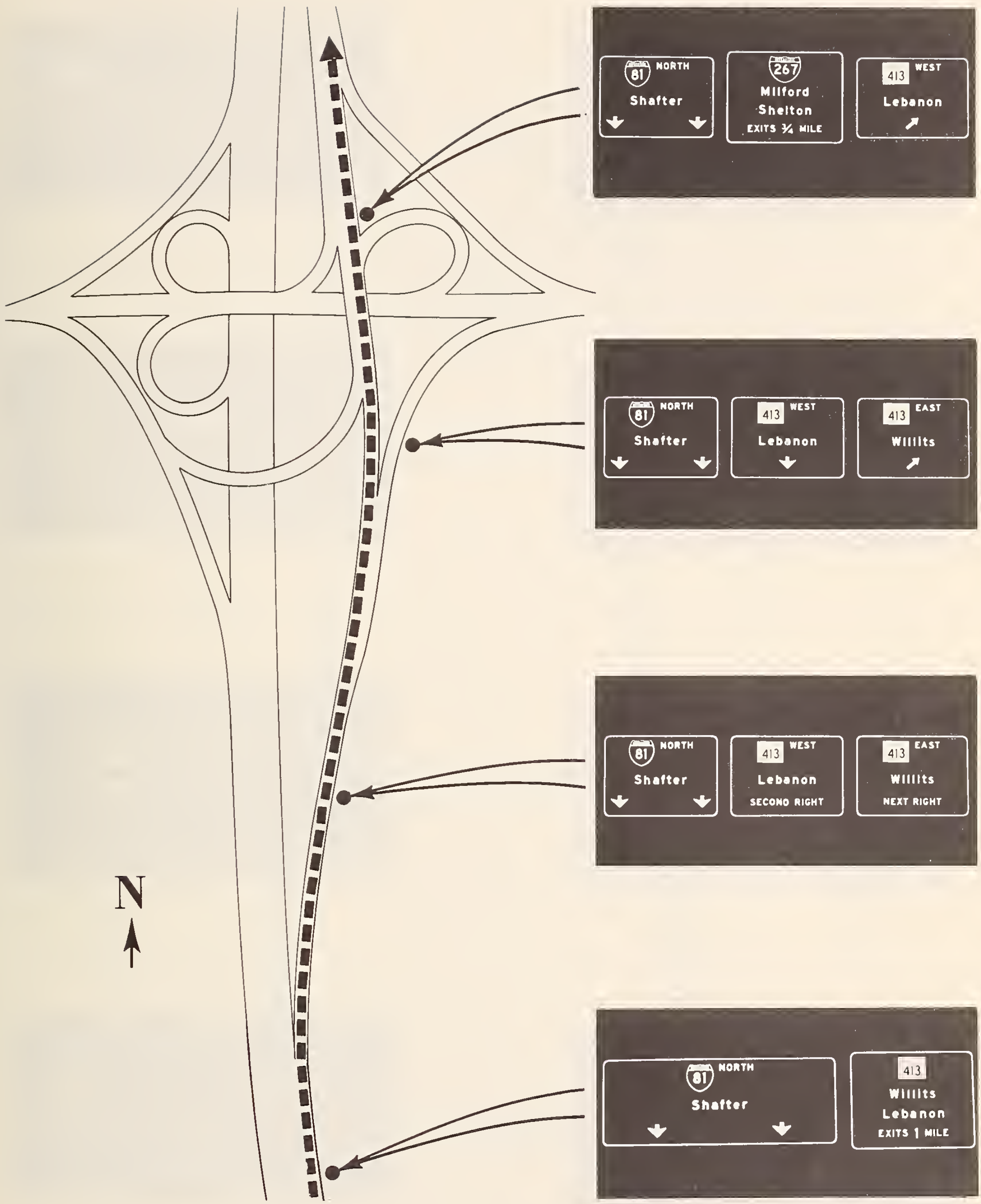

Figure 6-31. Northbound approach to Interchange E (conventional signing).

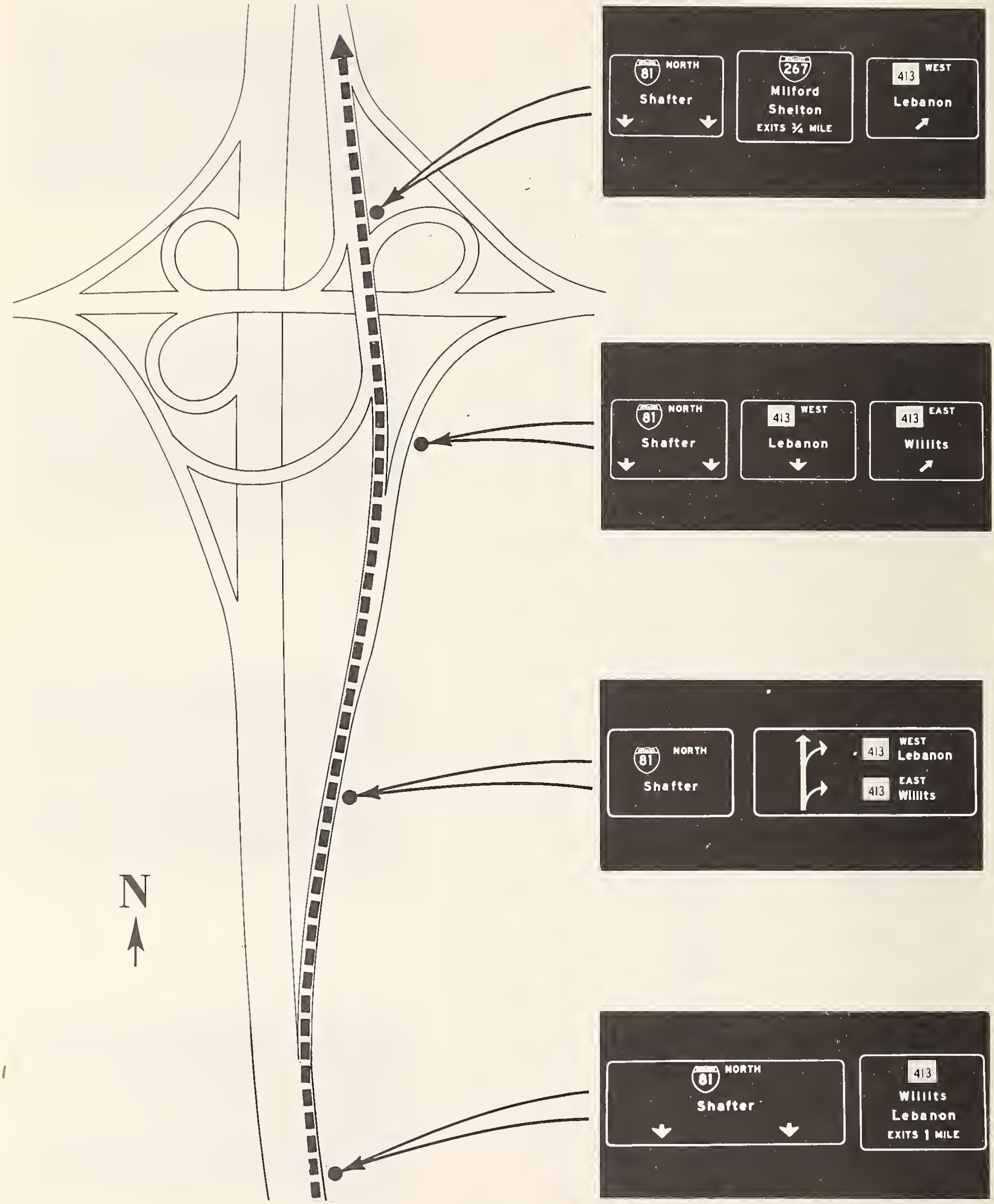

Figure 6-32. Northbound approach to Interchange E (Diagrammatic I signing).

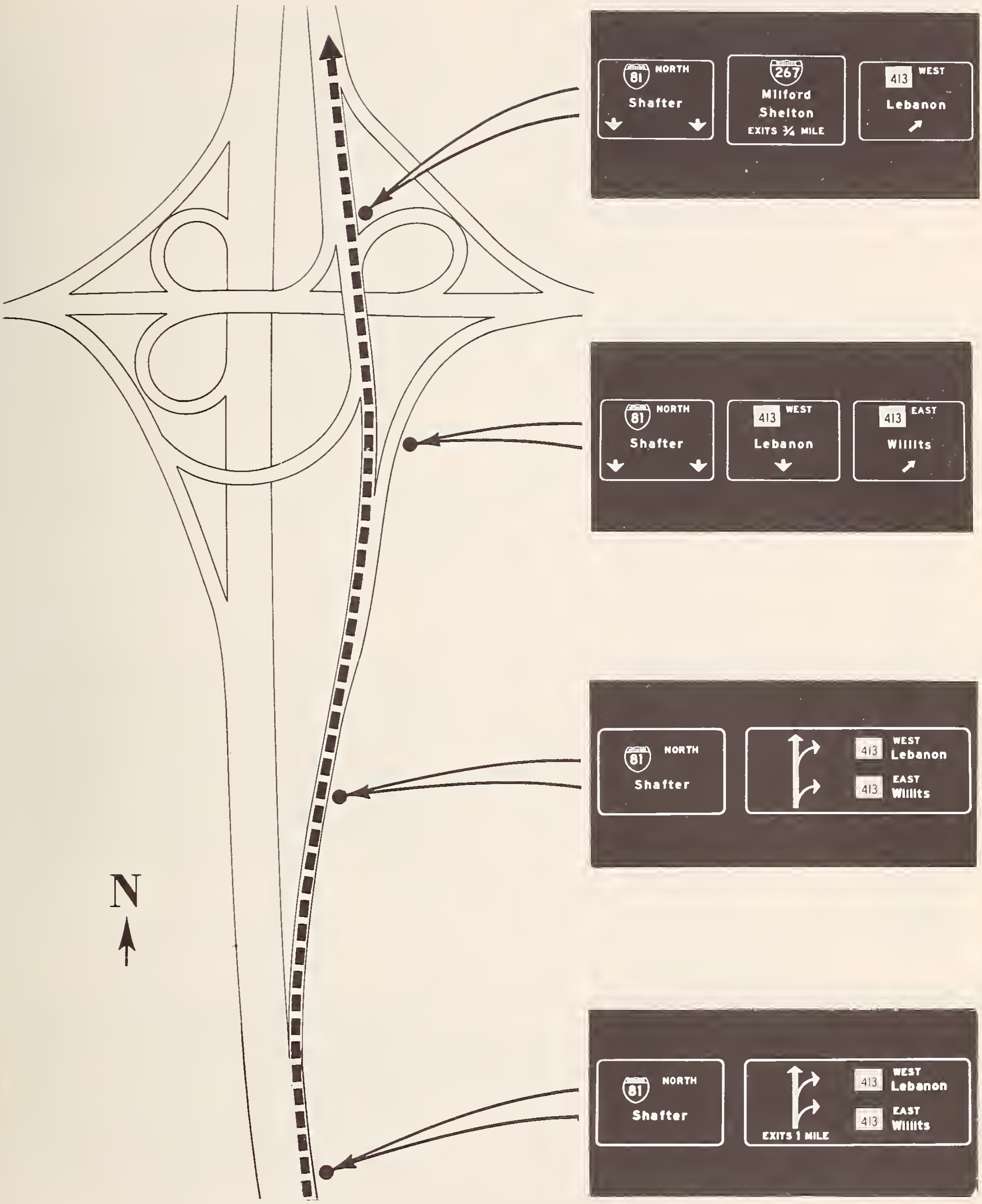

Figure 6-33. Northbound approach to Interchange E (Diagrammatic II signing).

Table 6-28

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT NORTHBOUND APPROACH TO INTERCHANGE E (CLOVERLEAF)

	(A) Cloverleaf			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
Sign Type	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	N	Mean (secs)	SD (secs)	A-B	A-C	B-C
Advance	25	3.82	1.33	27	3.84	1.86	28	3.92	1.28	0.054	0.262	0.162
Exit Direction	25	3.72	1.14	27	3.51	1.03	28	3.40	1.07	0.673	1.054	0.416
Exit East	25	3.42	0.90	27	3.43	1.25	28	3.35	0.89	0.026	0.262	0.247
Exit West	25	4.44	1.94	27	5.17	2.49	28	4.99	1.87	1.185	1.045	0.305

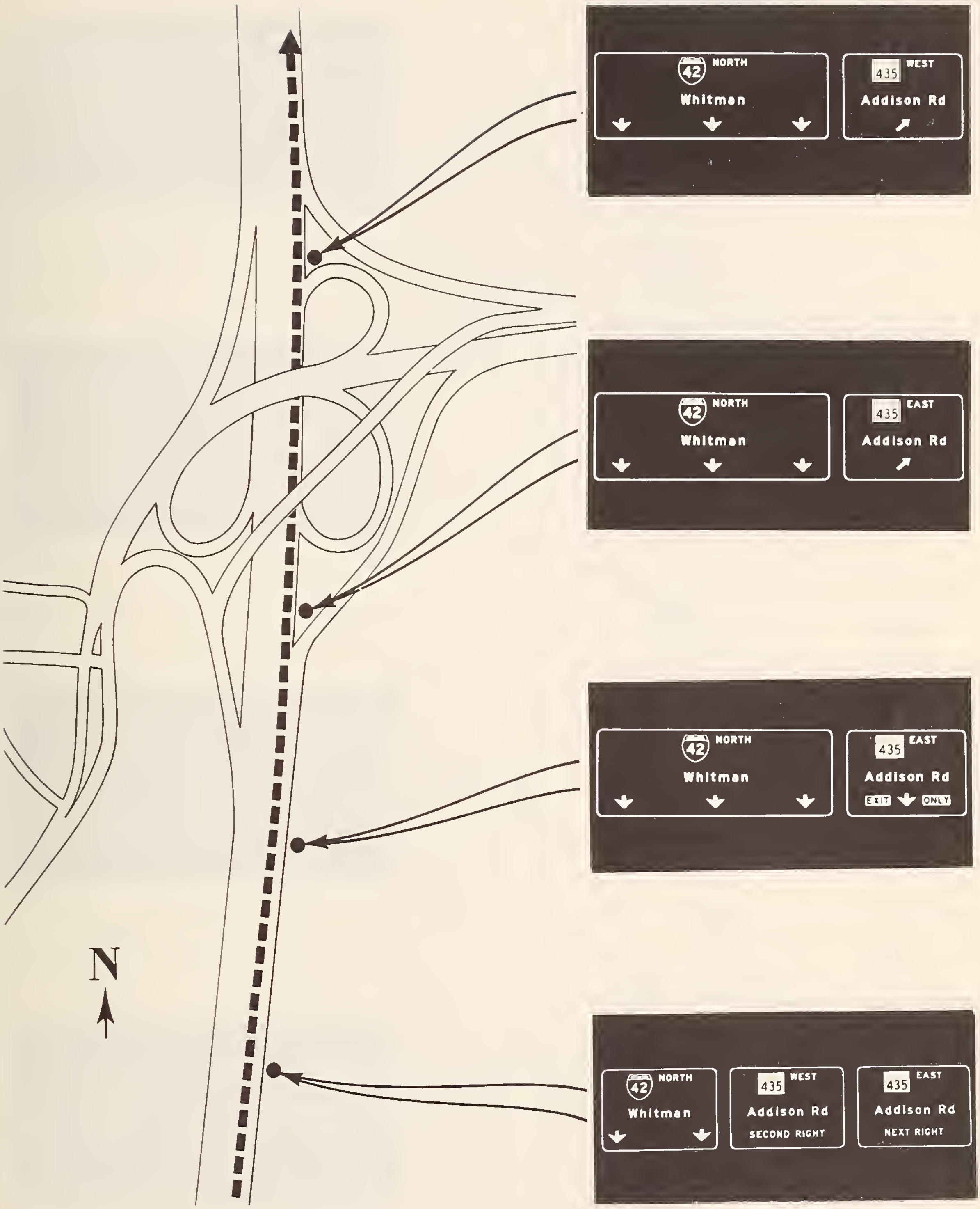

Figure 6-34. Northbound approach to Interchange B (conventional signing).

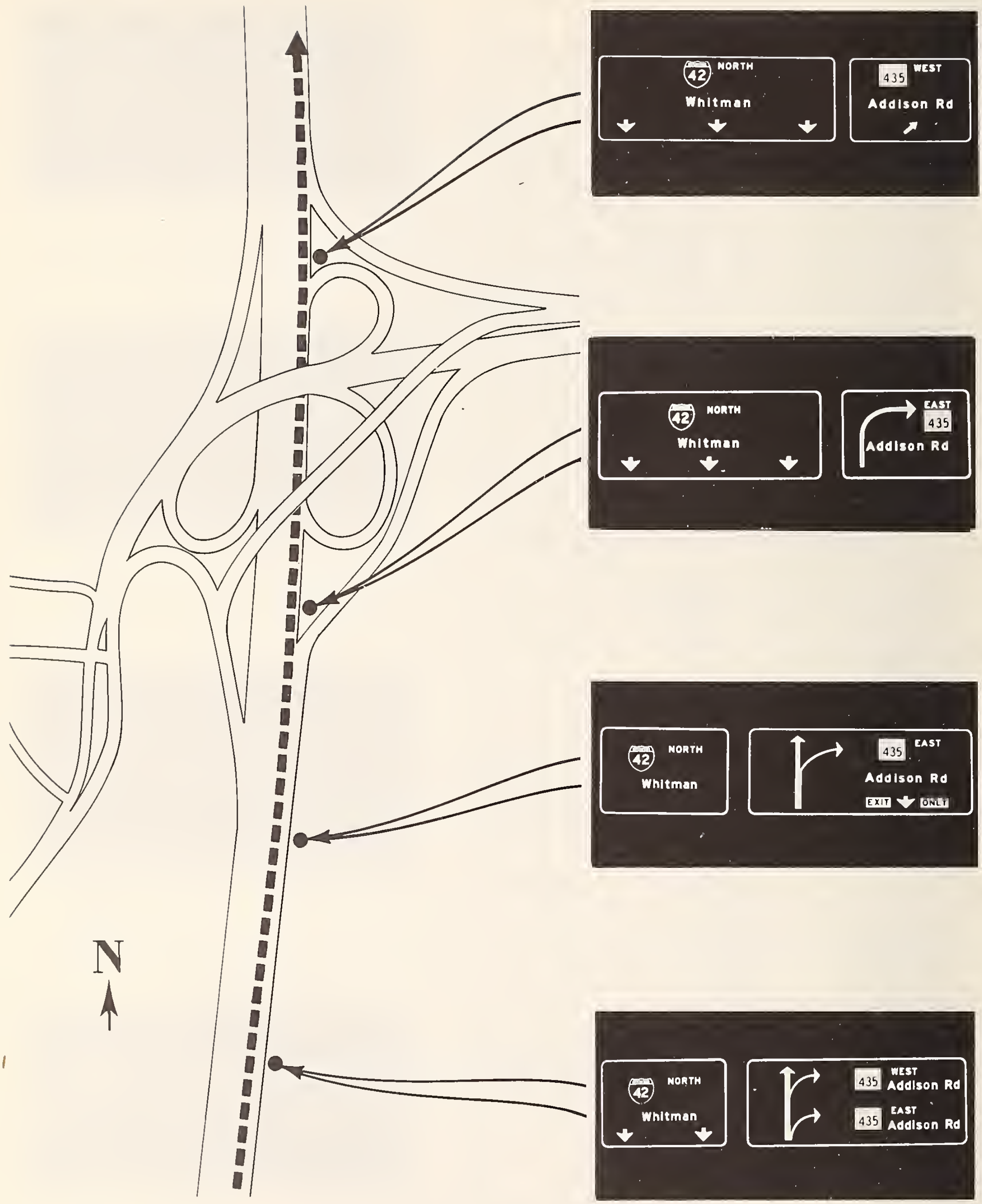

Figure 6-35. Northbound approach to Interchange B
(Diagrammatic I signing).

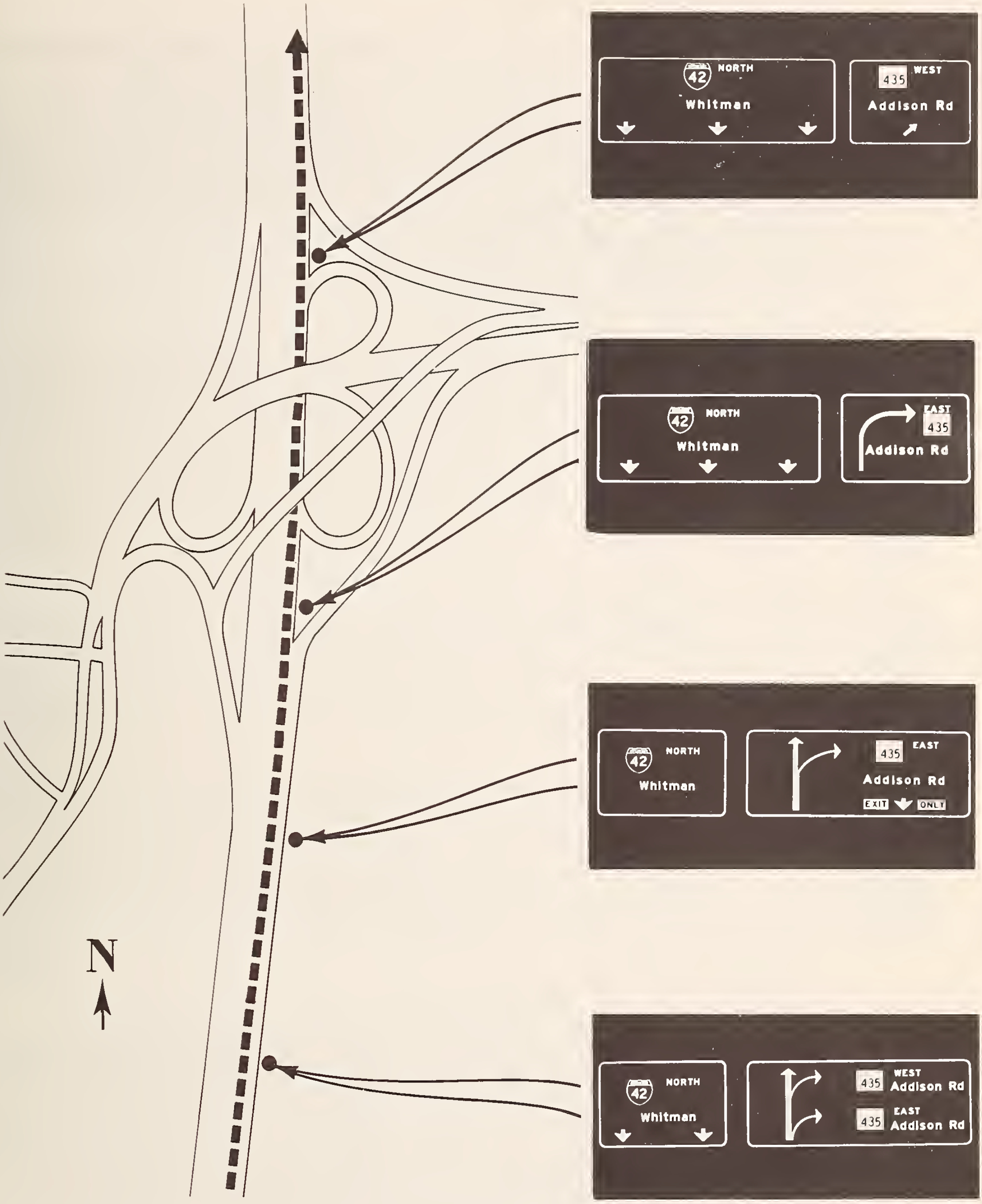

Figure 6-36. Northbound approach to Interchange B
(Diagrammatic II signing).

Table 6-29

MEANS, STANDARD DEVIATIONS, AND T RATIOS FOR INFORMATION INTERPRETATION TIME FOR SIGNS AT NORTHBOUND APPROACH TO INTERCHANGE B (CLOVERLEAF)

Sign Type	(A) Conventional			(B) Diagrammatic I			(C) Diagrammatic II			T Ratio		
	N	(secs)	(secs)	N	(secs)	(secs)	N	(secs)	(secs)	A-B	A-C	B-C
Exit Direction	23	4.89	2.89	27	4.54	2.02	28	4.85	2.39	0.493	0.057	0.521
Exit East (Lane Drop)	24	2.98	1.10	27	2.98	1.14	28	3.66	2.18	0.472	1.457	1.147
Exit East	24	2.62	0.96	27	2.72	0.98	28	2.88	0.86	0.380	1.032	0.645
Exit West	24	2.29	0.41	27	2.53	0.81	28	2.89	1.02	1.378	2.861*	1.445

* $P < .025$ (1 tail test)

Discussion

Single Right Exit (Interchange F, Southbound)

The southbound approach to interchange F was the first occasion where drivers were required to perform an exiting maneuver. Examination of the results based on the performance measures used in the study indicate that only one measure reflected a difference between the experimental signing conditions. This was the IIT measure. The IIT results suggest that the type of diagrammatic sign used here requires more time to interpret than the conventional type. However, the increase in average IIT amounts to little more than a second and is probably of no practical significance.

This finding with regard to the IIT measure was consistent with the results recorded in the McLean study reported in Chapter V. In both studies the magnitude of the average IIT increase with the diagrammatic sign was between 1 and 2 seconds. The two studies used test signs with similar diagrammatic formats. Furthermore, the results for the two velocity control measures, average velocity, and velocity noise, were consistent with results found in the McLean study. In both studies no difference between signing conditions were observed on these measures.

In general the results of this study coupled with the results from the McLean study lead to one conclusion. They indicate that no real benefit in terms of driver performance would be derived from the use of diagrammatic guide signs at interchanges with single right exits. How these results compare to other laboratory and field work will be discussed further in Chapter IX.

Double Lane Drop With Split Ramp (Interchange C, Northbound)

The results at the split ramp interchange indicate that the diagrammatic signs produced a definite degradation in driver performance. This was true for both of the diagrammatic signing conditions. In general, there was a greater proportion of erratic maneuvers, incorrect lane changes, late lane changes close to the ramp gore, and a substantial increase in average sign IIT.

Since the average IIT values for the more complicated diagrammatic signs were always greater than 7 seconds, it is certain that a real sign with this design would introduce substantial disturbance in the traffic stream. The very long IIT value for the sign would cause drivers to reduce their vehicular velocity in the vicinity of the sign in order to prolong the information processing time. In the absence of an offsetting benefit in terms of driver exiting performance at the interchange proper, there could be no justification for using this type of diagrammatic sign as opposed to the conventional signs at interchanges like the one tested here.

In terms of driver performance at the interchange proper, by far the worst impairment was produced by the Diagrammatic I condition. Under this condition there was a great deal of incorrect preparatory lane change behavior. Drivers would frequently move out of the correct lane in the vicinity of the exit direction signs only to learn with the presentation of the exit sign that they had to return to it to make the proper exit.

It is interesting to note that even though the exit sign remained the same under all three experimental conditions, the average IIT value for the exit sign under the Diagrammatic II condition was approximately 2 seconds longer. This is an example of how the characteristics of previous signs in a signing sequence can influence information interpretation time for signs later in the sequence. This same effect was observed under the diagrammatic signing condition in the study conducted at Germantown (See Chapter IV).

Cloverleaf With Collector Distributor (Interchange D, Westbound)

The increase in average IIT with the diagrammatic sign at the 1 mile advance location is consistent with previous findings. In essence, this particular collector distributor was signed like a single right exit as far as mainstream traffic was concerned. Consequently, conventional and diagrammatic signs depicting a single right exit were presented to drivers as they made the approach to the interchange. The results on the IIT measure indicated that the diagrammatic advance sign required approximately 1.28 seconds longer on the average to interpret compared to the conventional sign. This was very close to the 1.26 second difference found between similar conventional and diagrammatic signs used at the southbound approach to interchange F, a single right exit interchange.

In general, the results at the collector distributor indicated that there was no real improvement in driver performance with diagrammatic signs over conventional signs. No substantial benefit was observed in terms of driver exiting errors, erratic maneuvers, or porportion of incorrect or correct preparatory lane changes. Therefore, it is concluded that based on the evidence in this study, the motorist would not be benefited by diagrammatic signs deployed at this type of collector distributor interchange. This does not mean, however, that all types of interchanges with collector distributors cannot be benefited through the use of diagrammatic signs. But the results do strongly suggest that where the interchange can be signed in the main traffic stream as a single right exit, the diagrammatic sign will not provide a gain over the conventional sign.

Left Exit Preceded By A Right Exit (Interchange C, Eastbound)

The results at interchange C, eastbound, indicated that there were significant differences between the signing conditions on three measures: IIT, velocity control, and lane change performance. There were several significant differences between conditions on the IIT measure. But the most important one involved the diagrammatic sign at the 1 mile advance sign. Drivers in the Diagrammatic II group required on the average almost 7 seconds to interpret information on the sign, 3.1 seconds longer than the average for the conventional group. It is speculated that part of this increase was due to the fact that drivers did not expect to encounter a left exit. In fact, some drivers commented that when they first viewed this sign, they did not believe what it said was true. The incompatibility of the information on the sign with driver expectancy could have elicited a longer than normal IIT response. However, part of the long IIT must also be attributed to the complex nature of the diagrammatic sign in comparison with the conventional sign.

There was a substantial improvement in driver lane change behavior under the Diagrammatic II condition. This group demonstrated an increase in the proportion of correct preparatory lane changes with a concomitant decrease in the proportion of incorrect preparatory lane changes between the advance and exit direction sign (Figure 6-18). This meant that the diagrammatic II test signs also produced a significant enhancement in driver velocity control. Subjects in the Diagrammatic II group maintained constant average velocities throughout the approach to the left exit. This is apparent in Table 6-16. No doubt improved velocity control performance was related at least in part to the elimination of unnecessary lane changes, since most lane change maneuvers usually require changes in vehicular velocity.

The overall results at the eastbound approach to interchange C suggest that diagrammatic signs would produce a benefit at left exits. This conclusion is made in spite of the fact that the 1 mile advance sign exhibited a very long average IIT value. The benefits derived in terms of lane change behavior and velocity control were enough to offset the undesirably long IIT for the advance sign. In practice, the long IIT effect at the 1 mile sign could be accommodated by increasing the dimensions of the sign and the size of the sign letters. This would provide the driver with more sign information processing time and perhaps mitigate the driver's need to slow down in the traffic stream.

Partial Cloverleaf (Interchange A, Northbound)

The results at interchange A, northbound, on the IIT measure indicated that there was no difference between the conventional and diagrammatic signs at the exit direction and two exit signs. None of the groups were presented a diagrammatic sign at the 1 mile advance sign. These results at the exit direction sign are consistent with findings recorded in the Germantown and McLean studies reported in Chapter IV and V.

The significant reduction in proportion of correct preparatory lane changes between the advance and exit direction signs for the Diagrammatic II groups is difficult to explain. Since all three groups viewed a conventional sign at the advance sign location, this finding must be considered spurious as far as the experimental conditions are concerned. The lower proportion of preparatory lane changes required for this group coupled with the fact that 100 percent of the drivers in the conventional group executed their preparatory lane change prior to the exit direction sign may have produced this result. The fact that the B-C comparison was not significant suggests that this may be the explanation.

It follows from the preceding evidence that diagrammatic signs did not produce a benefit at the partial cloverleaf under the conditions of the study. On the other hand, a deficit in performance was not observed either as was the case in the Germantown study. The absence of a deficit in performance is interpreted as being due to the fact that in this study a simple graphic component was used in the diagrammatic format. It will be recalled that a more complex diagrammatic sign with an implied crossover design was employed in the Germantown study.

Non Exiting Interchanges

Discussion of results for the interchanges when the driver was required to make a through maneuver is restricted to the findings on the IIT measure. By and large there were no differences between conditions on this measure. The only two exceptions to this statement occurred at the 1 mile advance sign at the southbound approach to interchange B, the first test sign encountered by test drivers, and at the second exit sign on the northbound approach to this same interchange. In both cases, the average IIT values were greater for the diagrammatic signs.

The larger average IIT value for the advance sign at interchange B, southbound, cannot be attributed to a novelty effect, although it was the first diagrammatic sign presented to the Diagrammatic II group along the test route. The reason for this is that the exit direction sign presented to the Diagrammatic I group at interchange B, southbound, was also the first sign encountered by this group along the test route. Inasmuch as there was no difference between the conventional and diagrammatic condition at this sign, it is suggested that the novelty effect is not a factor contributing to the longer IIT value observed for the Diagrammatic II group at the advance sign. The most reasonable explanation is that the 1 mile diagrammatic sign simply has more information than the conventional sign and hence it requires additional interpretation time.

Summary

The purpose of this investigation was to evaluate the influence of diagrammatic versus conventional signs on driver performance at complex interchanges. Sign information interpretation time, driver velocity control, lane change behavior, erratic maneuvers, and exiting errors constituted the measures of driver performance. Drivers were tested individually in an instrumented vehicle. Experimental test signs were presented to the drivers on an in-vehicle information display as they navigated a predetermined test route. The test route required drivers to negotiate 10 interchange approaches open to normal traffic operations. Interchange geometrics consisted of a single right exit, multiple split ramp, left exit, cloverleaf with collector distributor, partial and full cloverleafs. The results of the study suggested that under the conditions of the investigation, diagrammatic signs produced no benefit over conventional signs to driver exiting performance at the single

right exit, cloverleaf with collector distributor, and partial cloverleaf interchanges. A benefit was recorded, however, at the interchange with a left exit. Furthermore, a degradation in performance was created at the multiple split ramp interchange under diagrammatic signing conditions.

References

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Walker, Helen M., and Lev, Joseph, Statistical Inference, Henry Holt and Company, 1953.

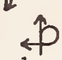
PART III

TRAFFIC STUDIES AND CONCLUSIONS

Chapter VII

THE EFFECTS OF DIAGRAMMATIC GUIDE SIGNS ON TRAFFIC BEHAVIOR AT A CLOVERLEAF INTERCHANGE

This investigation was conducted during the preliminary phase of the research program. The objective was to evaluate and make recommendations concerning the deployment and design of graphic information displays at the cloverleaf interchange. In comparison to the research reported in preceding chapters, a field study of "general traffic" behavior was conducted. Although a number of diagrammatic signing studies had previously been conducted in the field using the cloverleaf interchange, further research was required in order to more adequately make recommendations for the use of graphic displays on the Interstate highway system. In addition, the results of this study were expected to provide information which would influence the design of future studies to be conducted later in the program.

Other characteristics make this study distinctive from previous field work. First of all, the study was conducted concomitantly at the same test site as the instrumented vehicle investigation described in Chapter IV. Accordingly, a direct comparison was possible between measures of individual driver response and measures of general traffic performance under identical experimental test conditions. Secondly, the conventional and diagrammatic signing conditions were tested during the same month within a short period of time thus minimizing the influence of extraneous variables associated with seasonal variations and changing traffic parameters. Thirdly, the "implied crossover"  graphic design for a cloverleaf, as opposed to the "full crossover"  design, was evaluated. Its influence on traffic behavior had not been studied in the field.

Inasmuch as the instrumented vehicle appeared to the casual observer to be a standard sedan, it did not influence the results of the general traffic study reported here. By the same token, since time lapse photography was used to study general traffic behavior, the traffic evaluation technique did not influence results obtained in the instrumented vehicle work reported in Chapter IV. Four time lapse cameras were used to photograph the interchange gore areas and traffic flow in the vicinity of the sign placement locations. No sensors of any type were placed on any part of the pavement and cameras were unobtrusively positioned off the shoulder of the highway. Time lapse films were taken at points along the entire approach to the interchange beginning just upstream of the 1 mile advance sign and terminating at the interchange overpass. Time lapse films provided sufficient details of individual vehicles in the traffic stream so that the number, types, as well as origin of vehicles could be determined. The traffic measures included the frequency of erratic maneuvers such as gore crossings and center weaves as well as the frequency of braking maneuvers and lane change behavior.

It was conceptualized that diagrammatic guide signs would influence general traffic behavior which would be reflected in the movements of individual vehicles in the traffic stream. The experimental hypothesis was that diagrammatic signs with "implied crossover" graphics would affect the incident of erratic maneuvers, frequency of driver braking behavior and location of lane change maneuvers.

Method

Test Interchange and Signs

Drawings of the interchange geometry with pictures of the test signs used under conventional and diagrammatic signing conditions are presented in Figures 4-1 and 4-2 on pages 37 and 39, respectively. The experimental interchange used inthe study was located in the State of Maryland on Interstate 70-S and Maryland 118. This interchange carried four lanes of traffic along 70-S in the north-south direction and two lanes of traffic along Maryland 118 in the east-west direction. It was a full cloverleaf and was classified as a minor interchange with excellent sight distance. Only the signs, exit ramps, and approaches serving southbound traffic were employed in the investigation. Four shoulder mounted signs were involved in the study. The first sign, the 70-S southbound driver encountered was an advance sign located 1 mile in advance of the interchange. The second sign was an exit direction sign located at the 1/2 mile point. The third and fourth signs were exit signs positioned in close proximity to the two exit gores. The third sign was the Germantown exit sign and the fourth sign was the Damascus exit sign. Only the 1 mile advance sign and 1/2 mile exit direction sign were changed to a diagrammatic format for the after phase of the study. For more complete detail on the test sign designs, see the Method Section in Chapter IV of this report.

Time Lapse Photography

Four Minolta Autopak-8 D-10 super 8 cameras were used to record the time lapse films in the study. A picture of one of the cameras is presented in Figure 7-1. Each camera was equipped with a zoom lens system that was continuously variable in focal length from 7 to 70 mm. Camera intervalometers were powered by 1.50 volt dry cell batteries and were set at exposure rates of 2 frames per second. With this exposure rate, 30 minutes of continuous data were collected per roll of film. Ektachrome EF film was used.

Four cameras were positioned on tripods near the locations of the advance signs and Germantown exit gore area of the test interchange. The cameras were camouflaged so that they could not be seen by motorists on the highway. Presented in Figure 7-2 is a 35 mm picture taken from camera position four with the lens settings adjusted to approximate the time lapse cameras' fields of view. Two of the cameras recorded traffic behavior in the vicinity of the 1 mile advance sign. The principle purpose of the first camera, numbering camera positions from the advance sign to the interchange, was to record the number, type, and origin of vehicles

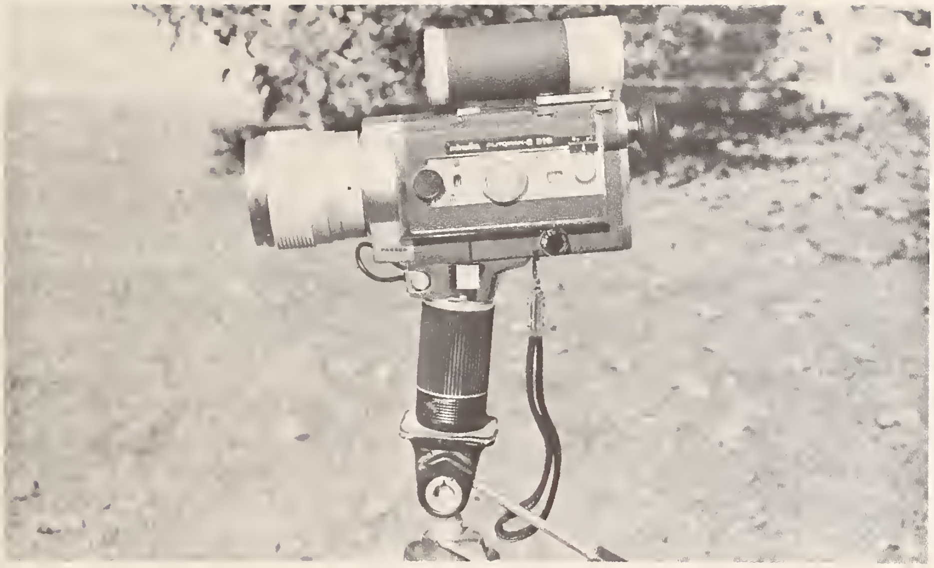


Figure 7-1. Picture of Minolta Super 8 time lapse camera.

Figure 7-2. Picture taken from camera Position 4 showing the camera's approximate field of view.

traveling in both lanes of the southbound traffic stream. This camera focused on a narrow field of view which provided a closeup record of vehicular license plates. The photographed portion of the highway was located prior to the 1 mile advance sign at the top of a horizontal curvature in the roadway where drivers were first able to view the 1 mile advance sign. Consequently, the frequency with which drivers performed braking maneuvers at the point of their initial encounter with the 1 mile advance sign was recorded.

The second camera was also positioned at a location to record traffic behavior in the vicinity of the 1 mile advance sign. However, it was focused to record a larger field of view which encompassed the area directly in front of or upstream to the sign. Vehicular lane changes, edgeweaves, centerweaves, braking maneuvers, and traffic volume were recorded from this camera position. The third camera was positioned to survey traffic behavior in the vicinity of the exit direction sign, located 1/2 mile in advance of the interchange. Again, this camera was focused to encompass a fairly large field of view, upstream from the exit direction sign, so that erratic vehicular maneuvers near the exit direction sign could be recorded. It recorded the same types of vehicular maneuvers as were recorded with the second camera. The fourth camera was positioned at a point to provide a panoramic view of the test interchange itself. Since the test interchange exhibited excellent sight distance, the camera at position 4 was able to record vehicular movements in the vicinity of the Germantown exit sign, Germantown exit gore, and Damascus exit sign. It recorded the same types of vehicular maneuvers as cameras two and three plus hazardous maneuvers as well as entering and exiting traffic volumes.

Procedures

Data Collection. Time lapse film data were collected during the first two weeks of August 1971. Conventional sign panels were in place during the first week and diagrammatic panels the second week. Film data samples were taken from Monday through Saturday during the daylight period from 10:00 a.m. to 4:30 p.m. A camera operator remained in the close vicinity of each camera throughout the period of camera operation. Operators remained out of sight, however, from drivers in vehicles traveling on the highway. The operators were responsible for changing film cartridges and monitoring camera operation. As soon as each film cartridge was placed in the camera magazine, the date, time of day, and camera position were slated on the film. Thus, this data became a permanent part of the film record.

It was not possible to record continuously each day throughout the period of data collection. Reasons for this included inclement weather conditions and temporary construction activities by a highway contractor in the test interchange area. In addition, some film could not be scored because of camera malfunctions or camera operator errors. After samples were matched across signing conditions in terms of day of the week and time of day of exposure, eight 1/2 hour samples of film from each camera positioned under each of the two signing conditions were scored and analyzed.

Hence, the results of this study are based upon a total of 32 hours of time lapse photography, 16 hours under conventional conditions and 16 hours under diagrammatic signing conditions.

Measures. The traffic measures employed in the study are listed in Table 7-1 along with the camera locations where they were recorded. Traffic volumes stratified by type of vehicle and vehicle origin were recorded by camera number 1. The classification of vehicles with respect to origin was based upon license plate color. Vehicles displaying Maryland colored license plates were classified as being in-state. The rest were considered to be out-of-state. Vehicles whose license plate color could not be determined because of coverage by dirt, or for some other reason, were classified as vehicles of unknown origin.

Braking maneuvers were scored when tail lights on the vehicles became activated. The increase in their brightness was easily discernable in the films. No attempt was made to determine velocity changes of individual vehicles in the traffic stream. Film data on braking maneuver incidents were recorded at all four camera positions.

Vehicle lane change maneuvers were recorded at camera positions 2, 3, and 4. They were broken down for analysis purposes into (1) left to right lane change and (2) right to left lane change. Vehicular edge and center weaves were also scored at these same camera positions. A center weave was defined as the temporary excursion of at least one of the vehicle's wheels into the adjacent lane. Edge weaves were scored when a vehicle's wheel crossed over to the outside of the white edge markings painted on the lanes. Diagrams of these maneuvers are shown in Figure 7-3. Also diagrammed in this figure are hazardous maneuvers which were only scored for film exposed at camera position 4. They consisted of unusual and dangerous maneuvers such as stopping and backing up in the gore area and crossing the painted gore (gore weaves) on exit or exit return maneuvers. The volume of exiting and entering vehicles were also recorded at camera position 4.

Data Reduction. After the exposed film was processed, two observers scored the film on the basis of the above measures. The observers recorded these measures by using a stenotype machine and an 8 mm analyzer projector. The stenotype machine was the courtroom type which produced a continuous paper tape record of the frequency of occurence of the various measures. The analyzer projector was designed with foot pedal control to provide forward, reverse, and stop action. For films exposed at camera position 4, the observers recorded the frequency of the events under "blind" conditions. That is, the film scorers did not know which signing condition was in effect for any of the rolls of film they viewed. This blind scoring technique was used to control for experimental bias. It could only be used for camera 4 film since the test signs were in view on film exposed at the other cameras.

Table 7-1

TRAFFIC MEASURES AND THE CAMERA LOCATIONS WHERE THEY WERE RECORDED

	CAMERA LOCATIONS			
	Advance Sign		Exit Dir. Sign	I.C. Gore Area
Measures	Camera 1	Camera 2	Camera 3	Camera 4
Trucks	X			
Out of State Vehicles	X			
In-State Vehicles	X			
Unknown Origin Vehicles	X			
Vehicles Left Lane	X	X	X	X
Vehicles Right Lane	X	X	X	X
Total All Vehicles	X	X	X	X
Braking Maneuvers	X	X	X	X
Lane Changes		X	X	X
Edge and Center Weaves		X	X	X
Hazardous Maneuvers				X
Total Exiting Vehicles				X
Total Entering Vehicles				X

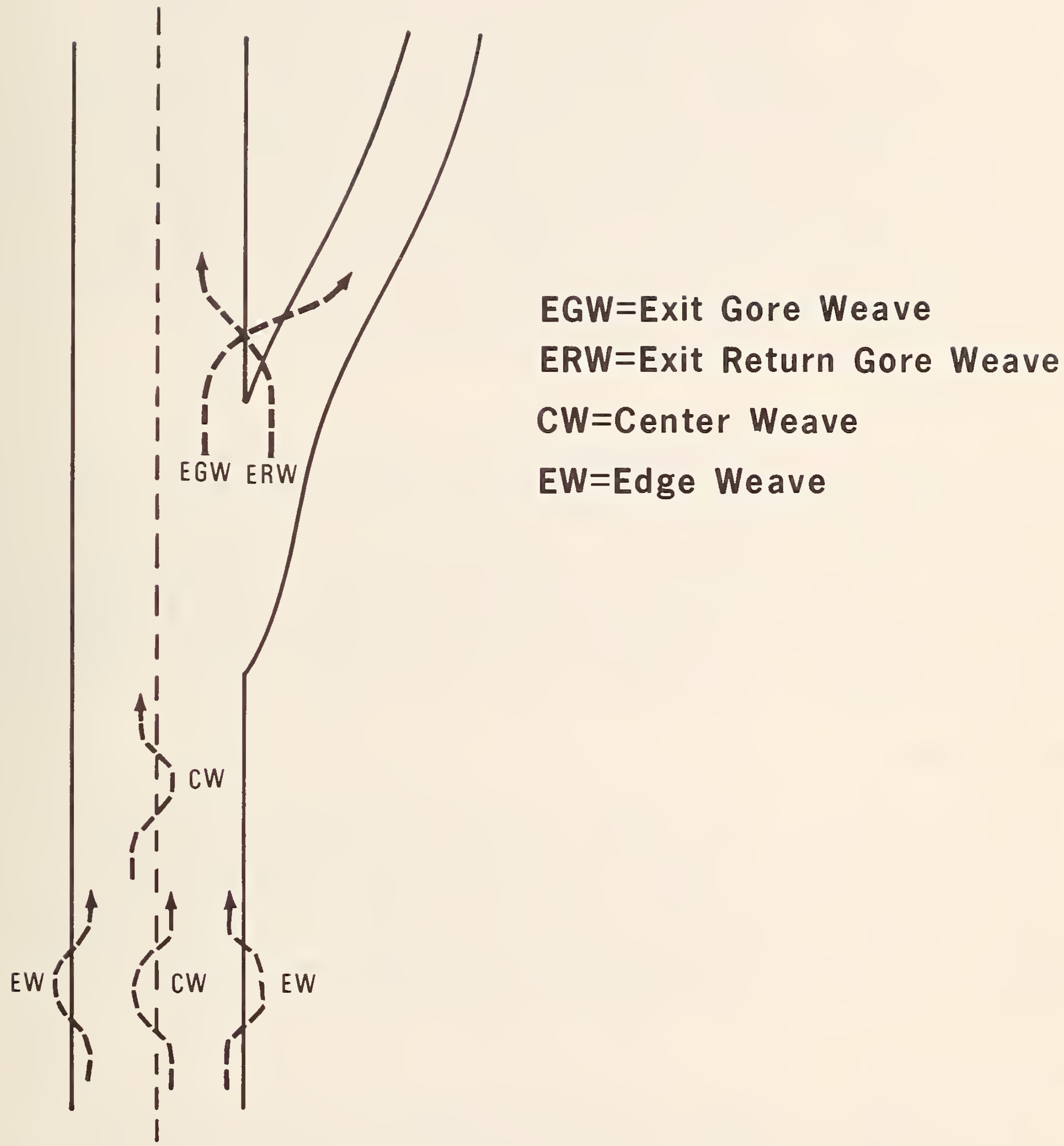


Figure 7-3. Diagram of center weaves, edge weaves, and gore weaves.

Results

Camera Position 1

Presented in Table 7-2 are the traffic volume means, standard deviations and Mann-Whitney U values for types of vehicles recorded per 1/2 hour at the 1 mile advance sign from camera position 1 under diagrammatic and conventional signing conditions. It can be seen from this table that the numbers and types of vehicles that negotiated the interchange remained very constant between signing conditions. The only exception to this was the number of trucks. The mean number of trucks increased under the diagrammatic signing condition from 32 to 41 per half hour. This difference, although statistically significant, probably had a minor effect on the traffic measures used in the study. The traffic mix in terms of ratio of out-of-state vehicles to in-state vehicles remained very stable over the two week period, with the numbers of out-of-state and in-state travelers remaining about equal.

Camera Position 2

The means, standard deviations and Mann-Whitney U values for lane changes and lane weaves recorded at the 1 mile advance sign from camera position 2 under the signing conditions are presented in Table 7-3. It is apparent from this table that the number of lane changes remained approximately the same under the two signing conditions. Moreover, the ratio of left to right and right to left lane changes remained essentially unchanged. However, both the number of edge and center weaves decreased under the diagrammatic signing condition. This decrease was statistically significant beyond the .05 level.

Camera Position 3

Table 7-4 presents lane change and weave results based on film data recorded at the 1/2 mile exit direction sign from camera position 3. At this sign the number of right to left lane changes significantly decreased under the diagrammatic signing condition. The number of left to right lane changes remained unchanged, however. There was a trend for edge and center weaves to decrease under the diagrammatic signs with the decrease in total number of weaves reaching statistical significance.

Camera Position 4

It is evident from Table 7-5 that the number of left to right lane changes decreased in the gore vicinity of the test interchange under the diagrammatic signing condition. This decrease was statistically significant beyond the .05 level. In contrast to the significant differences found for edge weaves and center weaves at the 1 mile advance and 1/2 mile exit direction signs, there were no differences on these measures between signing conditions based on film data gathered in the test interchange area. It should also be noted on Table 7-5 that there was a very low volume of exiting traffic at the test interchange during the study period.

Table 7-2

VOLUME MEANS, STANDARD DEVIATIONS, AND MANN-WHITNEY U VALUES FOR TYPES OF VEHICLES RECORDED PER 1/2 HOUR AT THE 1 MILE ADVANCE SIGN FROM CAMERA POSITION 1

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
Vehicle Type	N	Mean	SD	N	Mean	SD	U Value	Sign Level
Trucks	8	32.6	9.9	8	41.1	9.5	14.5	$P < .05$
Out-of-State-Vehicles	8	156.1	46.4	8	146.4	42.4	29.0	NS
In-State Vehicles	8	157.0	32.5	8	157.5	22.1	28.5	NS
Unknown Origin Vehicles	8	17.9	5.5	8	17.6	4.1	31.5	NS
Total Vehicles	8	363.6	44.8	8	362.6	41.4	30.0	NS

Table 7-3

MEANS, STANDARD DEVIATIONS, AND MANN-WHITNEY U VALUES FOR LANE CHANGES, EDGE WEAVES, AND CENTER WEAVES RECORDED AT THE 1 MILE ADVANCE SIGN FROM CAMERA POSITION 2

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
Measures	N	Mean	SD	N	Mean	SD	U Value	Sign Level
Left to Right Lane Changes	8	5.2	3.1	8	5.5	1.8	30.5	NS
Right to Left Lane Changes	8	15.1	7.5	8	12.2	3.4	22.5	NS
Total Lane Changes	8	20.4	9.7	8	17.8	3.1	26.5	NS
Edge Weaves	8	3.2	1.0	8	1.2	1.6	6.5	$P < .05$
Center Weaves	8	3.6	2.9	8	1.1	1.1	14.5	$P < .05$
Total Weaves	8	6.9	3.5	8	2.4	1.7	8.0	$P < .05$

Table 7-4

MEANS, STANDARD DEVIATIONS AND MANN-WHITNEY U VALUES FOR LANE CHANGES, EDGE WEAVES, AND CENTER WEAVES RECORDED AT THE 1/2 MILE EXIT DIRECTION SIGN FROM CAMERA POSITION 3

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
Measures	N	Mean	SD	N	Mean	SD	U Value	Sign Level
Left to Right Lane Change	8	8.1	4.3	8	10.1	6.8	26.0	NS
Right to Left Lane Change	8	16.5	6.0	8	10.8	4.3	11.5	$P < .05$
Total Lane Changes	8	24.6	7.5	8	20.9	9.3	23.0	NS
Edge Weaves	8	0.8	0.7	8	0.4	0.5	22.5	NS
Center Weaves	8	2.8	2.4	8	0.6	0.7	18.0	NS
Total Weaves	8	3.5	2.5	8	1.0	0.9	14.5	$P < .05$

Table 7-5

MEANS, STANDARD DEVIATIONS AND MANN-WHITNEY U VALUES FOR LANE CHANGES, WEAVES, AND NUMBER OF ENTERING AND EXITING VEHICLES RECORDED FROM CAMERA POSITION 4

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
Measures	N	Mean	SD	N	Mean	SD	U Value	Sign Level
Left to Right Lane Change	8	5.8	2.9	8	3.8	1.2	14.0	$P < .05$
Right to Left Lane Change	8	9.8	4.4	8	9.6	5.0	30.0	NS
Total Lane Changes	8	15.8	5.8	8	13.5	5.7	24.0	NS
Total Weaves	8	2.9	1.9	8	1.8	2.5	18.0	NS
Total Exiting Vehicles	8	11.5	4.1	8	9.4	2.7	19.5	NS
Total Entering Vehicles	8	40.6	8.3	8	42.5	7.2	27.0	NS

There were two other measures recorded from the camera 4 position which are not tabulated on Table 7-5. These were gore weaves and other hazardous maneuvers. There was only 1 gore weave recorded at camera 4 and it occurred under the diagrammatic signing condition. Three hazardous maneuvers (e.g., stopping or braking up in the gore area) were recorded, 2 under conventional signs and 1 under diagrammatic signs.

The braking maneuver data recorded from all four camera positions are summarized in Table 7-6. Comparisons between experimental conditions indicates that the incidence of braking increased significantly near the diagrammatic 1 mile advance sign. This was reflected in film data recorded from both cameras 1 and 2. These differences were statistically significant beyond the .05 level.

Discussion

The study of general traffic behavior under the influence of diagrammatic and conventional signs pointed out some revealing differences in the effects of the two types of signs. The differences observed can be directly attributed to the signing conditions since traffic volumes, ratio of familiar and unfamiliar drivers, and weather conditions were extremely stable throughout the study period. The only exception to this was the small increase in truck traffic during the diagrammatic sign phase of the study. It is important to note that the test interchange was characterized by very low exiting traffic volumes (Table 7-5). Approximately 3 percent of the traffic exited during the course of the study. This means that, in essence, most of the effects recorded in the study were the response of through traffic to the experimental signs.

The most striking difference found between the signing conditions was the almost 5 fold increase in braking maneuver incidents at the diagrammatic 1 mile advance sign (Table 7-6). These results are consistent with the instrumented vehicle findings (Chapter IV) in that vehicular velocity noise was found to significantly increase under the diagrammatic format. No difference was found between experimental conditions for the braking maneuver measure at the 1/2 mile exit direction sign. Again this corresponded to the finding in the instrumented vehicle in that the diagrammatic exit direction sign had no effect on velocity noise. The braking maneuver findings in this study, coupled with the instrumented vehicle results reported in Chapter IV, suggest that drivers had more difficulty interpreting information displayed in a diagrammatic format.

The significant decrease in edge weaves and center weaves in the vicinity of the 1/2 and 1 mile signs is interpreted as being the result of the drivers increased level of alertness brought about by the increased attentional demands of the diagrammatic signs. In other words, this interpretation suggests that the tightening up lateral vehicular control by the driver is associated with the increase in his level of cognitive activation. The reduction in lane weaves should not be construed

Table 7-6

MEANS, STANDARD DEVIATIONS AND MANN-WHITNEY U VALUES FOR BRAKING MANEUVERS RECORDED FROM CAMERA POSITIONS 1 - 4

	CONVENTIONAL SIGNS			DIAGRAMMATIC SIGNS				
Camera Positions	N	Mean	SD	N	Mean	SD	U Value	Sign Level
Camera 1	8	2.0	1.3	8	12.8	19.9	13.5	$P < .05$
Camera 2	8	0.4	0.5	8	2.8	1.8	7.0	$P < .05$
Camera 3	8	0.9	1.0	8	0.2	0.4	28.0	NS
Camera 4	8	1.9	2.4	8	0.6	1.1	21.0	NS

to be a benefit of diagrammatic signs because of a decrease in driver uncertainty, ordinarily considered to be related to the frequency of some types of erratic maneuvers, but rather as a function of the shift in driver alertness processes.

The decrease in right to left lane changes in the vicinity of exit direction signs and decrease in left to right lane changes in the gore area of the interchange under diagrammatic signs are difficult to interpret. The magnitude of these differences are small (see Tables 7-4 and 7-5) and the reasons for them are not clear. This points out the limitation of the time lapse photography technique for studying traffic behavior. It can be effectively used for the descriptive analysis of traffic behavior but as a tool for understanding why traffic behaves as it does, it is very limited. The traffic lane change results cannot be related to instrumented vehicle findings since lane change behavior was not recorded in the instrumented vehicle.

Based on the findings in the instrumented vehicle and the general traffic study, it is concluded that the diagrammatic sign with the "implied crossover" graphic component did not produce a benefit at this particular interchange. In fact the evidence suggests some impairment in the motorist's performance with diagrammatic signs.

Summary

The purpose of the study was to determine the influence of diagrammatic guide signs on general traffic behavior at a cloverleaf interchange using the "implied crossover" graphic sign design. Time lapse photography was used at four points in the vicinity of the advance signs and exit gore area. The traffic measures recorded included braking, lane changes, lane weaves, and hazardous maneuvers. Primary results indicated that there was a significant increase in braking maneuvers in the vicinity of the 1 mile advance sign under the diagrammatic condition. This result was consistent with findings in the instrumented vehicle study which was conducted concurrently with the traffic study. Edge weaves and center weaves significantly decreased under the diagrammatic condition near the 1/2 mile exit direction sign and 1 mile advance sign. This result is interpreted as being due to an increase in driver alertness brought about by the attentional demands of the diagrammatic signs and not because of a reduction in driver uncertainty. Because of the low volume of exiting traffic there were only four hazardous maneuver incidents and these were equally divided across signing conditions. It was concluded that the diagrammatic sign did not produce a benefit at this interchange. In fact, taking the instrumented vehicle and general traffic findings together, the evidence suggests some impairment in the motorist's performance with diagrammatic signs.

Chapter VIII

NATIONAL SURVEY OF DIAGRAMMATIC GUIDE SIGNS

A survey was conducted through the field offices of the Federal Highway Administration in 1971 and 1972 to inventory diagrammatic sign installations in the United States. This chapter presents the results of that survey. In order to provide a clear perception of the types of diagrammatic signs that have been put into use, several pictures of diagrammatic signs are presented.

Hundreds of diagrammatic signs have been installed across the country. In over half the States at least one such sign has been deployed. A few diagrammatic signs were installed primarily for experimental evaluation purposes in response to the AASHO request (1970) and the demonstration projects effort of FHWA (PPM 20-6.3). Project reports from eight of these studies are abstracted below under the heading, "Experimental Installations."

Most diagrammatic signs were installed as an attempt to remedy operating problems in response to motorist complaints. Examples of these signs are presented below under the heading, "Problem Oriented Installations." The locations where these signs were installed and the problems they were designed to alleviate are briefly described. If available, opinions on the sign's effectiveness are also noted. It must be pointed out, however, that unless an empirical evaluation was conducted, as was the case in the eight abstracted studies, the reported sign effects should be considered as anecdotal opinion and not judgment based on experimental evidence.

Experimental Installations

Arizona

Snyder, Jack and Crosette, Joseph G., Test of "Diagrammatic" Sign at Interstate 10 and S.R. 93 (South of Chandler), Arizona Highway Department, 1969. (Abstract)

An exit direction sign was replaced with a diagrammatic sign at a single exit, loop ramp interchange on flat terrain. There were no curves on the main roadway for a long distance before the interchange.

The diagram was a 10 inch wide arrow with an I-10 shield in the center and a 5 inch wide curved arrow off to the right pointing down. An Arizona 93 shield was to the right of the small arrowhead. "Chandler" and "Mesa" place names were below the small arrowhead. "Phoenix" was to the right of the large arrowhead at the top of the sign. A bridge symbol was shown near the base of the shaft of the large arrow. All information components were enlarged for the diagrammatic sign.

Before-after speeds were recorded (using radar): (1) 500 feet prior to the sign, (2) 176 feet prior to the exit point, and (3) 171 feet after the exit point. All exiting traffic was interviewed after the signs were in use one month. No differences in speeds were recorded at any of the three locations. Nearly all the motorists interviewed thought the sign was helpful. Traffic engineers agreed that the diagrammatic sign was more descriptive and easier and quicker to understand.

Connecticut

State of Connecticut, Department of Transportation's Bureau of Highways, Motorist Reaction to Diagrammatic Signing, Interim Report, 1972. (Abstract)

A ground mounted diagrammatic advance sign was added 1/2 mile prior to a left exit which was 700 feet in advance of a major bifurcation of I-91 and I-95. The sign displayed a 9 foot tall diagram in its center to depict the interchange's decision points (see Figure 8-1). At 1/4 miles prior to the interchange, the exit direction sign was changed. Three conventional sign panels were replaced on an overhead sign structure. The panels that were removed used down pointing lane assignment arrows. The new diagrammatic panels used large, long shaft, upward curving arrows. A Connecticut 34 route shield replaced "EXIT 47" and "DOWNTOWN" on the left panel.

Before-after video tape recordings were taken of weaving prior to the left exit. Traffic volumes and gore crosses were taken by mechanical counters. Vehicle speeds were sampled by radar. The signs had no effect on operating speeds. Preparatory lane changes to the left occurred earlier after the sign changes. Gore cross data was discarded due to characteristics of counters. The authors conclude, based on preliminary data analysis, that supplementary diagrammatic signing facilitated traffic operations at this interchange.

Illinois

Mitchell, R.H., and Davidson, J.N., An Investigation of Diagrammatical Signing to Control Turning Movements at a Major Intersection, Illinois Department of Transportation, 1972. (Abstract)

At the test site used in this study, I-80 and I-74 traffic must exit through a cloverleaf interchange to stay on route. Diagrammatic signs were placed at four points prior to where I-80 or I-74 traffic had to exit.

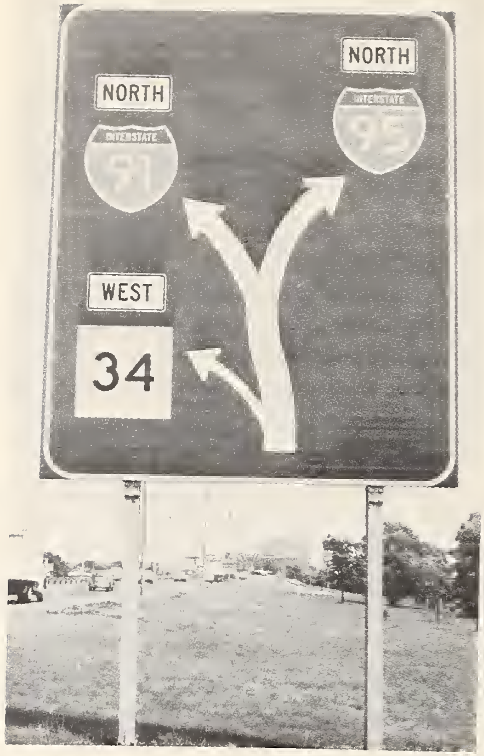


Figure 8-1. Diagrammatic Sign in New Haven, Connecticut

Figure 8-2. Diagrammatic Sign in New Brunswick, New Jersey

The two signs located prior to the loop ramps used "implied crossover" diagrams. The two signs for the outer connections depicted a gradual curve to the right. On all signs the crossing road and the continuing road were shown, but the movement of interest was emphasized by having a wider shaft. All signs contained appropriate Interstate shield(s), cardinal directions, and NEXT RIGHT.

Observers recorded traffic (through and exiting) and erratic actions (stop prior to exit, sudden lane change near exit, pass exit, and backup). No tests of statistical significance were applied. However, there was an increase in late lane changes, a decrease in stop/backup maneuvers, and approximately similar numbers of stops prior to the exit. At least one "near accident" per hour was observed. The authors concluded that diagrammatic signs reduced the more dangerous type (stop/backup) maneuvers, while increasing the less dangerous (late lane change) type. Although diagrammatic signs improved traffic operations somewhat, the optimal solution to problems at this interchange requires rerouting of the two Interstate highways.

Michigan

Orne, Donald E., Rural Freeway Operational Surveillance Used to Evaluate Symbol Signs, presented at Highway Research Board, 1966. (Abstract)

During phase construction, I-75 traffic had to exit ignoring two completed through lanes. Four signing additions or modifications were performed in phases. An externally illuminated ground mounted diagrammatic sign was added behind a guard rail in the gore area. The diagram has a broad shafted arrow pointing up and curving to the right. On the right side of the sign were I-75 and U.S. 27 shields. The diagram also included a narrower arrow curved only slightly to the left. These arrows shared a common base. On the left side of the sign were Michigan route shields for M-18 and M-76. A duplicate sign was mounted on the right 1000 feet prior to the overhead exit direction sign a few months later. About a month after that, the 1/2 mile advance sign was moved from the median to the right side and "LEFT LANE" across the bottom was changed from white on green to black on yellow. The final modification (another month later) was to remove M-18 and M-76 shields from the overhead exit direction sign.

Erratic Maneuvers (EM) not operationally defined were observed between the phases listed. Results indicated that 7.8 percent of daytime and 9.5 percent of nighttime traffic performed EM before any change. After the first improvement (illuminated gore sign) this decreased to 6.1 percent day and 2.5 percent night. After the advance sign was added, a further reduction to 2.2 percent day and 0.3 percent night was observed. After the advance sign was moved to the right and hatches painted in the gore, the EM was 0.8 percent day and 0.6 percent night. With the final modification, the EM became 1.2 percent day and 0.4 percent night.

New Jersey

Roberts, A.W., Diagrammatic Sign Study, New Jersey Department of Transportation, 1971. (Abstract)

All five signs were modified on northbound I-287 approaching the interchange with U.S. 22. This interchange had a right exit followed by (less than 1000 feet) a two lane left exit with a double lane drop. Three lanes went through. Signs were modified three times. The signs were brought up to standard, changed to diagrammatic, then lane lines were added to the diagrams.

The first sign (12 feet wide by 16 feet tall) was a 1/2 mile ground mounted advance sign with a 3 foot wide through arrow, a 2 foot wide arrow curving off of the left side and a 1 foot wide arrow curving off the right side. Each of the "exit" arrows pointed to a U.S. 22 shield. Below the left arrow was "Easton" and below the right arrow was "New York." The other signs were reproductions of the appropriate portions of the advance sign. The overhead exit direction sign is shown in Figure 8-2.

TV recorders and hourly traffic counters recorded traffic behavior. Data was collected in the afternoon. Unusual maneuvers (UM) such as any stopping, backing, or crossing of gore line between physical gore and 200 feet upstream were analyzed. No more than one UM was counted for each vehicle. Data was collected only at the second (left) exit.

No difference in UM was observed between original signs (conventional) and modified signs (conventional). Reduction in UM was observed between modified conventional and diagrammatic signs. There was a further reduction in UM between diagrammatic signs and the same signs with lane lines added to the graphic components. The author concluded that diagrammatic signs markedly reduced the number of unusual maneuvers under the conditions of the experiment. The addition of lane lines provided more improvement.

Virginia

Hanscom, Fred R., Evaluation of Diagrammatic Signing at Capital Beltway Exit No. 1, Virginia Highway Research Council, 1971. (Abstract)

The overhead exit sign for westbound traffic at I-495, "Exit 1," was changed to diagrammatic. There were no advance signs for this exit. An I-495 shield replaced "THRU TRAFFIC" on the sign panel over the center and left lanes. The diagram on the new sign was a "choice point" type indicating three exits: Mt. Vernon Highway; U.S. 1 (route shield) NORTH; and U.S. 1 (route shield) SOUTH. A black on yellow "EXIT ONLY" panel was also added at the bottom of the diagrammatic sign. Alexandria and Fort Belvoir destinations were removed. The diagrammatic sign is shown in Figure 8-3. The interchange had a collector-distributor road with three exits on a controlled access facility with 81,000 vehicles per day. The sight distance was limited by a bridge abutment. The exit lane was a lane drop.

Time lapse super 8 film was exposed to record erratic maneuvers in one zone. Visual observers recorded erratic maneuvers in two zones. The zones were: (1) before the bridge, (2) after the bridge and before the exit point, and (3) on the C-D road before the second choice point. Erratic maneuvers were classified as: (1) weaves, (1a) gore weaves, (2) hesitating, (3) stopping/backing, and (4) partial weaving.

A significant decrease in gore weaves and an increase in partial weaves and hesitations was found. Driver behavior was more consistent after the signs were changed. The prior accident rate was more than one per month, with only two accidents occurring during the eight months following the sign change. The author concludes that a tradeoff of hesitations and partial weaves for gore weaves is in the interest of safety. A reduction in weaves on C-D road was interpreted to mean drivers had been more adequately prepared for decisions on the C-D road.

Wisconsin

Graham, Gary A., and Volk, Wayne N., Report on Evaluation of Diagrammatic Signs, Wisconsin Department of Transportation, Division of Highways, 1972. (Abstract)

Nine ground mounted advance and exit direction signs and seven overhead exit signs were changed at three continuous interchanges on I-90 east of Madison, Wisconsin. One interchange was a cloverleaf, the other two were directional interchanges, including some left exit situations. The directional interchange exit signs originally had down pointing lane assignment arrows which were replaced by longer shafted, up and curving, "Expected movement" arrows. The ground mounted signs used disconnected arrows to indicate lane drops (see Figure 8-4). The cloverleaf used an "implied crossover" diagrammatic sign design.

Traffic volumes and gore crosses, also called erratic maneuvers (EM), were counted at five choice points for a continuous week by an observer during working hours and by mechanical counters. One mechanical traffic counter was installed in the gore area to record gore crosses. Visual records of gore crosses were classified from A to F. A and B were most severe and recorded four counts on the mechanical counter. E and F were least severe and recorded one or two mechanical counts. A Statewide auto club requested motorist's comments regarding the signs' effectiveness from readers of its newsletter.

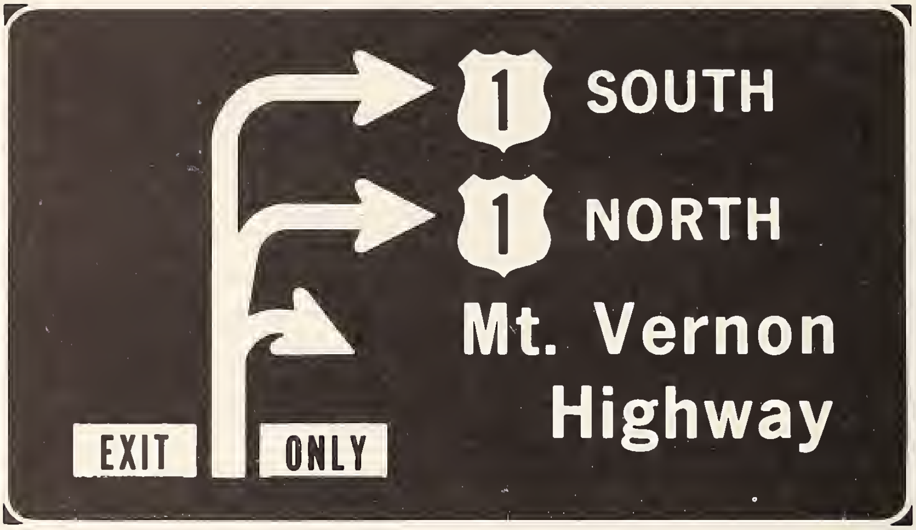


Figure 8-3. Diagrammatic sign in Alexandria, Virginia.

Figure 8-4. Diagrammatic sign in Madison, Wisconsin.

Erratic maneuvers (EM) increased at one of the left exists (with 25 percent exiting traffic). This left exit was soon followed by a right exit. Where a right exit (with 50 percent exiting traffic) preceded a left exit, EM at the left exit increased in the daytime (visual counts), but decreased over the week (mechanical counts). At a left exit (with 25 percent exiting) soon after a right exit, EM also decreased. At the first exit of a cloverleaf (with only 4 percent exiting traffic) EM increased slightly. At a left exit (with 10 percent exiting) a very short distance before a right exit, EM increased slightly. Over 100 responses from an auto club newsletter were all favorable.

The authors conclude that since only 0.4 percent of the traffic violated the gore, these interchanges function too well to effectively measure signing differences. Four of the signs have experienced wind damage due to the size and/or the temporary supports. Eliciting comments from auto club members did not seem helpful in terms of evaluating signing effectiveness.

Wyoming

Wyoming State Highway Department, Traffic Engineering Department, Evaluation of Diagrammatic Signing, 1970. (Abstract)

A diagrammatic sign was added between the exit direction sign and the exit sign at one approach to each of three interchanges on I-25 and I-80 in Cheyenne. One was a full cloverleaf and two were partial cloverleafs. The diagrams on the signs showed one choice point and the amount of loop ramp to be expected. For the cloverleaf, a full crossover diagram was used (see Figure 8-5). Through traffic route and cardinal direction was given; exiting traffic route and "Casper" or "Cheyenne" or "Central Business District" were given. At another (rotary) interchange of I-25, four existing gore signs were changed from stack type to diagrammatic. These signs controlled entering, exiting, and crossing traffic. The diagrams were expanded "choice point" type diagrams.

Visual counting of volumes and erratic movements were recorded at four locations at the rotary and one location at each of the other interchanges. All 91 drivers of vehicles making erratic movements during 4 days were interviewed at a partial cloverleaf. Erratic movements were classified as group 1: stop, or near stop, and abrupt or last-minute turns; and group 2: missed turns (backup, circle interchange, or return by different route). Erratic movements decreased slightly (not statistically significant). Half of the drivers interviewed had not decided whether to exit in Cheyenne or, if so, which of the exits to use. The author cites the "Cheyenne, All Exits" sign as a major cause of driver indecision, and recommends "Cheyenne, Next _____ Exits." He also recommends further study of diagrammatics, in light of the small decrease in erratic movements found at this location.

Figure 8-5. Diagrammatic sign in Cheyenne, Wyoming.

Figure 8-6. Diagrammatic sign in Phoenix, Arizona.

Problem Oriented Installations

Most of the diagrammatic signs installed across the country were part of an effort by individual States to correct some type of interchange problem or deficiency. However, little, if any, attempt was made to conduct a systematic or objective evaluation of the signing effects. The following examples of diagrammatic signs serve to illustrate the different types of diagrammatic signs used as well as the kinds of problems they were designed to alleviate. When available, information is also provided on the diagrammatic sign's effect on the problem, based on the opinion or judgment of State or city personnel. The examples are categorized and presented on the basis of type of interchange problems.

Temporary Route Termination Point

As the Interstate system is being completed, there are temporary endings. Traffic on the portion that is complete and in use must be directed to the primary system until the next section is complete. In these cases traffic engineers must announce to the driver in thru traffic lanes that his 70 mph trip will soon be interrupted. These cases are less frequent now than they were during the earlier stages of the Interstate construction program. Therefore, they are less expected by drivers and more dangerous. For examples, after passing Graling, Michigan, I-75 traffic must exit, ignoring the straight, two lane completed section of roadway. I-75 traffic is routed onto U.S. 27 during the construction period (Orne, 1966). Accidents and dangerous maneuvers were common prior to improved signing.

Phoenix, Arizona. In Phoenix, Arizona, there is a similar problem. Until I-10 to Los Angeles is completed, traffic must leave the combination of I-17 and I-10 and be routed temporarily over U.S. 60. At the point where I-10 and U.S. 60 traffic depart the I-17 roadway, the freeway is depressed. The exit is a loop which is hidden by structures over the freeway. The exit ramp then splits into two ramps. One goes straight and is more easily seen by the exiting traffic; this takes traffic to a local streeet. The I-10 and U.S. 60 traffic must continue around the ramp. The traffic on I-10 was making dangerous, last minute movements when the continuation of the loop ramp came into view. Personnel from the State of Arizona Highway Department believe the diagrammatic sign (Figure 8-6) has reduced the problem. However, the overall problem still exists (a major separation of the Interstate highways with a loop ramp and short sight distance). The design of this sign in Phoenix uses the complete crossover type of diagram. The State plans to reconstruct the geometry of this connection soon.

St. Louis, Missouri. In St. Louis Missouri, there is a major fork that functions as a two-lane left exit, tangential off-ramp. The two-lane left exit is complete and awaiting the finish of the interstate; in the interim it is merely an exit to a main city street. In the future these lanes will carry traffic for U.S. 66 and I-44. This sign (Figure 8-7) has a very large diagram.

Figure 8-7. Diagrammatic sign in St. Louis, Missouri.

Figure 8-8. Diagrammatic sign in Moline, Illinois.

The diagram is 4 feet wide (12 inches per lane ratio across the base) and lane lines are indicated with 1 inch by 6 inch strips of black. This appears to be the largest sign diagram in the United States. The sign is quite simple. The right arrow indicates I-55 and the through arrow indicates 14th Street. Traffic control at this junction was a problem. The diagrammatic sign is credited with improving the situation noticeably whereas other attempts have failed. The diagrammatic sign replaced signs with a great deal more information, however. It replaced a sign with U.S. route shields and with lane assignment arrows that said U.S. 66 for the two left lanes and U.S. 50 for the two right lanes. It cannot be determined whether improvement in traffic flow through this interchange is due to the diagram or due to the simpler and more pertinent information.

Route Discontinuity

Illinois. East of the quad cities of Davenport, Moline, Bettendorf, and Rock Island, is a temporary situation that has created a very unfortunate route discontinuity problem. Eventually, when the interstate is complete, traffic in this metropolitan area will go around the south and west side of the cities. In the interim, I-80 traffic is routed around the north and east quadrants of a cloverleaf interchange. I-74 traffic uses the other two quadrants. The Illinois Department of Highways recorded erratic maneuvers at this interchange before and after adding diagrammatic signs (Figure 8-8). Mitchell (1972) indicated that there were more erratic maneuvers after the diagrammatic signs were added to the signing array. This increase could have been due to any of several methodological factors. For instance, the erratic maneuvers were counted by different persons; traffic conditions changed because three years elapsed; different roads or sections of roads were opened that were not in use at the earlier time.

Mitchell noted that the erratic maneuvers were quite hazardous and it was believed near accidents occurred from some of the backing up, rapid deceleration, or sudden stop maneuvers. When the I-280 bypass is complete at this location, Iowa and Illinois plan to ask for a change of interstate route designation in order to remove the route discontinuity problem.

Poor Visibility

Drivers can negotiate complex interchanges when they can see the path they will follow. Diagrammatic signs have been used in attempts to alleviate problems caused by poor sight distance. In Phoenix, the freeway was depressed and structures obstructed the driver's vision, thereby hiding the exit ramp. In St. Louis, Missouri, there is inadequate visibility due to structures and a vertical curve. Diagrammatic signs described earlier (Figures 8-6 and 8-7) were installed in an attempt to alleviate the problem.

Boston, Massachusetts. West of Boston, Massachusetts, there is a cloverleaf interchange where signs were changed to diagrammatic signs. The interchange is on Massachusetts 128 which is a circumferential highway around Boston. The main line has a left horizontal curve and the exit ramps were not easily visible. A large exit direction sign (Figure 8-9) with a cloverleaf diagram including the complete crossover was installed. A local newspaper requested its readers to write in listing their comments on the signing for that interchange. The results of the newspaper survey were mixed (half favorable and half unfavorable). Most of the favorable comments began with, "I saw these kinds of signs in Europe and it's about time we are using them in this country." Most of the unfavorable comments were of the type, "those signs are too busy, I don't have time to read all that stuff." The exit direction sign went through three or four modifications, each one simplifying and removing information that was present on the previous phase. These were temporary signs and only in use for two years. They have now been replaced by permanent overhead signs. These are conventional signs with destination names and lane assignment arrows.

Springfield, Virginia. Another cloverleaf interchange not easily visible to the approaching traffic is at exit 4 on the Capital Beltway near Washington, D. C. Southbound traffic on I-95 approaching I-495 (Capital Beltway) comes to a cloverleaf interchange; the first exit leads to Fairfax and has two exiting lanes. Through traffic then goes over a vertical curve, under a bridge, and encounters an exit loop ramp marked "Baltimore."

In 1968, the Office of Traffic Operations of the Federal Highway Administration installed diagrammatic signs at this interchange. One was a shoulder mounted sign with a complete crossover design replacing the exit direction sign; the other, located after the first gore, was an overhead sign showing the remaining part of the interchange, also using a complete crossover. Data was collected on running speeds of traffic in the left two through lanes and in the right two exiting lanes approaching the first exit. Erratic movements were recorded and classified during December of 1967, before the signs were changed; and in August 1968, after the signs were changed. The character of traffic changed in the interim and the erratic maneuvers could not be compared.

The conclusion of the experimenters was that the complete crossover was misleading to the driver. The loop ramp crossed over the top of the through traffic lanes. This was indicated on the diagram by a standard bridge symbol from map making symbology. This bridge symbol apparently was very confusing; some people interpreted it as indicating the through lanes were barricaded (not continuous). These diagrammatic signs were removed shortly after the study was completed.

Concord, New Hampshire. I-89 begins near Concord, New Hampshire with a ramp exiting from I-93. This is a sharply curving, steep, downhill loop ramp. The accident record on this ramp was quite bad. A diagrammatic sign (Figure 8-10) has been added at the loop ramp. It also has a flashing light on top, and two warning signs and one regulatory sign on its face. These read, "sharp curve," "steep grade," and "ramp 25 miles per hour." Mr. F. Lindh of the

Figure 8-9. Diagrammatic sign in Boston, Massachusetts.

Figure 8-10. Diagrammatic sign in Concord, New Hampshire.

New Hampshire Department of Public Works and Highways indicated the accident record on this ramp has improved (except when slippery conditions occur). It is impossible to assess whether the improvement is due to the diagram or the alerting characteristic of this very unusual sign.

Arlington, Oregon. The State of Oregon has used diagrammatic signs to alert drivers to diamond interchanges where the crossroad goes under the interstate. The road crossing over the highway is considered a valuable cue to an exiting driver. This helps him estimate where his exit will occur. At interchanges without an overpass, the sign is the only warning to the driver that an interchange is near. These occur along the Columbia River where traffic exits on the river side and goes down grade to a collector road which passes under the interstate and feeds the towns south of I-80. One of these interchanges is the Arlington Interchange, although the signs do not name Arlington. The existing signs direct traffic to the Fossil Beds and John Day Valley (Figure 8-11). The signs are so overwhelming that people who have been watching for an exit in order to obtain services miss the exit. The sign does not indicate that there is a town at the exit. In fact, traffic is so unprepared for the exit that the State patrolmen have issued many citations to people who have passed the proper ramp and made 180° U turns onto the wrong way ramp to reach the town for services.

Unusual Interchange for Area

New Philadelphia, Ohio. In Ohio, near New Philadelphia, there is an interchange with a directional quadrant. Southbound traffic on I-77 must exit on the right, then use a ramp to cross over and to the left onto U.S. 250. This area of Ohio is quite rural in character and travelers don't expect this type of interchange. At this location, I-77 is on a left horizontal curve, so the dual lane exit ramps on the right function as a 2 lane tangential off-ramp. A diagrammatic sign (Figure 8-12) was added to the signing sequence for this interchange. This sign shows the complete crossover, which may lead some travelers to expect a left exit. However, this problem has not been reported.

Ogden, Utah. Ogden, Utah, has recently completed a full cloverleaf interchange. This is reported to be the only cloverleaf interchange in the State of Utah. Therefore, it was felt necessary to provide additional information to the travelers. One exit of the cloverleaf goes to Ogden Airport, the other to 31st Street, the main street of Ogden. There had been many reports of U turns on 31st Street. Some vehicles were involved in accidents while performing these U turns. Mr. Prisbrey of the Utah Highway Department indicated that this problem was alleviated by the diagrammatic signs in both directions at the interchange. These signs also utilize the full crossover type diagram. Pictures of these signs were not available.

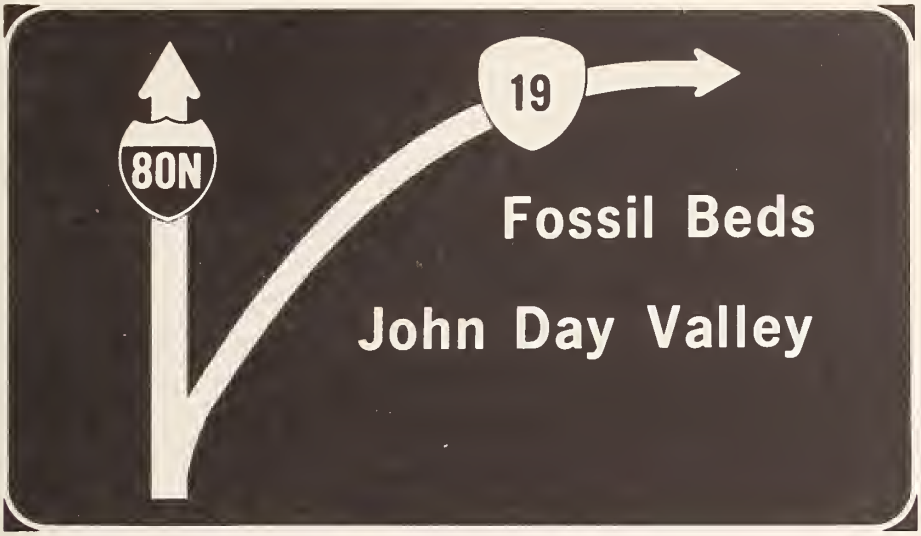


Figure 8-11. Diagrammatic sign in Arlington, Oregon.

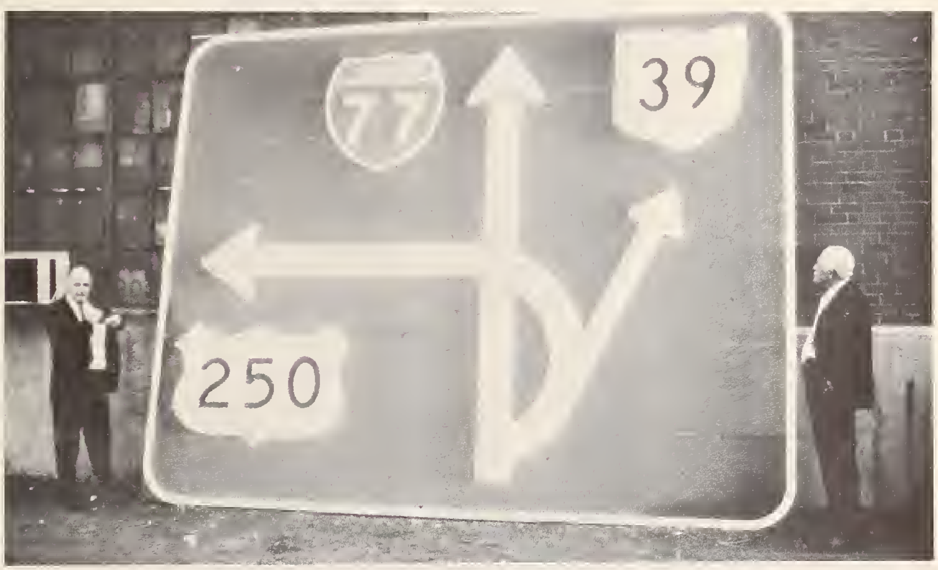


Figure 8-12. Diagrammatic sign in New Philadelphia, Ohio.

Tangential Off-Ramps

Tangential off-ramps are exit ramps which are located at a point where the main roadway begins to curve. The exit ramp may appear to be the main roadway. A driver with a low level of attention may be drawn off the highway. The ramps fit nicely into the terrain and many were built in the early days of the Interstate program. Most of these are still in use. Some of these interchanges have been mentioned earlier. St. Louis is operating a tangential off-ramp until Interstate 44 is completed. Michigan is operating one until I-75 is completed. There is another tangential off-ramp in Michigan which has had a diagrammatic sign added to warn drivers that an exit is straight ahead.

Nashua, New Hampshire. In New Hampshire there is a left exit tangential off-ramp where the mainline curves to the right and the off-ramp follows a sharp curve to the left. There is a recovery area for the drivers who leave the road at this gore area. The New Hampshire Department of Public Works and Highways has added a diagrammatic sign (Figure 8-13) in advance of this exit. They believe that fewer people have been leaving the road by mistake at this point.

In Salt Lake City, Utah, U.S. 40 curves to the left and a city street exits straight ahead. This is not a controlled access facility but has separated roadways. Complaints from tourists indicated that this was a bad intersection; officials in the State of Utah considered it unusual that tourists would take time to call. They have put a very simple diagrammatic sign at this location and have had no more complaints from tourists. A picture of the sign was not available.

Misleading Geometrics

Hebron, Ohio. There are examples where the partial cloverleaf misleads drivers. At the Hebron exit from I-70 in Ohio, westbound traffic approaches what appears to be a diamond interchange. It is a partial cloverleaf where the loop (second) exit is behind the overpass. The first exit goes to Hebron and the second exit goes to Buckeye Lake. A well advertised truck stop is near Buckeye Lake. Drivers can easily see the truck stop (built on high ground, visible from I-70). The interchange appeared to be a diamond so many truckers took the first exit, expecting to turn left. They had to turn around on Ohio 79 which has separated roadways with few places for large trucks to turn. Numerous complaints were received from residents in and near the town of Hebron.

A diagrammatic sign was installed in this case and is given credit for indicating to approaching truckers that this is a cloverleaf like interchange. This sign shows the complete crossover, just like the first three interchanges in Springfield, Illinois. Since the unfamiliar traffic is largely truck traffic, the full crossover loop diagram seems to convey the message. Buckeye Lake is a residential community with no through traffic, minimizing unfamiliar automobile traffic.

Figure 8-13. Diagrammatic sign in Nashua, New Hampshire.

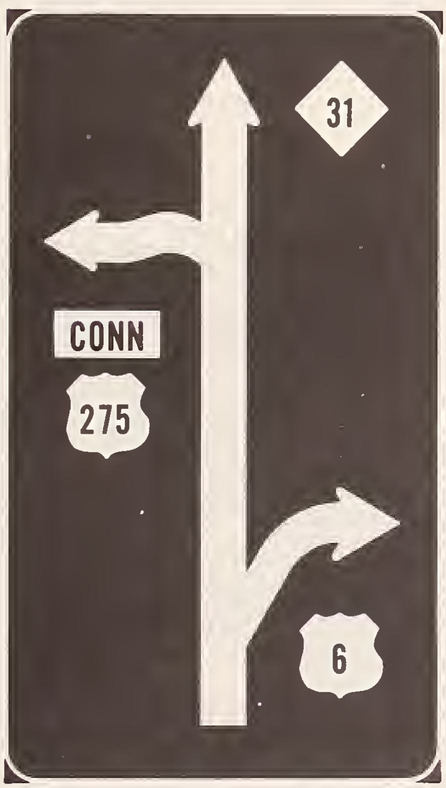


Figure 8-14. Diagrammatic sign in Ashland, Nebraska.

Ashland, Nebraska. In Nebraska there is a unique interchange (Figure 8-14) between Lincoln and Omaha. The diagrammatic signs shown have been used since 1959. This very unusual interchange had heavy traffic during the construction phase of I-80. After I-80 was completed, traffic decreased. Recently, traffic on this primary road is increasing more rapidly than was anticipated or can be explained. This interchange is a modified half cloverleaf. The outer connections and the loops share a portion of roadway as a weaving area. Each ramp has part one way traffic and part two way traffic.

Kansas. There are hundreds of diagrammatic signs in the State of Kansas at the junctions of primary routes. They refer to them as "Colorado map boards," although the current Colorado signing standards do not include similar signs. At some locations, diagrammatic signs are in use to direct traffic onto the proper I-70 entrance ramps (Figure 8-15).

Map Signs

There are some examples where maps were painted on signs to give the drivers route information for 10 to 150 miles. This information could not be extracted by the driver in available time at the speeds traveled. These signs were installed in Portland, Oregon, (Figure 8-16), Atlanta, Georgia, (Figure 8-17), and east of Mobile, Alabama, (Figure 8-18). The Portland sign was erected in September 1969 and removed 3 weeks later. It was installed over I-5, which carries 65,000 vehicles per day at about 65 mph (85th percentile). The estimated sight distance to the gore is about 800 feet. The maximum time available to read this sign was about 5 seconds.

In none of these cases would it be possible for the driver to extract the necessary information without reducing speed significantly. Therefore, signs of this type are likely to be disfunctional unless placed where the driver is expected to stop.

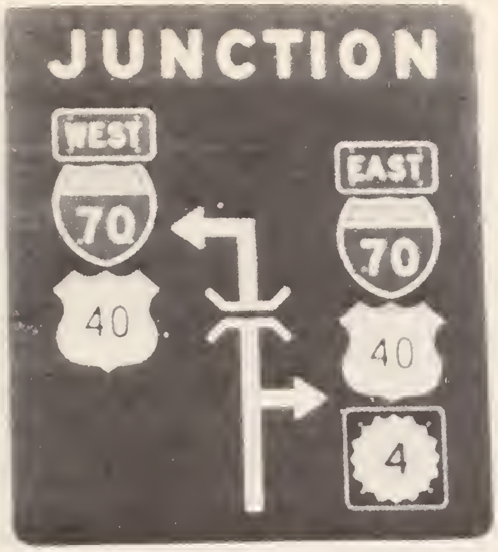


Figure 8-15. Diagrammatic sign in Kansas.

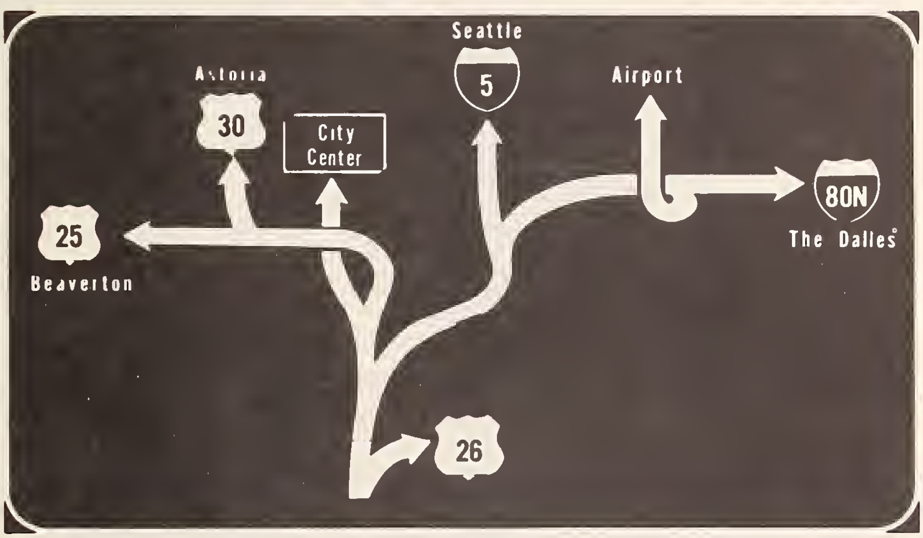


Figure 8-16. Map sign in Portland, Oregon.

Figure 8-17. Map sign in Atlanta, Georgia.

Figure 8-18. Map sign in Mobile, Alabama.

Chapter IX

GENERAL DISCUSSION AND CONCLUSIONS

The general discussion will address two main topics. The first and primary topic concerns the influence of diagrammatic versus conventional highway guide signs on driver performance at complex interchanges. Discussion will focus on the instrumented vehicle study results and how they compare to other laboratory and field findings. No comparisons will be made with the results found in the Capital Beltway (I-495) study, however. These comparisons will be made and discussed in Volume III of the project report. The second discussion topic will concern methodological issues. Since this topic is also dealt with in considerable detail in Volume III, discussion here will again focus on instrumented vehicle methodology. The capabilities and limitations of the instrumented vehicle approach in guide sign evaluation will be examined relative to laboratory and before/after field study techniques. Both discussion topics have a direct bearing on the two main objectives of the diagrammatic signing project. Namely, to make recommendations for the design and deployment of diagrammatic guide signs on controlled access highways and to provide recommended techniques for the evaluation of highway guide signs by State Highway Departments.

Research results from the instrumented vehicle studies will be reviewed and placed in perspective relative to findings by other investigators. The instrumented vehicle work, sometimes referred to as controlled field studies, had two specific objectives: (1) evaluate diagrammatic versus conventional highway guide signs at complex interchanges and (2) develop and evaluate the in-vehicle sign simulation technique as a means for evaluating highway signing. Discussion of the instrumented vehicle work will center around interchange geometrics. Five different types of interchange geometrics were studied relative to the effects of diagrammatic signs on driver performance. These were the cloverleaf, single right exit, collector distributor, multiple split ramp, and left exit. The effects of diagrammatic signs on driver performance at these interchanges will be compared to results obtained in State traffic studies and in laboratory work. Comparisons with laboratory work will concern the Berger (1970) findings, summarized in Chapter II, and the more recent work conducted by the Federal Highway Administration, reported in Chapter III. The work on diagrammatic signing by Breda, Kirkpatrick, and Shaffer (1972) at North American Rockwell will also be included in this discussion. Comparisons with results obtained in State traffic studies will be limited to those studies where systematic empirical evaluations were conducted. There were eight such studies, all of which are abstracted in Chapter VIII.

Chapter IX will close with the conclusions arrived at on the basis of in-house laboratory and instrumented vehicle work as well as State field work. However, final conclusions arrived at under the project must await an overview of the results obtained from all work conducted under the project.

In other words, findings in the Capital Beltway study must be weighed against the outcome of the in-house work before conclusions will be finalized and translated into specific recommendations. The Capital Beltway work was an extensive evaluation of diagrammatic guide signs under operating conditions. Therefore, it constitutes a major part of the research effort under the diagrammatic signing research program. After all the evidence gathered under the project plus that which is available from other sources has been evaluated and interpreted, final conclusions about the efficacy of diagrammatic signs will be presented. These conclusions, along with specific recommendations for deployment and design standards will be given in Volume I of the project report.

Left Exit

Results obtained in the controlled field experiments (instrumented vehicle studies) suggest that diagrammatic signs may be used to facilitate driver performance at left exits on controlled access highways. The results obtained with the instrumented vehicle at a left exit are presented and discussed in detail in Chapter VI. In general, the results indicated that lane changing behavior as well as driver velocity control is enhanced with diagrammatic guide signs. Incorrect preparatory lane changes were virtually eliminated with diagrammatic signs for exiting drivers. Furthermore, correct preparatory lane changes occurred further upstream in advance of the interchange gore area. Exiting drivers maintained vehicular velocities in the main traffic stream at levels commensurate with through traffic.

The results obtained in the instrumented vehicle study are consistent with those found in three different State traffic studies. States where the influence of diagrammatic signs on traffic behavior were studied at left exits were Connecticut, New Jersey, and Wisconsin. Interim or final reports on these studies are abstracted in Chapter VIII.

The Connecticut Department of Transportation (1972) in their interim report indicated that preparatory lane changes occurred earlier after diagrammatic signs were added 1/2 mile and 1/4 mile prior to the interchange gore at a left exit. The authors tentatively concluded, based on their preliminary data, that diagrammatic signs facilitated traffic operations at the left exit in their study. Roberts (1971) in a study conducted by the New Jersey Department of Transportation reported a significant reduction in erratic maneuvers at a left exit after diagrammatic guide signs were installed. In this case, the left exit was preceded by a right exit and the left exit exhibited a double lane drop. There was a further reduction in erratic maneuvers when lane lines were added to the graphic components on the diagrammatic guide signs. The results reported by Graham and Volk (1972) in a study conducted by the Wisconsin Department of Transportation were inconclusive. However, the diagrammatic signs serving the left exit in their study used graphic components that were divided into separate elements at the advance signs. This separation of the graphic component into individual elements may have in this case reduced the effectiveness of the diagrammatic sign at the left exit in this study.

Findings in the laboratory by Berger (1970) did not show a significant difference between diagrammatic and conventional signing conditions at a left exit on the lane choice measure. Although there was a trend for an increase in percentage of correct lane choices under the diagrammatic condition, Gordon (1971, Chapter III) concluded that there was no difference between the conventional and diagrammatic test signs in number of lane choice errors at the left exit. Although the error data were not tested statistically, there appeared to be no difference between the two signing conditions. Gordon did report, however, that there was a significant increase in subject reaction time to the diagrammatic signs at the left exit. These reaction time results are consistent with the findings in the instrumented vehicle study on the driver information interpretation time measure.

The failure of both laboratory investigations to indicate a facilitation in driver lane choice behavior at the left hand exit may be attributed to the fact that the graphic components in the diagrammatic signs at the advance sign were separated. Thus, the separated components failed to provide the driver with a clear depiction of the required left maneuver relative to the through traffic stream. When the left maneuver was shown with regard to the through traffic route, Berger (1970) with the third sign in his sequence showed a large difference favoring the diagrammatic sign. The Gordon (1971) data showed an increase in the number of errors in lane choice with this diagrammatic sign.

Results in the instrumented vehicle indicated that driver information interpretation time (IIT) was significantly longer at the advance sign under the diagrammatic signing condition. Part of this is due to the increase in information content on the sign provided by the graphic component. However, a large part is also due, no doubt, to the fact that the information concerning the left exit violates the driver's expectancy. Drivers would be expected to attend longer to a sign with information that is incompatible with their stereotyped or accustomed response of exiting to the right from controlled access highways.

The significant increase in IIT found in the instrumented vehicle at the advance sign in the left exit signing sequence, particularly in magnitudes approaching 7 seconds, increases the likelihood that drivers will decelerate in the main traffic stream. This must be interpreted as a negative factor or negative side effect of the diagrammatic sign. One way of accommodating the longer IIT under the diagrammatic sign would be to increase the dimensions of the sign, making the information on it available to the driver earlier than what is usually the case. This would make more information processing time available to the driver and thus decrease the liklihood that he will decelerate in the main traffic stream. Of course this approach is only justified if the diagrammatic produces a benefit on other measures of traffic operation efficiency. In the case of the left exit, it would appear that the diagrammatic sign does produce a benefit on other performance measures; thus, enlarging the sign as a counter measure against prolonged IIT would be warranted.

Hence, it is concluded, based on instrumented vehicle work and State field studies, that an appropriately designed diagrammatic sign at a left exit will produce a benefit to motorist performance. It is further suggested that in order to offset the increased IIT at the advance sign, increased sign dimensions should be considered. Final recommendations and conclusions will be weighed against the findings in the Capital Beltway study. Specific recommendations concerning sign design and deployment will be presented in Volume I.

Multiple Split Ramp

The multiple split ramp interchange used as a test interchange in the instrumented vehicle study was located on the I-95 southbound approach to I-95/I-495 Interchange (Capital Beltway Exit 4). It exhibited heavy through and exiting traffic volumes, three through traffic lanes, a double lane drop, and was one of a series of closely spaced interchanges. Traffic operations were further complicated by the fact that there were two entering lanes of traffic, one from the left and one from the right, within 1/2 mile of the interchange gore area at the northbound approach.

Results obtained in the instrumented vehicle study, reported in detail in Chapter VI, indicated that the diagrammatic signs tested at this interchange produced a decrement in driver performance in comparison with the conventional signs. Simplified conventional signs with lane assignment arrows proved to be more superior than either of the two diagrammatic signing conditions tested. It may be argued that there are other possible types of graphic sign designs that were not evaluated and that perhaps another type of graphic design might show a benefit. To be sure, there are a number of possible graphic sign designs that might be considered at this interchange approach. However, it is virtually impossible to design a graphic component that will be both simple and at the same time provide an accurate depiction of this interchange's geometry. Both simplicity in graphic design and accuracy in geometric representation are required before a diagrammatic sign will produce a benefit in driver performance. When the simple, but less accurate, diagrammatic sign was tested in the instrumented vehicle study (Chapter VI, it produced the most deleterious effects on driver lane change behavior. Of the two diagrammatic signing conditions, better performance was achieved with the more complex diagrammatic sign, but the conventional signs remained superior.

The complex diagrammatic sign tested in the instrumented vehicle study could be improved upon. The sign could be made larger, permitting improved spacing of the graphic elements. Even with this modification it is highly unlikely that the diagrammatic sign would equal the performance of the conventional sign.

It is important to note, however, that simple conventional signs as opposed to complex conventional signs should be used at this type of interchange.

That is, the signs should convey a minimum number of destination place names and route shields. Furthermore, it is suggested that lane assignment arrows be employed, beginning as far upstream as possible. The sign panel for each lane, particularly in the double lane drop, should not contain more than one route shield, one cardinal direction, and one place name plus the yellow "exit only" panels. This was the conventional sign configuration used in the instrumented vehicle study. It is believed that this signing is preferred to the present signing being used at the particular site. The signs now in place at this interchange display too much information.

In a complicated geometric situation like this, the route shields and cardinal direction panels must be relied upon to carry most of the routing information. Place names require too much information processing time. Moreover, the gain in providing place name information is greatly offset by the deficit it produces in terms of information interpretation time. The driver is overloaded at this type of interchange approach in trying to cope with traffic congestion and he cannot assimilate large quantities of signing information.

The instrumented vehicle results at this interchange support the Gordon (1971) laboratory work but not the Berger (1970) findings. Berger reported that the diagrammatic signing condition that he used was superior to his conventional condition. An examination of the conventional signs tested by Berger, however, indicates that they were definitely inferior conventional signs. In Berger's study, lane assignment information was not given to the driver at the second advance sign under the conventional condition. Moreover, "exit only" panels were not present on any of Berger's conventional signs. The "exit only" panels serve as important cues to exiting as well as through traffic lane choice.

In the Gordon study (1971), there were more lane choice errors committed under the diagrammatic signing condition and longer subject response times. The contradictory findings between the Berger and Gordon findings at this interchange are difficult to explain since both studies used identical sign stimulus material. The difference in the findings between these two studies may be a function of the correct lane choice criteria used by the investigators. Personal communication with Gordon revealed that his correct lane choice criteria was commensurate with that used to score correct and incorrect preparatory lane change behavior in the instrumented vehicle. In the Gordon study the degrees of freedom were restricted in terms of what was the correct lane choice after the first exit direction sign was presented to the subject. Since Berger (personal communication) allowed more degrees of freedom in what was scored as a correct lane choice at the exit direction sign locations, this could account for the contradictory findings.

The absence of lane lines on the stimulus material complicates subject choice of either of the two exiting lanes at the exit direction signs. Without the lane lines to distinguish between the two exiting traffic lanes in the double lane drop, it is very difficult for the subject to determine which of the two exiting lanes is the correct choice.

Information governing the correct lane selection of the two exiting lanes was not available at the first exit direction sign. Moreover, at the second exit direction sign, this information is implied in the graphic, but not depicted directly.

The multiple split ramp interchange was not tested in any of the State traffic studies. Nor was it evaluated by Biotechnology in the Capital Beltway study. However, based on the instrumented vehicle findings and results obtained by Gordon in the laboratory, it is suggested that diagrammatic signs deployed at multiple split ramp interchanges like the one at the northbound approach to I-95/I-495 would produce an impairment in driver performance rather than a benefit. Conventional signs with lane assignment arrows, "exit only" panels on signs over dropping lanes, and minimum number of place names are superior over diagrammatic signs with complicated graphics.

Single Right Exit and Collector Distributor

Driver performance at the single right exit and at the collector distributor interchanges will be discussed together. The signing evaluated for the main traffic stream was identical for both of these interchanges in the instrumented vehicle studies. The characteristics in driver performance were also similar. Results found in the instrumented vehicle for the single right exit are presented in detail in both Chapters V and VI. Findings at the collector distributor are reported in Chapter VI.

Neither of the two interchanges studied in the instrumented vehicle investigations were problem interchanges. Both exhibited two through traffic lanes, heavy through traffic volume, but light exiting traffic volumes and no lane drops. The collector distributor interchange was in fact signed like a single right exit in the main traffic stream since there was only a single exit from the main stream to the collector road. The two exit ramps at this interchange were served by the collector road.

For both the single right exit and collector distributor interchanges, diagrammatic signs did not show a benefit over conventional signs. In fact, driver information interpretation time was greater at the advance sign under the diagrammatic signing condition. The magnitude of the average increase was not much more than 1 second, however. There was no difference between the two signing conditions at the interchanges in terms of driver velocity control, lane change behavior, erratic maneuvers, and driver exiting errors.

The findings in the instrumented vehicle studies are consistent with results obtained by Breda, Kirkpatrick, and Shaffer at North American Rockwell. These authors employed a driving simulator to examine driver performance as a function of different types of route guidance systems. Test drivers sat in a moving base automobile body and viewed a TV scene provided by a closed circuit TV camera. The TV camera moved along roadways of a scaled terrain model in response to steering, braking, and accelerating actions of the subject.

Diagrammatic versus conventional signs were evaluated in the simulator at diamond and collector distributor type interchanges. Both interchanges exhibited single right exits from the main traffic stream. The diagrammatic sign design used at the diamond interchange was very similar to the graphic design used in the instrumented vehicle at the single right exit. The through route shield was incorporated in the graphic component and the emanating arrow was a "choice point" type of design. At the collector distributor interchange, the conventional and diagrammatic signing serving the main traffic stream was identical to the diagrammatic interchange signing. However, diagrammatic signing on the collector road used the "implied crossover" type sign design.

The simulator results indicated that on the basis of probability of exiting errors, there was no difference between signing conditions at the diamond interchange. At the collector distributor interchange there was a trend toward increased probability of exiting errors under the diagrammatic condition. The trend did not reach statistical significance, however. Similarly, there were no statistical differences between signing conditions at these two interchanges based on the other measures employed in the study, including the average speed measure.

No direct comparisons were available on the single right exit type of interchange between the instrumented vehicle studies and the two laboratory studies conducted by Berger and Gordon. Empirical evaluation of a diagrammatic sign at a single right exit was conducted in the field by Snyder and Crosset (1969). They reported no significant difference between the two types of signs based on their speed measure, although motorist opinion was favorable to the diagrammatic signs.

Laboratory (Berger 1970; Gordon 1971) and field (Hanscomb, 1971) comparisons were made between diagrammatic and conventional signs at an unusual type collector distributor interchange. However, results in these studies are not directly comparable to the instrumented vehicle findings since the characteristics of the collector distributor interchanges were distinctly different. The collector distributor interchange evaluated in the laboratory and by Hanscomb exhibited a lane drop and three exits off the collector road. The result found at this unusual interchange will be discussed in detail in Volume III of the report.

It is concluded that diagrammatic signs will not produce a benefit over conventional signs at a single right exit type of interchange. It is further concluded that a benefit will not be derived from diagrammatic signs at typical collector-distributor interchanges. They can be signed in the main traffic stream as single right exits and can, therefore, be effectively signed by conventional signing methods.

Cloverleaf

A number of diagrammatic sign evaluations have been conducted at cloverleaf interchanges. More different types of graphic designs have been studied for this type of interchange than for any other kind of geometric configuration. Evaluations have been conducted in the laboratory (Berger, 1970; Gordon, 1971) in a driving simulator (Breda, Kirkpatrick and Shaffer, 1972) in the field in instrumented vehicles (Chapters IV, V, and VI; Bhise and Rockwell, 1972) and in traffic studies (Office of Traffic Operations, 1969; Office of Research, 1971; Roberts, 1971; Graham and Volk, 1972; Wyoming State Highway Department, 1970). Most of these studies have shown an impairment or no effect on driver performance with diagrammatic signs.

Instrumented vehicle studies conducted by the Office of Research (1971 and 1972) indicated a performance decrement at a cloverleaf interchange with diagrammatic signs using an "implied crossover" graphic design. These studies are reported in detail in Chapter IV and V. In both studies, however, the interchanges could not be characterized as being problem interchanges. They both exhibited two through traffic lanes and low exiting volumes. One interchange had excellent sight distance and no lane drop (Chaper IV), whereas the other had poor sight distance and a lane drop at the second exit (Chapter V). Performance degradation under the diagrammatic signs was in terms of increased information interpretation time and driver vehicular velocity control.

In later Office of Research tests (1972, Chapter VI), using a "choice points" graphic design, the diagrammatic signs had no effect on driver performance. These tests were conducted at an interchange which exhibited good sight distance, three through traffic lanes, no lane drop, and low to moderate exiting traffic volumes. The differences in results between these studies are probably attributable to the different graphic designs employed. It is reasonable to conclude that the more complex graphic, with the "implied crossover" configuration, produced the performance impairment. When the simpler "choice points" design was tested, there was no evidence of degradation in performance. On the other hand, there was no improvement in performance over the conventional signs either.

The laboratory work in general supports the findings in the instrumented vehicle studies. Berger (1970) concluded that modified conventional signing was significantly better than diagrammatic signing at a cloverleaf interchange. Moreover, Gordon (1971) reported more lane choice errors and longer subject reaction time under diagrammatic signing conditions at the cloverleaf interchange. Implied crossover graphic designs were used in both of these studies. In a laboratory driving simulation study, Breda, Kirkpatrick, and Shaffer (1972) found no difference between conventional and diagrammatic signs at a cloverleaf interchange. An "implied crossover" design was also used in this study. However, the diagrammatic sign was less complex than the previously mentioned designs in that no place names or route shields were located near the emmanating arrows, only cardinal direction panels. This may account for the lack of performance impairment in the simulator study.

Bhise and Rockwell (1972) used an eye-marker camera to record driver eye movements as they processed information on conventional and diagrammatic guide signs. Data was gathered on five subjects as they drove and instrumented vehicle through a cloverleaf interchange under actual driving conditions. In this case the diagrammatic sign exhibited the "full crossover" graphic design. On the average, subjects spent 6.67 seconds obtaining information from the diagrammatic sign as opposed to 1.76 seconds on the conventional sign. This result and further analysis of the eye movement data suggested that the information displayed on the diagrammatic sign was difficult to comprehend as compared to conventional highway signs.

Traffic studies conducted in the field using "full crossover" graphics (Office of Traffic Operations, 1968; Wyoming State Highway Department, 1970) and "implied crossover" designs (Graham and Volk, 1972; Office of Research, 1971) have failed to show a conclusive benefit with diagrammatic signs deployed at cloverleaf interchanges. In addition, reports from State highway departments based on cursory observation or anecdotal incidents, described in Chapter VIII, fail to substantiate a conclusive benefit from diagrammatic guide signs deployed at the cloverleaf interchange. In fact, the weight of the evidence suggests that the diagrammatic sign has produced a degradation in traffic operations, particularly where the full crossover design has been used. Where small benefits have been reported, it has been impossible to isolate the diagrammatic sign's effect from other confounding variables. For example, benefits reportedly produced by complex diagrammatic signs may have been due to transient novelty effects or the high target value of the sign. In essence, the sign may have been functioning primarily as an early warning device by informing the motorist that something unusual was awaiting him up ahead. Based on evidence from experimental work, it is evident that the small benefits, where they have been reported in the field, cannot be a function of the facilitation of driver information processing or the provision of a clearer understanding of interchange geometry. The evidence is very clear on this point.

Highway engineers have much more efficient early warning devices at their disposal than diagrammatic signs to forewarn motorists of anomalous driving situations. The early warning feature of the diagrammatic sign in the absence of facilitated information processing or other benefits to driver performance cannot be adequate justification for deploying diagrammatic signs at cloverleaf interchanges, certainly not on a nationwide basis. Therefore, it is concluded that diagrammatic signs will not produce a substantial benefit when deployed at typical cloverleaf interchanges. Furthermore, it is apparent that complex graphics, such as "full crossovers" or "implied crossovers" should not be used on any type of diagrammatic sign, regardless of the interchange's geometry. Too many motorists are confused and fail to understand the meaning of crossing or implied crossing graphic elements.

Sign Evaluation Methodology

Discussion of sign evaluation methodology will focus on the instrumented vehicle as a sign evaluation tool. Detailed consideration of the full scope of evaluation techniques, including laboratory and traffic study techniques. will be presented in Volume III.

Experience thus far with the in-vehicle sign simulation technique suggests that it is an effective sign research method. It provides the sign researcher with the experimental control of the laboratory and the realism of actual traffic conditions. Experimental test signs can be developed in the form of hard art copy and then photographed as colored film transparancies. Like the researcher in the laboratory, the investigator using the in-vehicle sign simulation technique can study an almost unlimited number and types of sign design variables. The technique offers several advantages over field studies where test signs have to be erected along the highway and used under normal traffic operating conditions. The advantages relate to cost, efficiency in terms of time and logistics, experimental control, and flexibility in the manipulation of sign variables. The last point needs emphasis. Many times the researcher needs to experimentally degrade information processing tasks in order to accentuate effects produced by various independent variables. This has frequently been done in laboratory studies, particularly where tachistoscopic techniques have been employed. Berger (1970) did this in his study by limiting sign exposure times to 1 second. In effect, this escalated the overall lane choice error rate, thereby sensitizing the effects of his independent variables. In a traffic study conducted in the field, the researcher is not at liberty to purposefully increase driver error rates so that the effects of sign variables can be better understood.

This can be done with the in-vehicle sign simulation technique, however. In fact it was done in the McLean study (Chapter V) where drivers were forced to make exiting maneuvers based only on information provided at advance guide signs. As one would expect, the overall exiting error rate was increased. It is unlikely that a field researcher would ever be granted the opportunity to eliminate exit signs at an interchange in order to study the effectiveness or information presented at advance signs.

The in-vehicle sign simulation technique is not without its limitations, however. It should not be used to test aged drivers who are likely to have visual accommodation problems with the in-vehicle display. Furthermore, the technique cannot be recommended to State highway departments for use on a routine basis. Considerable resources are required in conducting sign evaluations with instrumented vehicles. Resources in the form of personnel with specialized skills being the paramount necessity. The technique requires fabrication and maintenance of relatively complex instrumentation. Experienced human factors researchers are needed to establish stimulus response paradigms, determine indices of driver performance, develop test stimuli, and to conduct driver screening and testing. These are routine activities for researchers experienced in instrumented vehicle work, but not commonplace tasks for State highway departments. In short, as a specialized sign research tool, the in-vehicle sign simulation technique is very promising. But at this stage in its development, it cannot be recommended for use by State highway departments for routine sign evaluation.

Some discussion of laboratory sign evaluation techniques is in order at this point. Relative to the instrumented vehicle findings, results from laboratory work was either in agreement or contradictory, depending upon the characteristics of the test interchange. The Berger (1970) findings were in agreement at the cloverleaf interchange, but were in conflict at the multiple split ramp. Gordon's work (1971) was in agreement at the cloverleaf, but was in disagreement at the left exit. In the case of the left exit, Gordon and Berger were in accord. Examination of these findings suggests that the laboratory techniques were not very consistent with field results. It must be pointed out, however, that in many respects inconsistencies between the field work in the instrumented vehicle and the laboratory work were probably due to the differences in sign stimulus material. The laboratory work laid the ground work for the instrumented vehicle studies. That is, the laboratory findings were used to provide input for the development of better graphic designs. In the course of the program, laboratory findings and field findings were never compared using exactly identical stimulus material.

Work directly comparing the Gordon technique with the instrumented vehicle method, using identical sign stimulus material, is now in progress. This investigation is being carried out in the laboratory of the Office of Research. Similar work is also being conducted at Wayne State University using sign stimulus material representing the diagrammatic and conventional signs evaluated in the Capital Beltway study.

The inconsistency in findings between the two laboratory techniques is another matter because the exact same sign stimulus material was used The only explanation lies with the correct lane choice criteria used and the different procedures used in presenting the test stimuli -- group technique versus individual response technique. Work is and should continue to be done to establish a valid and reliable laboratory technique for the evaluation of highway guide signing. A good laboratory method is still the technique of choice for use on a routine basis by State highway departments. Further discussion of laboratory techniques relative to the findings in the Captial Beltway study will be presented in Volume III.

Summary of Conclusions

1. An appropriately designed diagrammatic sign will produce a benefit to motorist performance at an interchange with a left exit.

2. Diagrammatic signs deployed at a multiple split ramp interchange, like the one at the northbound approach to I-95/I-495, will produce a degradation in motorist performance. Simplified conventional signs with lane positioning and lane drop information are superior to complex graphic signs at this type of interchange.

3. Diagrammatic signs will not produce a benefit over conventional signs at single right exits.

4. Diagrammatic signs will not produce a benefit over conventional signs at typical collector-distributor interchanges. These interchanges can be effectively signed in the main traffic stream as single right exits.

5. Diagrammatic signs will not produce a benefit over conventional signs at ordinary cloverleaf interchanges.

6. Complex graphics should not be used on any type of diagrammatic sign. Full crossover and implied crossover graphics are confusing to many motorists.

7. The in-vehicle sign simulation technique is an effective highway guide sign research tool.

8. The in-vehicle sign simulation technique must be further developed and refined before it can be recommended to State highway departments for routine sign evaluations.

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