EVALUATION OF GROUND MOUNTED DIAGRAMMATIC ENTRANCE RAMP APPROACH SIGNS

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16. Abstract

Highway-freeway interchanges can be a source of confusion to unfamiliar drivers. Typically, freeway entrance ramp information is provided by means of trailblazer assemblies (interstate or highway shield, cardinal direction, and a small white arrow on a blue shield). Trailblazer assemblies are generally located right at the interchange location, giving unfamiliar drivers very little advance notification as to the proper lane choice needed to gain access to the freeway entrance. Advance located ground mounted diagrammatic guide signs provide this much needed information well in advance of the interchange entrance, thus giving drivers more time to change lanes, if needed. Diagrammatic signs have been used in Europe for many years with great success. The present study investigated the effectiveness of ground mounted diagrammatic signs in the context of urban multi-lane arterials leading to a freeway. The diagrammatic sign layout was designed as part of this project in collaboration with ODOT. Six highway-freeway interchanges were selected in the Greater Columbus, Ohio, area to determine the effectiveness of the diagrammatic signs in the field. Traffic flow video footage was collected at the selected sites before the diagrammatic signs were installed. The finalized diagrammatic sign designs were then installed and the traffic flow videotaping was repeated. The collected video footage was automatically analyzed with Mobilizer PC. The resulting vehicle count, speed, and headway data was used as input to a closed form analytical model to determine the probability that drivers could successfully change lanes as needed, prior to reaching the gore of the freeway entrance. The theoretical analysis indicated a much higher probability that an unfamiliar driver could execute a required lane change when diagrammatic signs are used. ODOT/FHWA evaluators visited the six interchange sites and provided their input and opinions as to the use of diagrammatic signs. The vast majority of the evaluators fully embraced the idea of diagrammatic signs. Eye movement recordings were performed at night at the six sites in order to determine if the presence of the diagrammatic signs was distracting. The results of the eye movement analysis indicate that the diagrammatic signs are not looked at excessively often or excessively long. The overall median first look distance to the diagrammatic signs was found to be 125m. An evaluation with unfamiliar test drivers corroborated the findings of the theoretical model analysis, in that drivers were able to execute a needed lane change much earlier when diagrammatic signs were provided. A set of application guidelines for diagrammatic signs is provided.

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Last, but not least, thanks to all subjects, test drivers, and evaluators, whose names we cannot disclose.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

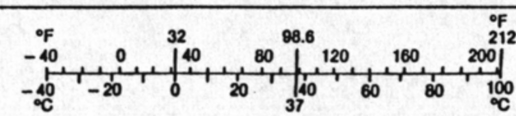
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Ohio Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

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1 INTRODUCTION

The present study was conducted to investigate the effects of ground mounted diagrammatic entrance ramp approach signs on driver behavior. Typically, drivers need the aid of guide signs to navigate on the urban road network. This is especially true for drivers in an unfamiliar road environment. Highway-freeway interchanges represent an area of confusion in the road system where unfamiliar drivers may benefit from the use of guide signs. Currently, trailblazer assemblies (Figure 1a) are used in Ohio to guide drivers approaching a freeway-highway interchange on an urban arterial. These trailblazer assemblies are located relatively close to the interchange, and due to their small size and limited information content, they do not give a driver much advance information about the lane alignment in the entrance ramp area. Additional non-diagrammatic guide signing is typically located along the interchange approach as indicated in Figure 2. Conventional Road Guide Signs are described in the OMUTCD [1] section 2R. Road Guide Signs generally display a destination and the distance in miles to this destination. Freeway and Expressway signs are described in section 2U of the OMUTCD [1]. Figure 3 shows two typical overhead diagrammatic freeway guide signs.

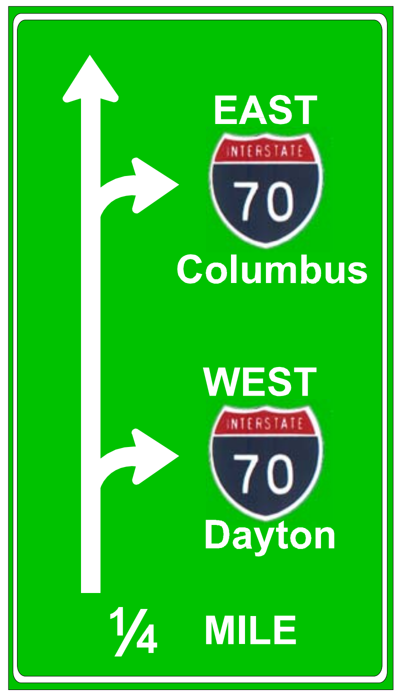
Ground mounted diagrammatic entrance ramp approach signs (Figure 1b) are another type of guide sign, intended to give drivers information as early as possible during approaching a highway-freeway interchange. The use of ground mounted diagrammatic entrance ramp approach signs will provide a lower cost alternative to the use of overhead span type sign bridges. This field study was sponsored by the Ohio Department of Transportation (ODOT) and the Federal Highway Administration (FHWA) to determine if there are any driver benefits if some of the advance guide information at highway-interchanges is displayed in diagrammatic fashion as shown in Figure 1b.

While over the years, the expressway guide signing concept has been somewhat optimized for visibility, legibility, and easy information processing to allow for efficient and correct motorist decision making, the Route Marker and Conventional Guide Signing concept has not been improved to the same degree. Thus, the conventional guide signing system does not fully address the ever-increasing information acquisition and information processing demands imposed upon the motorist operating his/her vehicle in an urban freeway interchange setting. In fact, multiple variations in interchange design and inadequate signing make it often difficult for an unfamiliar motorist approaching a freeway or expressway interchange to determine which way to turn in order to enter the freeway entrance ramp in the desired direction of travel. This is especially true on multi-lane approaches to freeway interchanges. Considering the increased driver workload on multi-lane freeway interchanges and the relatively poor conspicuity, visibility, and legibility of the current conventional guide signing concept, timely and safe lane changes are often not possible since the relevant information may not be processed in due time. This may

- compromise driver safety (erratic last moment lane changes),
- reduce interchange throughput due to slowing and/or stopping, and/or
- cause additional traffic (and additional fuel consumption) due to drivers who cannot merge as required and must therefore turn around some distance away from the interchange and approach again from the other side.

The Federal Manual on Uniform Traffic Control Devices (MUTCD) [2] states in section 2F-24 that "diagrammatic signs have been shown to be superior to conventional guide signs for some interchanges". Figure 3 shows typical freeway guide signs as described in [2]. The MUTCD encourages the highway agencies to continue with further experimentation using diagrammatic signs. Thus, the research shown herein was aimed at improving the conventional guide signing concept with regard to its application along freeway/expressway interchange approaches. Figure 2 shows the application of the Conventional Guide Signing System at a typical diamond freeway interchange. It seems that the Conventional Guide Signing System used in an interchange approach as shown in Figure 2 does not provide as much advance information about appropriate lane changes as would be possible and desirable from a human factors and ergonomics point of view.

a. Trailblazer assembly.



b. Diagrammatic sign.

Figure 1. Examples of Entrance Ramp Signing

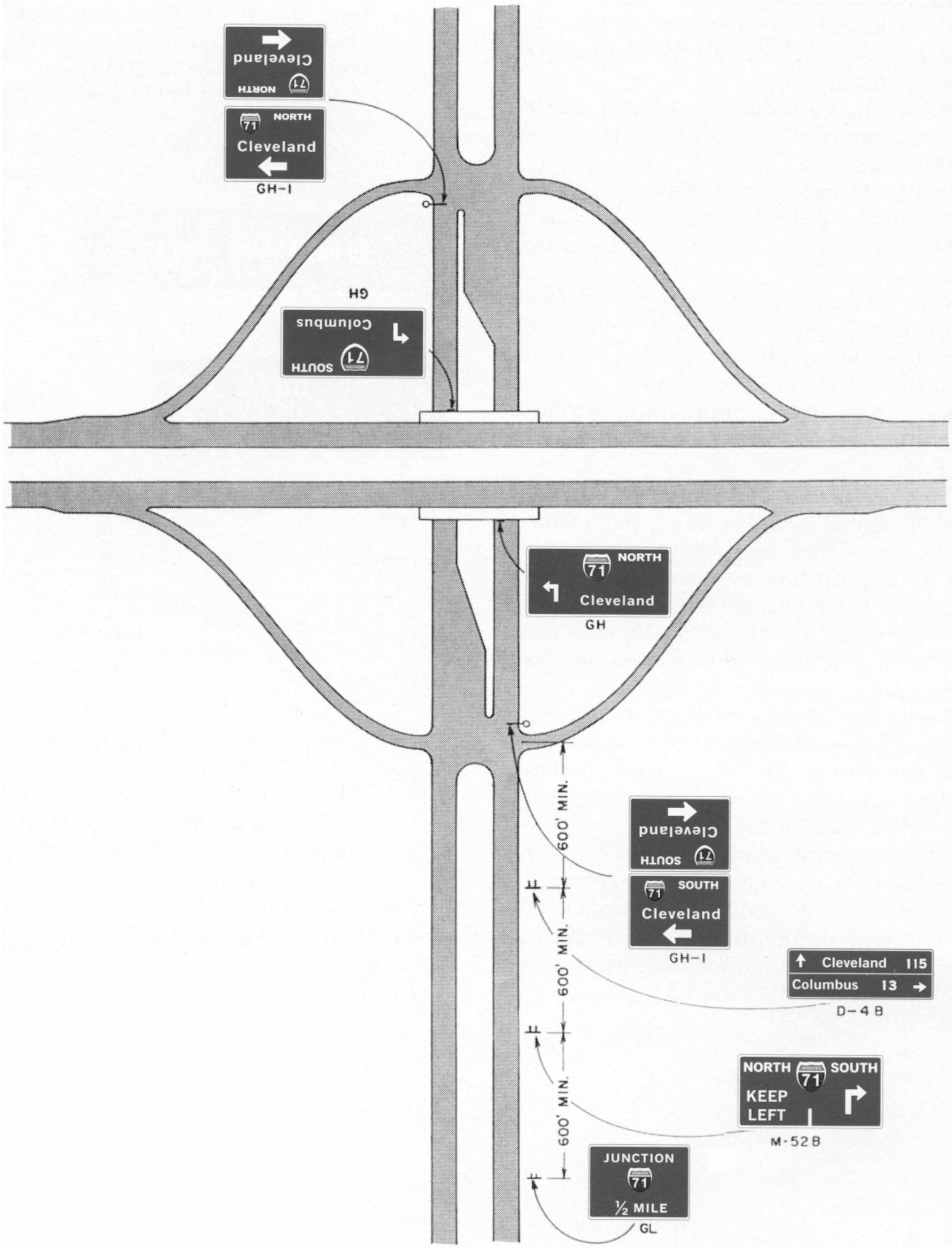


Figure 2. Diamond Interchange, Freeway Over Rural Expressway (Figure reproduced from [1], Figure GS-20)

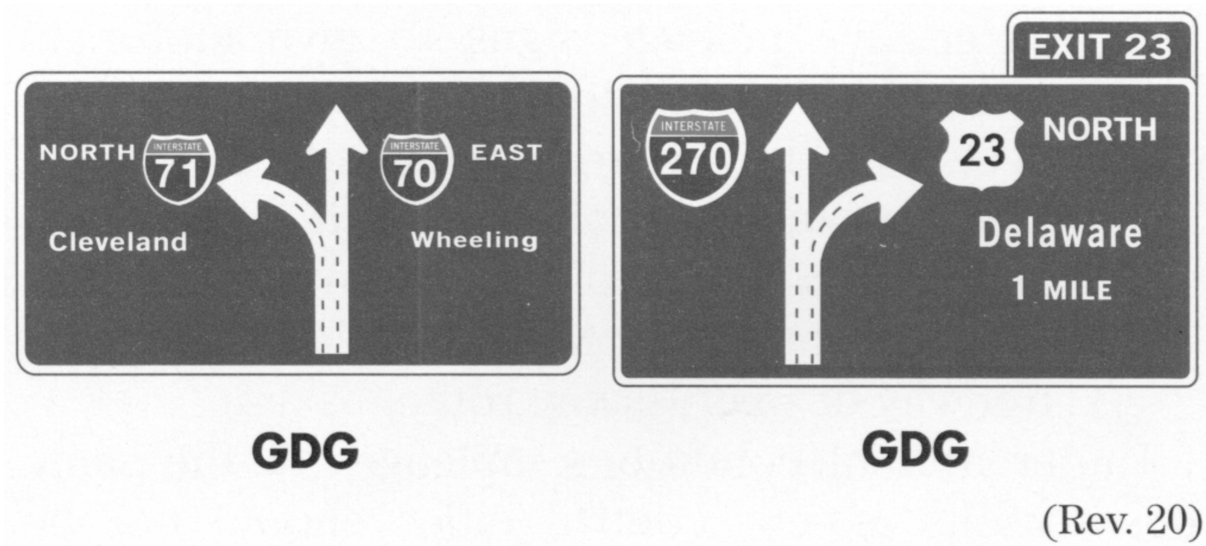


Figure 3. Example of Typical Overhead Mounted Diagrammatic Freeway Guide Signs

This research was conducted in the greater Columbus, Ohio, area and involved the following studies:

1. Collection of video flow data under the before condition (preexisting guide signing).
2. Collection of video flow data under the after condition (supplemental diagrammatic guide signs).
3. Analysis of the video flow data using the automated traffic analysis and classification software package Mobilizer PC. This task was used to unobtrusively determine the headway maintenance behavior, vehicle speeds, and interchange throughput under the before and after condition.
4. Driver eye movement recording and analysis during approaches to the test interchanges. This task was used to determine the first look distances, number of looks, and the last look distances to diagrammatic and other guide signing.
5. Test driver behavior was recorded with video cameras to determine when an unfamiliar test driver would recognize that he or she had to change lanes in order to enter a specified freeway.
6. Expert evaluation questionnaire to determine the opinions of ODOT traffic engineers regarding the use of diagrammatic guide signs

1.1 Statement of the Problem

The current trailblazer assemblies give the approaching drivers little advance indication of which lane should be used to complete the entrance onto the freeway in the desired direction of travel. Interchanges may require right turns for both available directions of travel (cloverleaf interchange), a left turn to travel left and a right turn to travel right (diamond interchange), or other combinations of right and left turns. This lack of consistency can cause problems if drivers do not recognize a necessary lane change soon enough. Late recognition of the required entrance ramp lane may cause drivers to perform risky weaving maneuvers to gain access to the desired lane. This type of maneuver causes disturbances in the traffic flow and increases the potential for collisions. If drivers determine that there is not enough time to make a weaving maneuver, they must continue in the same direction of travel until they can locate an acceptable gap to change lanes. Drivers must then exit the roadway, turn around (e.g. at a gas station), and try to find the interchange from the opposite direction. This causes an increase in traffic volume as well as emissions. Signs can be mounted on overhead span type sign bridges to provide additional guidance to the motorist. This type of signing is very effective, but quite costly. Ground mounted diagrammatic signing may be able to give drivers more information about the proper lane for each available direction of travel well in advance of the interchange, at a more cost-effective level.

2 LITERATURE

Opland [4] and the state of Michigan Department of Transportation conducted a Positive Guidance Demonstration project on a major freeway split off of I-96. The site experienced a high accident rate as well as a high incidence of erratic maneuvers and lane changes. As a result of an implementation of the Positive Guidance procedure, changes were made to the information system. The major feature of the change was a diagrammatic treatment. A "before/after" evaluation showed a statistically significant reduction of two of the four measures of effectiveness. These were erratic maneuvers and brake applications. Accident reports were positive from this treatment, also. It was concluded that the positive Guidance principles and the Diagrammatic treatment were encouraging.

Berger [5] studied and tested several signing designs for better communication of interchange information and route guidance. Most important consideration was in the area of map signing and graphical communication. Considerations of the study were: laboratory testing methods, graphic concepts and characters, determination of what types of intersections need the new signs, and the presentation method for the audience of highway designers. Opland [6] produced a paper which dealt with the same situation as in [4].

The Wyoming State Highway Department conducted a study [7] to evaluate the diagrammatic signing system and to compare it with the current highway signing system. The main point of this investigation focused around diagrammatic sign comprehension and motorist response time behavior. This study used visual observations and motorist interviews to compare the situations before and after the change to the diagrammatic road signs. This study showed only slight improvements in the erratic movement metric.

Hanscom [8] reported that diagrammatic signs were a success on a location on the Beltway around Washington D.C. The conditions before and after were evaluated by the type and frequency of 'erratic maneuvers'. Erratic maneuvers were subdivided into weaving, hesitations, stops and backups, and partial weaving. The findings were: a large reduction in the amount of weaving, more consistent patterns of traffic and no accidents in the experimental area in 4 months, (a significant decrease). There was also an increase in the number of weaves, but much fewer stops and backups. Another conclusion is that the diagrammatic signing may be initially confusing due to being so different from the signing of the time of the study.

Shepard [9] used video segments in a laboratory environment to simulate road conditions. The use of diagrammatic signs was recommended for the sites included in the study. When the signs were put into the field, the results were not significant in the number of erratic maneuvers metric.

Roberts [10] concluded that a significant reduction in the rates of erratic maneuvers was obtained when diagrammatic signs were used in a test site in New Jersey. This study concerns the application in left-hand exits. TV cameras were used for surveillance and to obtain the responses. Much data was presented in this report including information on the time, type of maneuvers, number of axles, and the traffic volume at the time. The results showed the good potential for this signing method in this application.

King [11] studied the applications of highway signing methods to urban areas and how and what modifications are needed in the urban areas. The current methods of urban guidance were investigated along with questionnaire surveys of motorist perceived problems of the current system. One of the possible improvements suggested was the use of persons not professionally involved with traffic engineering to check the entire system for accuracy and functionality.

Mast and Kolsrud [12] conducted a study that was to set the standards for the use of freeway diagrammatic guide signs. Vol. 1 is a summary of the diagrammatic signing research sponsored by the Federal Highway Administration. Vol. 2 investigates the research of diagrammatic and conventional signing done both in laboratory experiments and in the field using vehicles with instrumentation. Research completed by state highway departments and an extensive survey is included. Vol. 3 contains the details of the field studies of the earlier volumes. The results showed slight improvements with the new signing methods in some areas and no worsening of the situation in any of the sites included.

Shepard [13] investigated ways of increasing the legibility of signs. The signs investigated had backgrounds that were relatively bright. The results of this study indicated that the legibility can be increased by modifying the font or shape of the characters on the sign.

Gordon [14] investigated the informational load on motorist due to highway guide signs. Of importance in this investigation was faulty lane choices and response delays. The main experiment used 50 people to look at new signings and then they had to select the correct lane for a destination using highway situations. Results showed that as the number of signs are increased, the time required to find the correct route increased. Another result was that when a place (a destination) was listed on the sign, the response was fast. When a route number by itself was listed on the sign, the response time was increased.

Fenno [15] researched the legibility of Texas highway guide signs with particular interest with older drivers. Static and dynamic tests were performed. Recommendations for letter height and cardinal direction markers are provided. The increased sign legibility is needed for the older driver because the older driver's legibility distances were observed to be 12-17 percent shorter than their younger counterparts.

Zwahlen, Sunkara, and Schnell [16] conducted an extensive review of the relevant legibility literature in order to provide normalized legibility performance data for a comparison and consolidation of past legibility research. The data was normalized by expressing the legibility performance in terms of visual angle subtended by the character height. The data revealed large variations in visibility performance among the reviewed studies, despite similar or even identical experimental treatments. These variations may be attributed to the large range of applied experimental protocols and experimental boundary conditions such as the display luminances etc. The normalized data was grouped into sets, relating the visual angle to the width to height ratio W/H, the inter- character spacing to height ratio S/H, and the stroke width to height ratio SW/H, for both negative and positive contrast. Second order polynomial least squares functions such as the ones shown in Figure 4 were established to obtain a proposed and tentative functional relationship between the visual angle and W/H, S/H, and SW/H.

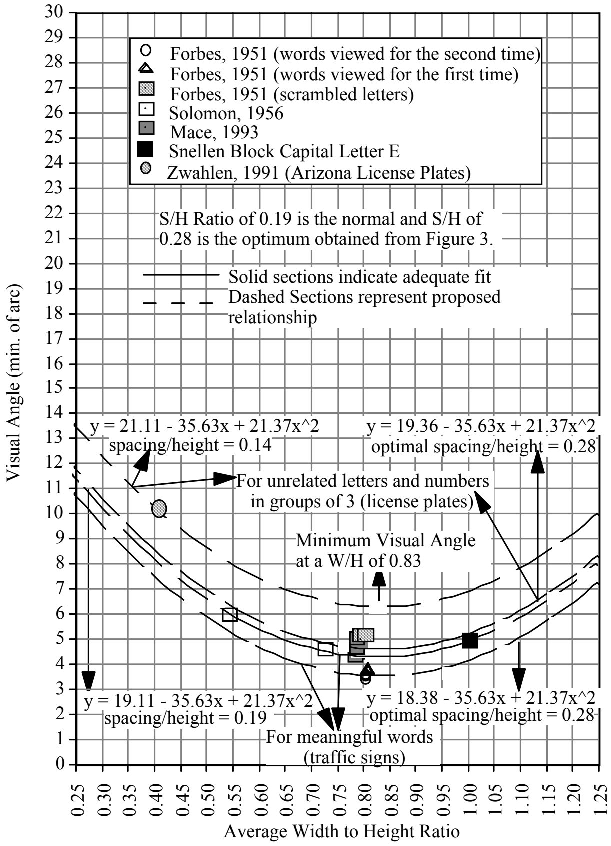


Figure 4 a. Visual Angle As A Function Of Average W/H Ratio For Positive Contrast (White on Dark Background)

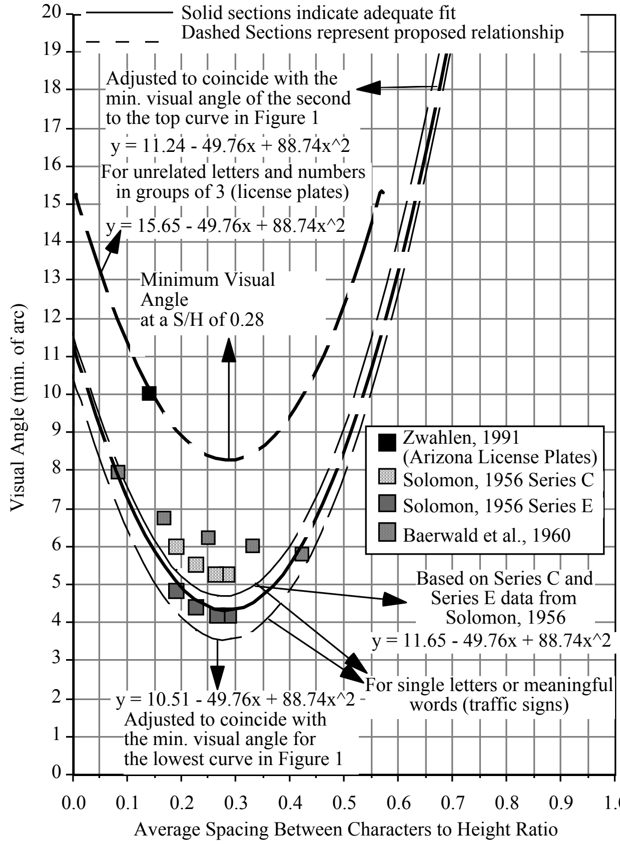


Figure 4 b. Visual Angle as a Function of Average Inter-Character S/H Ratio within a Word for Positive Contrast (White on Dark Background)

Overall, it was found that single characters/numerals or meaningful words (typically found on traffic signs) are more legible than unrelated groups of characters/numerals (typically found on license plates). Further, the data indicated that positive contrast characters generally require smaller stroke-widths SW than negative contrast characters and that more widely spaced characters show an increased legibility over closely spaced characters. The data the authors compiled provides display designers with proposed analytical functional relationships between legibility performance (visual angle) and typographical properties, thus allowing for display optimization with regard to legibility. The authors conclude that future legibility research should be based upon a standardized set of experimental protocols and a systems design approach.

Zwahlen [17] analyzed video taped eye fixations and saccades (30 frames per second) for 32 young, healthy unfamiliar drivers, along rural two lane highways in Ohio under low beam illumination conditions at night for the approach to a curve/turn warning sign (curve/turn symbol) for two selected curves. The first-look distance (longitudinal distance measured from the sign to a driver's eyes at which a driver foveally fixates the sign for the first time), last-look distance (the distance measured from the sign to a driver's eyes where he/she moves the eyes away from the sign for the last time before reaching the sign), number of looks and durations of looks at the warning sign were of main interest in this study. The obtained eye scanning data was used to formulate two models that provide the Minimum Required Legibility Distance (MRLD).

Figure 5a and Figure 5b illustrate the MRLD for model 1 (last look time independent of speed) and model 2 (last look distance independent of speed) respectively.

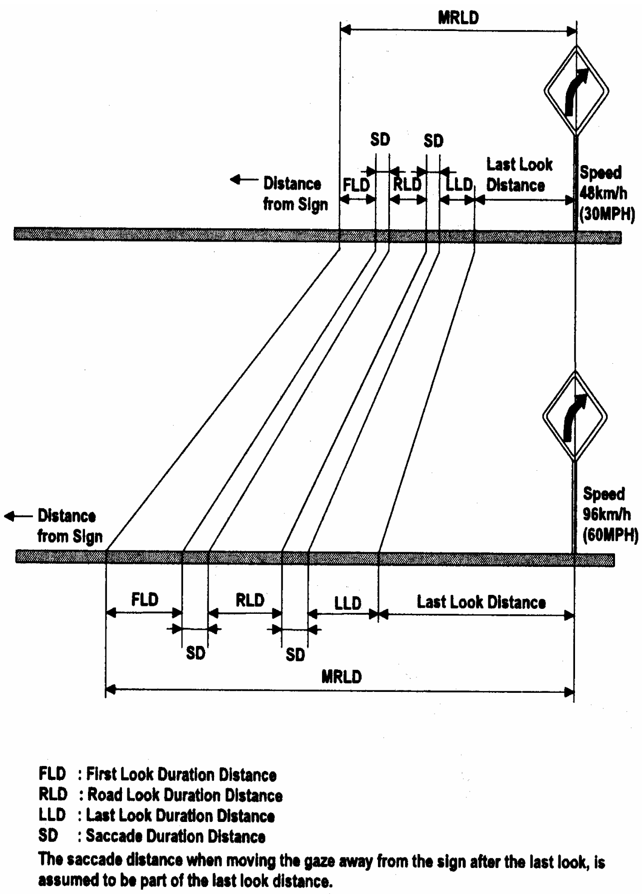


Figure 5 a. Model 1 for a Speed of 48km/h and for a Speed of 96km/h

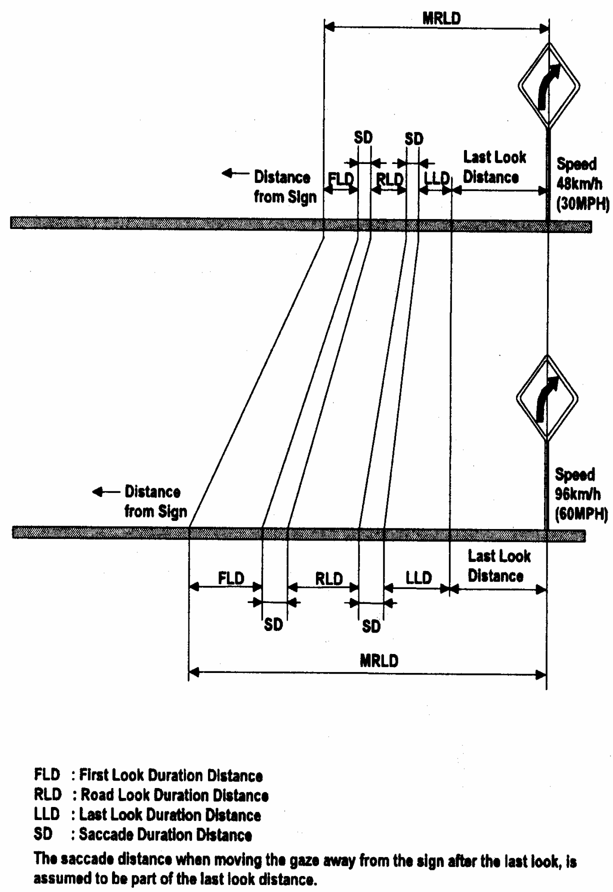


Figure 5 b. MRLD Model 2 for a Speed of 48km/h and for a Speed of 96km/h

Cumulative last-look distance, first-look duration and last-look duration graphs were established. The results of this study and a previous similar study indicate that drivers look on the average about two times at a warning sign during a night time low beam approach. It was found that between the first-look (information acquisition) and the last-look (confirmation) at a sign there was usually at least one eye fixation on the roadway ahead. Using cumulative eye fixation duration data obtained for straight road driving under low beam nighttime conditions published in another study and an average saccade duration of about .03 seconds, a sign reading distance model was developed which determines the distance (minimum required legibility distance, MRLD) at which a simple bold symbol on a warning sign must be recognized.

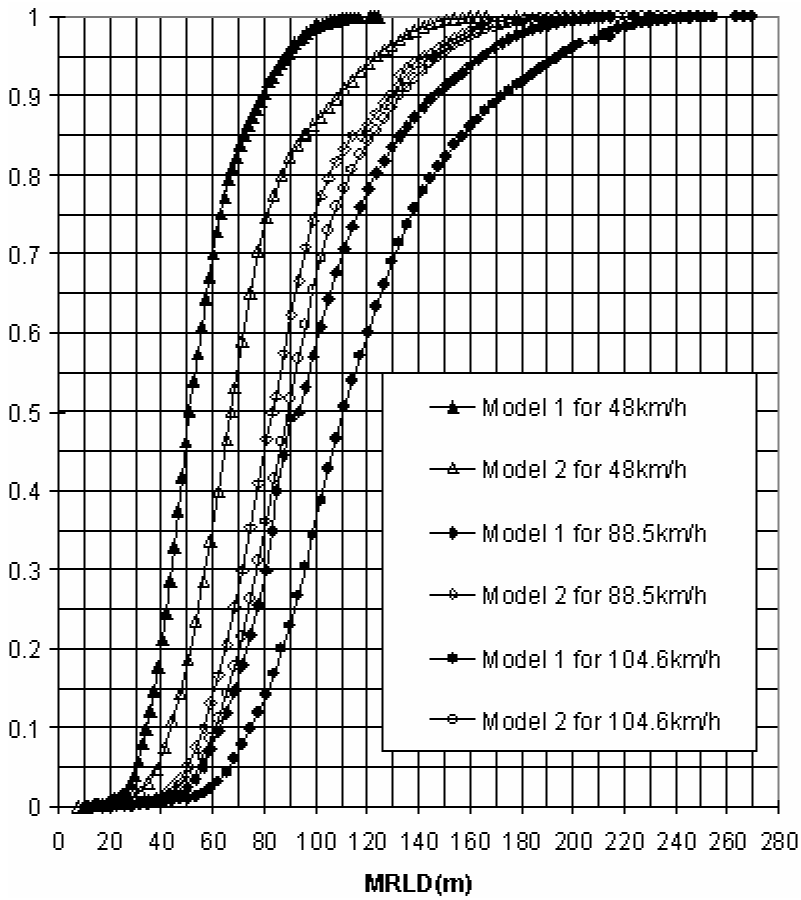


Figure 6. Cumulative Frequency as a Function of MRLD for Model 1 and Model 2

The model provides for a given speed the overall cumulative probability distribution function for the MRLD in terms of distance or in terms of time. The advantage of this model, which is applicable to warning signs with simple symbols under low beam illumination at night, is that it is totally based upon observed, recorded, and analyzed driver eye scanning and information-seeking behavior in the field.

Ground mounted diagrammatic guide signs are commonplace in Europe. The FHWA conducted a scan tour of innovative technologies in Europe [18]. Figure 7 shows diagrammatic guide signs applied in Germany, France, and England.

a. Diagrammatic Guide Sign in Germany

b. Diagrammatic Guide Sign in Germany

c. Diagrammatic Guide Sign in France

d. Diagrammatic Guide Sign in the UK

Figures reproduced from [18]

Figure 7. International Use of Ground Mounted Diagrammatic Guide Signs

3 DETAILED DESCRIPTION OF THE INTERCHANGES STUDIED

The following section shows maps, aerial views, and surface approach views of the test sites used in this study. The test sites were selected based upon ODOT traffic crash reports and traffic congestion reports. With the exception of the test site at Plain City Georgesville (SR 142) that was added later by the ODOT panel, all test interchanges were selected as typical examples of various interchange configurations. The following test interchanges were used:

1. SR 315 Southbound with I 270 (See Figure 8 through Figure 10).
2. Brice Road Northbound with I 70 (See Figure 11 through Figure 13).
3. Georgesville Road Westbound with I 270 (See Figure 14 through Figure 17).
4. Roberts Road Eastbound with I 270 (See Figure 18 through Figure 20).
5. Hilliard Rome Road (Southbound) Interchange with I 70 (See Figure 21 through Figure 24).
6. Plain City Georgesville Road (SR 142) Southbound with I 70 (See Figure 25 through Figure 27).

3.1 SR 315 Southbound Interchange with I 270

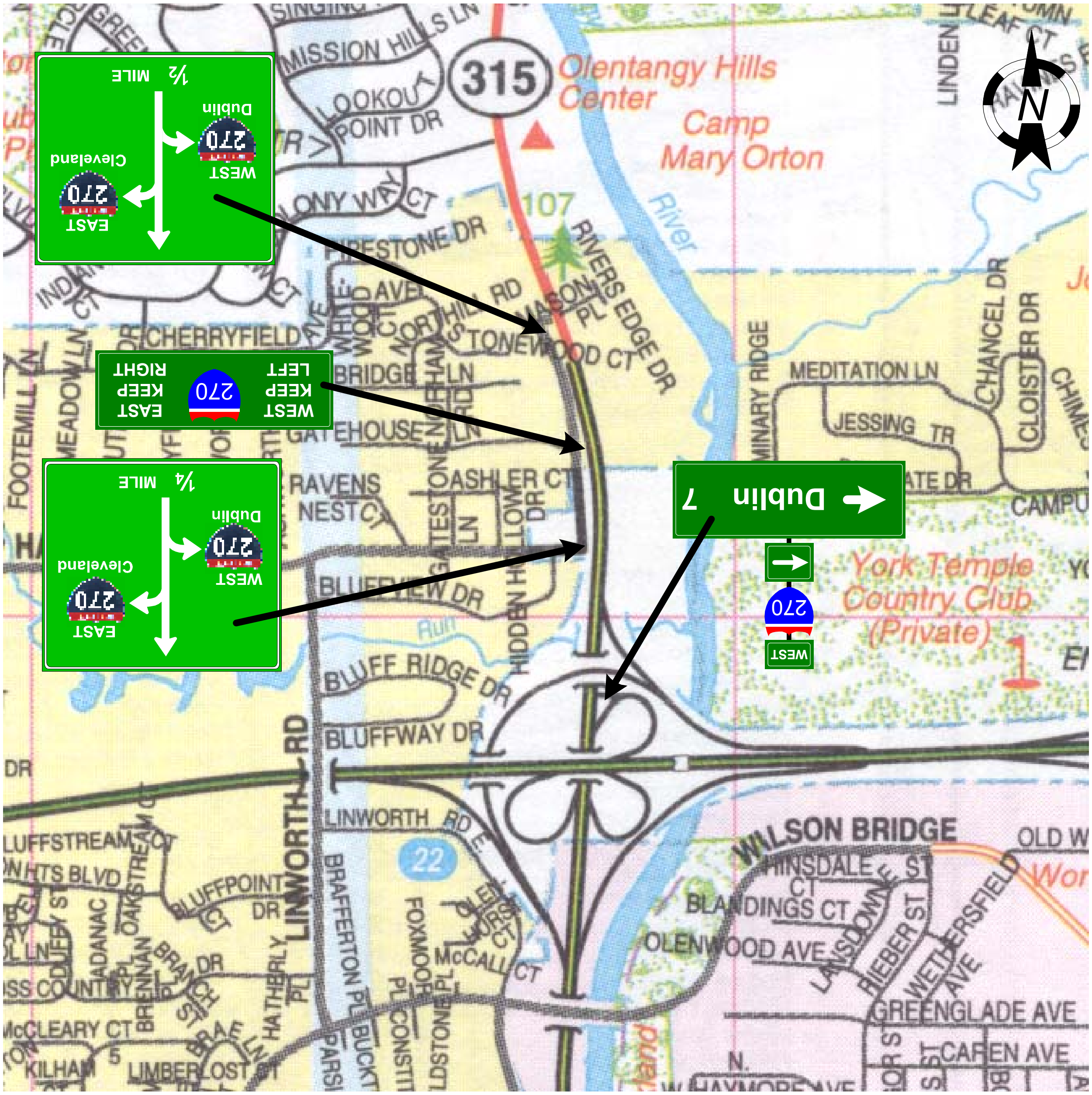


Figure 8. Map View of the SR 315 (Southbound) Interchange Site with I 270

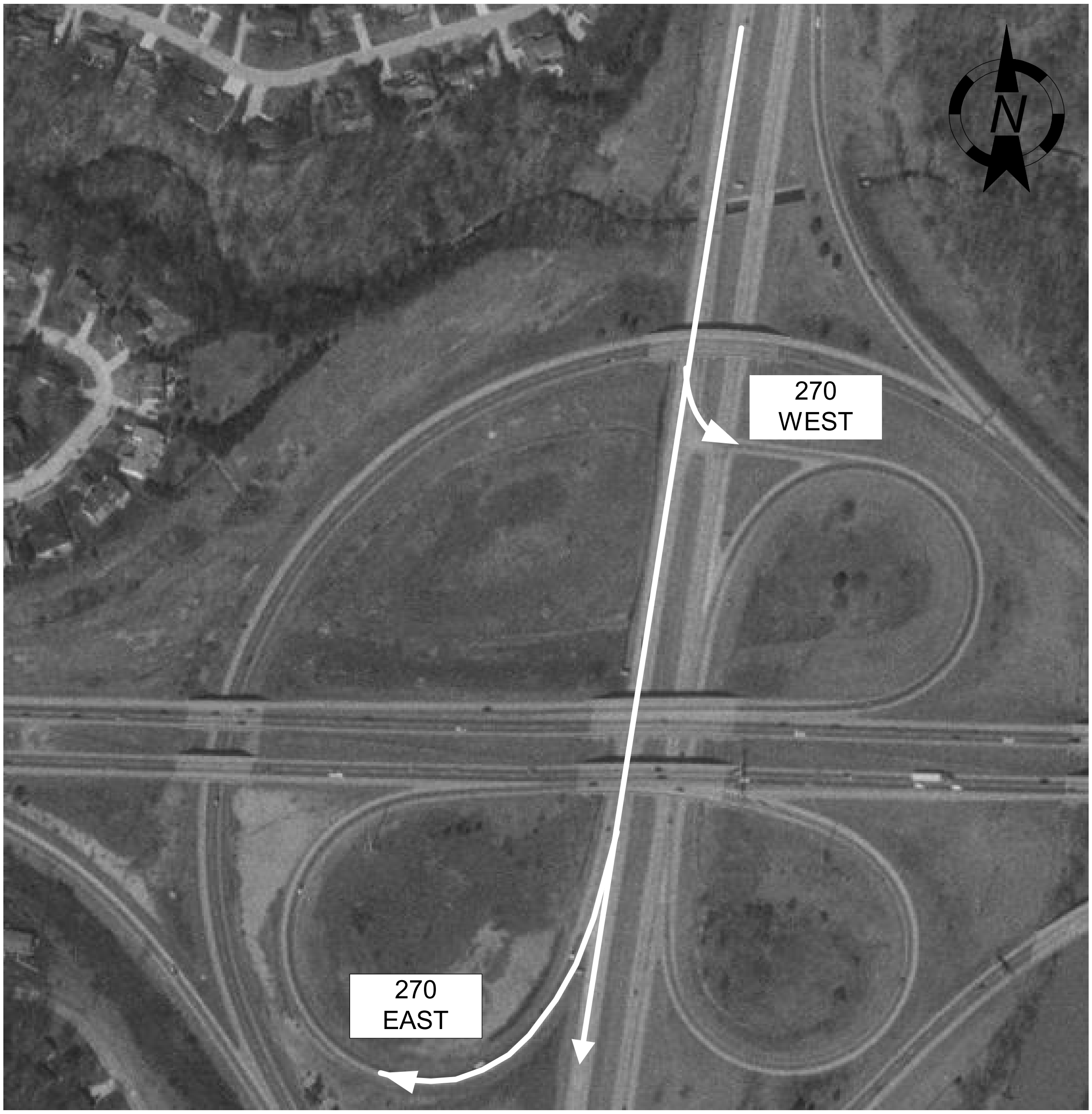
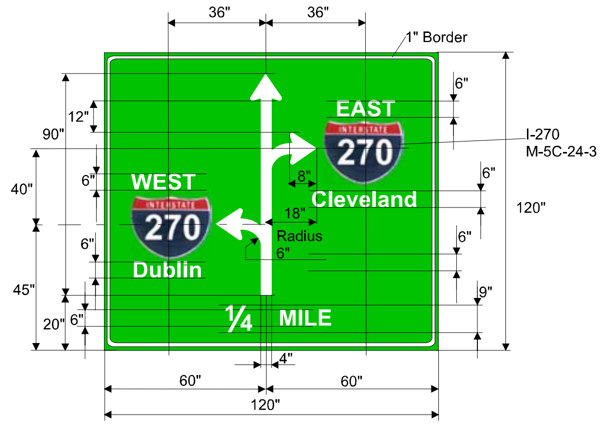


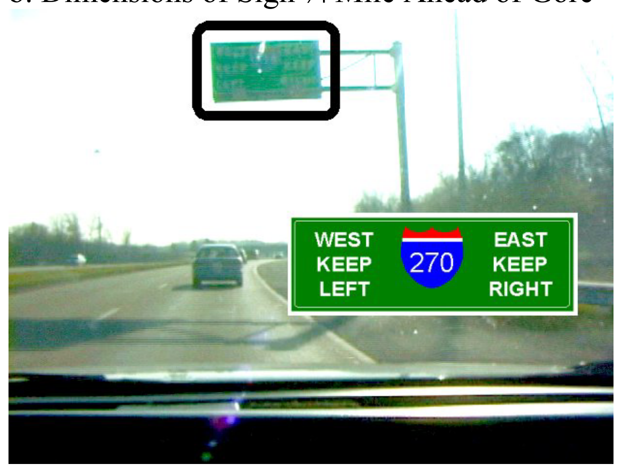
Figure 9. Aerial View of the SR 315 (Southbound) Interchange Site with I 270

a. Dimensions of Sign ½ Mile Ahead of Gore



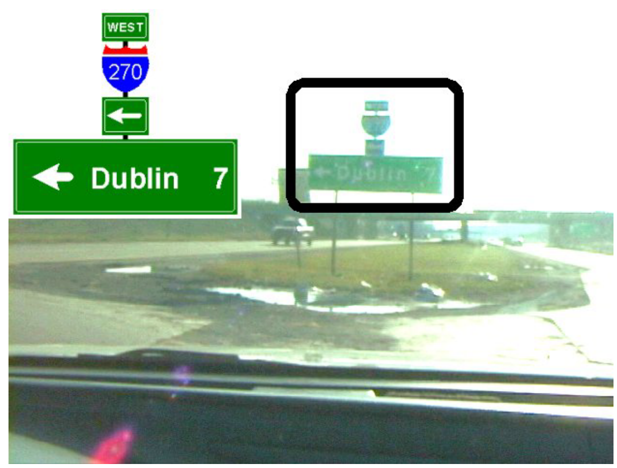
b. Dimensions of Sign ¼ Mile Ahead of Gore

c. Actual Diagrammatic Sign ½ Mile Ahead of Gore



d. Cantilever Overhead Sign 0.38 Miles Ahead of Gore

e. Actual Diagrammatic Sign ¼ Mile Ahead of Gore



f. Trailblazer Assembly at First Gore

Figure 10. SR 315 (Southbound) Interchange Site with I 270

3.2 Brice Road Northbound with I 70

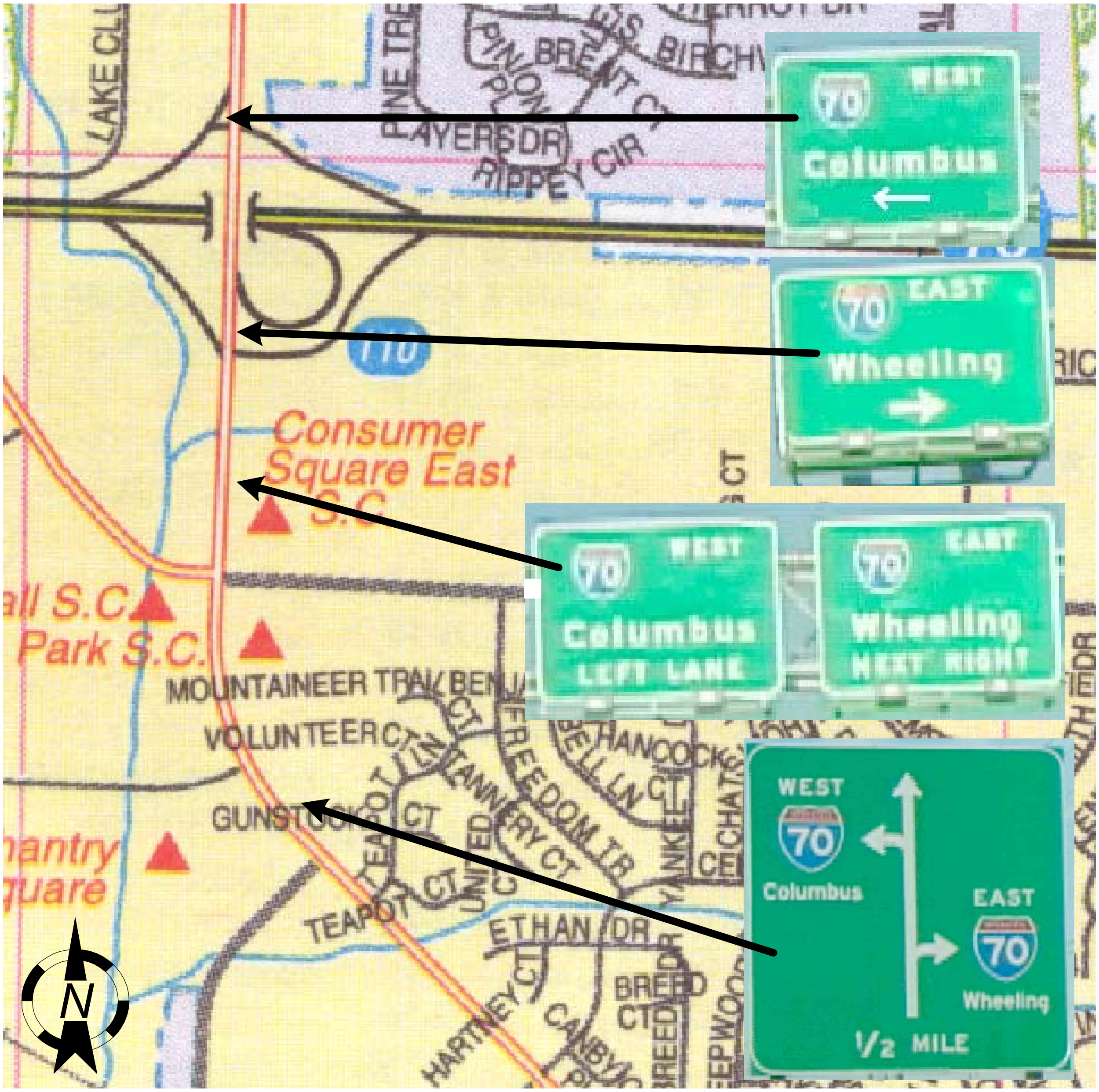


Figure 11. Map View of the Brice Road (Northbound) Interchange Site with I 70

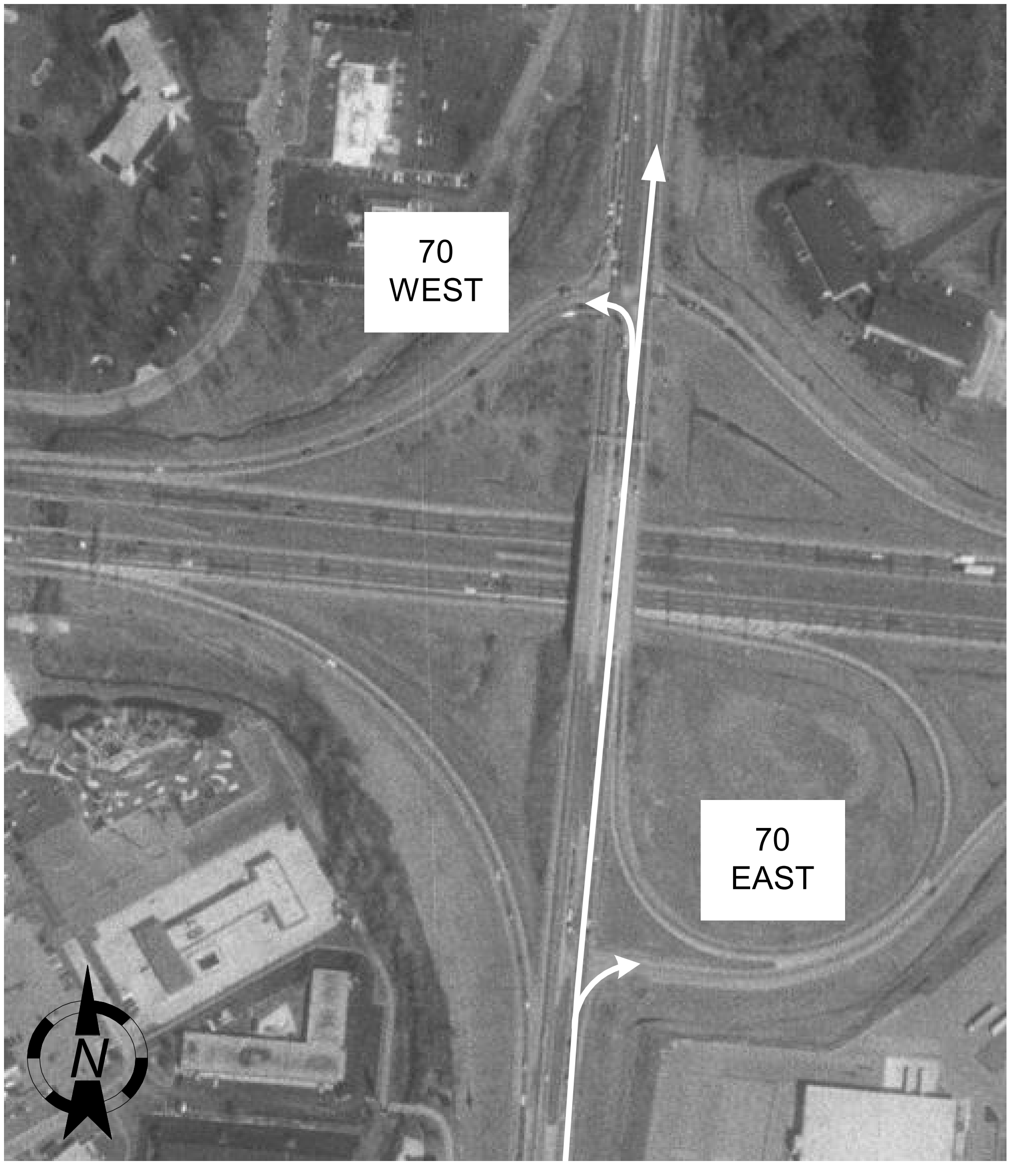
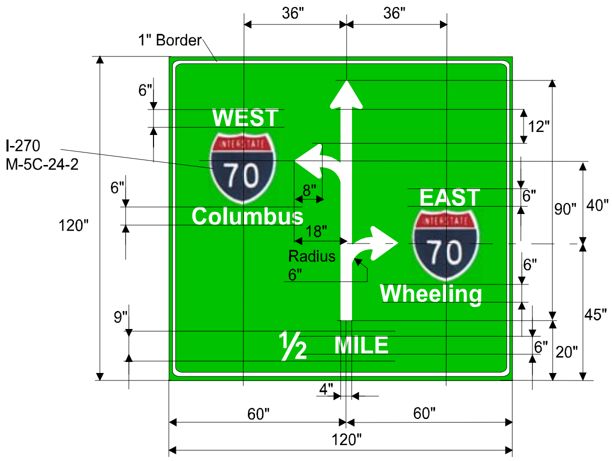
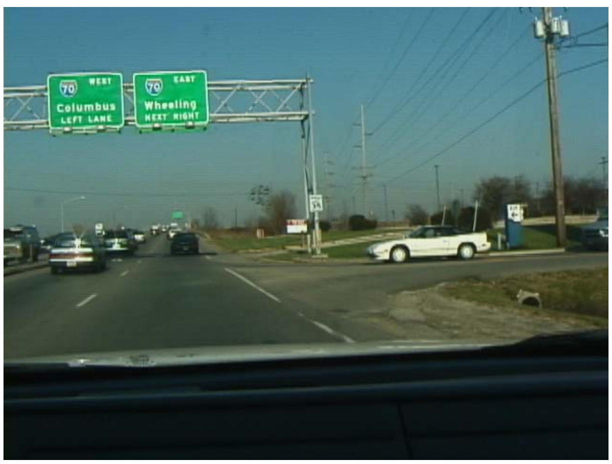


Figure 12. Aerial View of the Brice Road (Northbound) Interchange Site with I 70

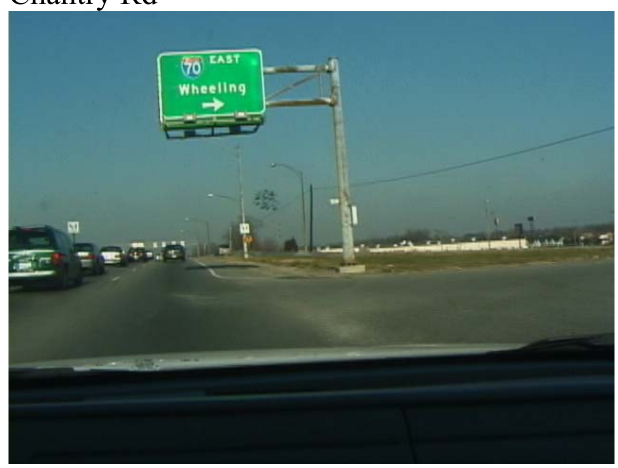


a. Dimensions of Sign ½ Mile Ahead of Gore

b. Shoulder Mounted Diagrammatic Sign ½ Mile Ahead of Gore, Located just ahead of Chantry Rd



c. Sign Bridge, Just after Tussing Rd



d. Cantilever Sign for 70 EAST at Gore

e. Cantilever Sign for 70 WEST at Gore

Figure 13. Brice Road (Northbound) Interchange with I 70

3.3 Georgesville Road Westbound with I 270

Figure 14. Map View of the Georgesville Road (Westbound) Interchange Site with I 270

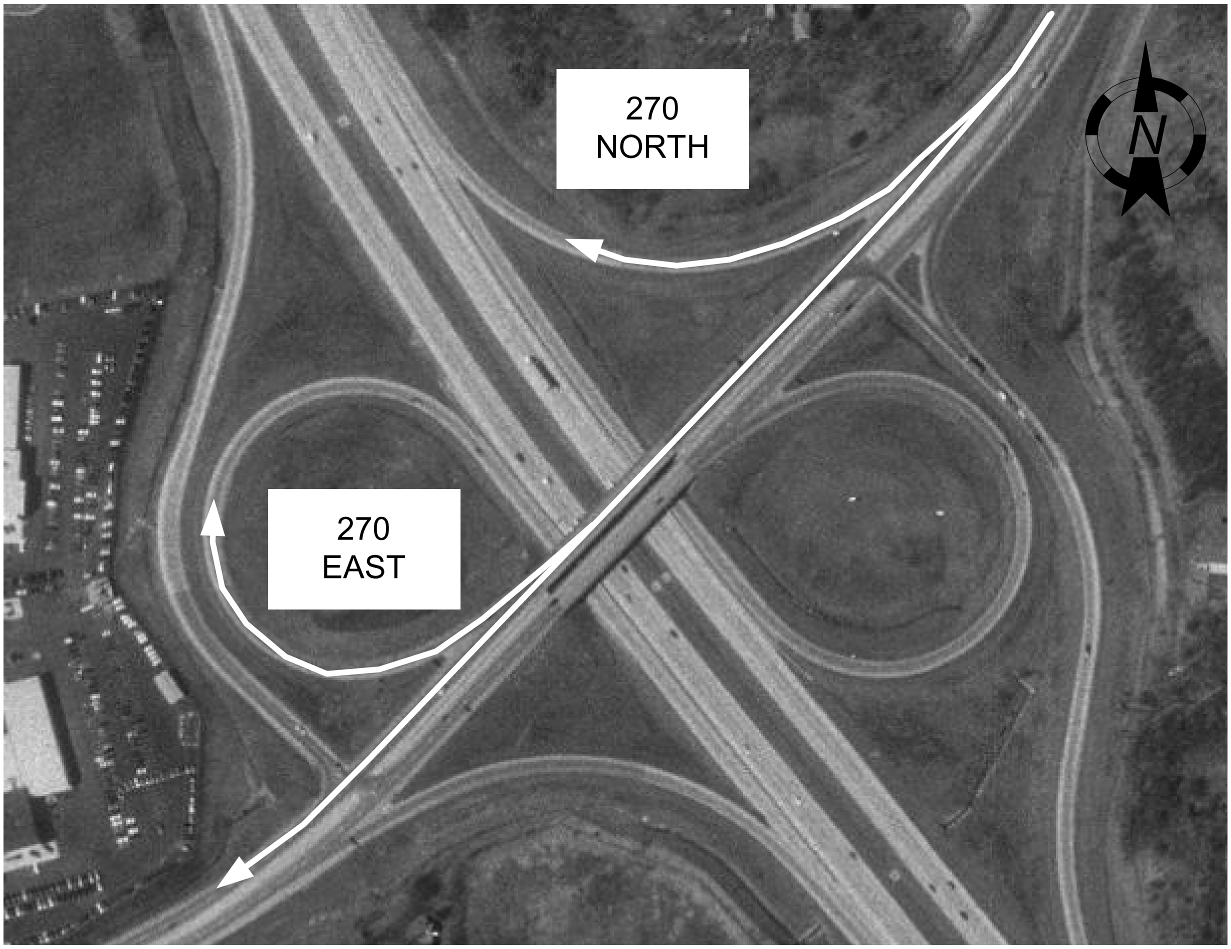
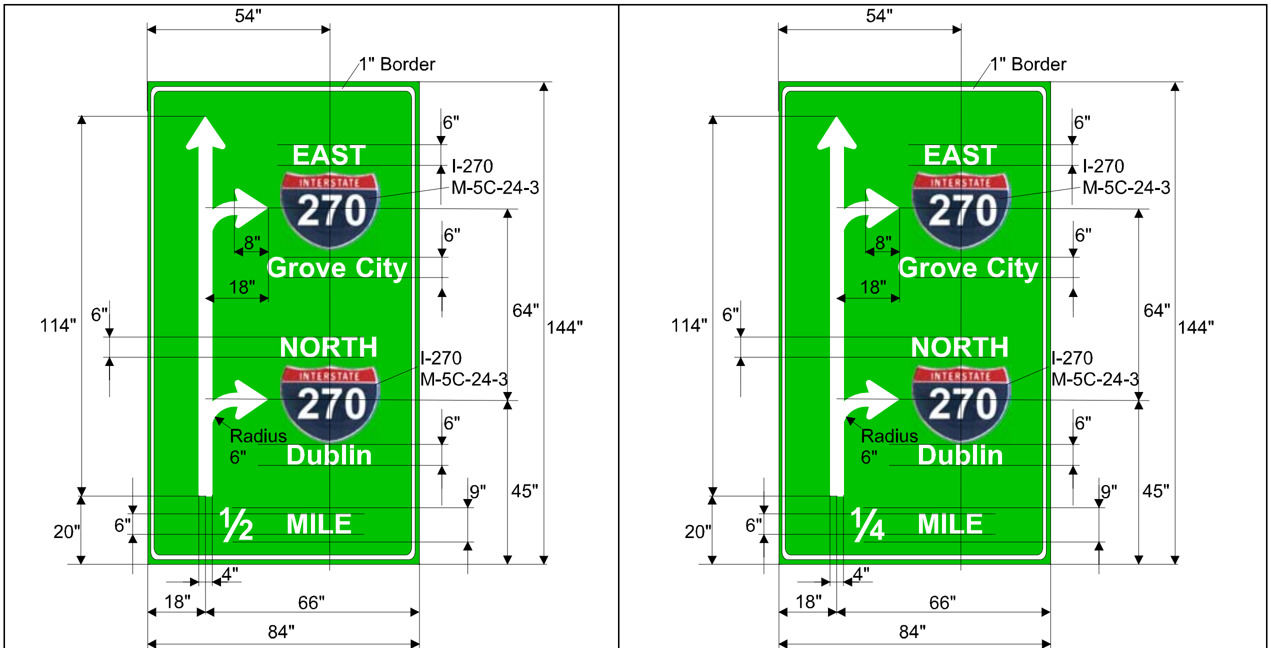


Figure 15. Aerial View of the Georgesville Road (Westbound) Interchange Site with I 270



a. Dimensions of Diagrammatic at ½ Mile

b. Dimensions of Diagrammatic Sign at ¼ Mile

Figure 16: Dimensions of Ground Mounted Diagrammatic Signs at Georgesville Road (Westbound) Interchange with I 270

a. Actual Diagrammatic Sign at ½ Mile

b. Actual Diagrammatic Sign at ¼ Mile

c. Trailblazer Assembly

d. Cantilever Overhead Signs Before and at First Gore

e. Ground Mounted Sign at Second Gore

Figure 17. Georgesville Road (Westbound) Interchange with I 270

3.4 Roberts Road Eastbound with I 270

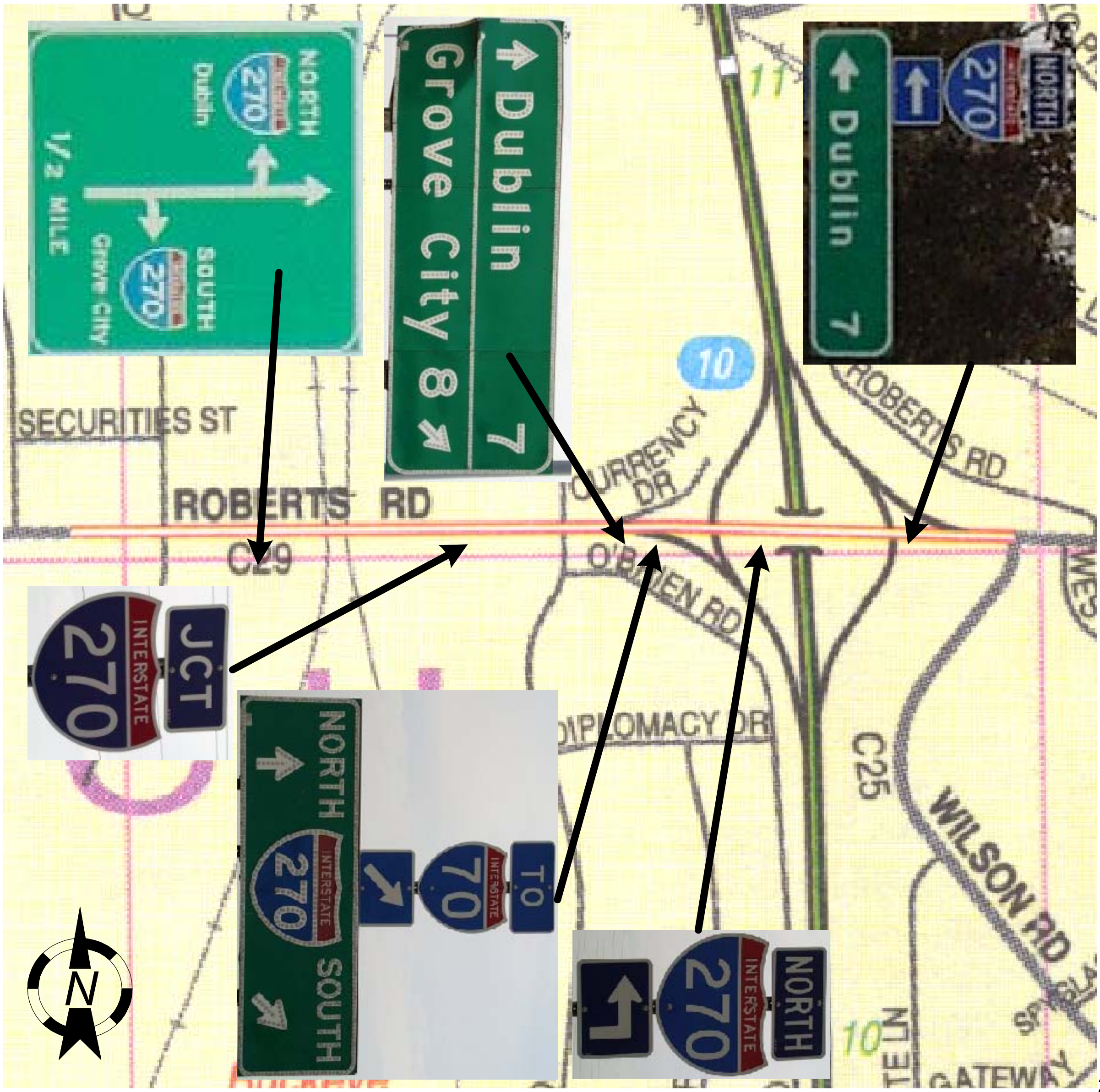


Figure 18. Map View of the Roberts Road (Eastbound) Interchange Site with I 270

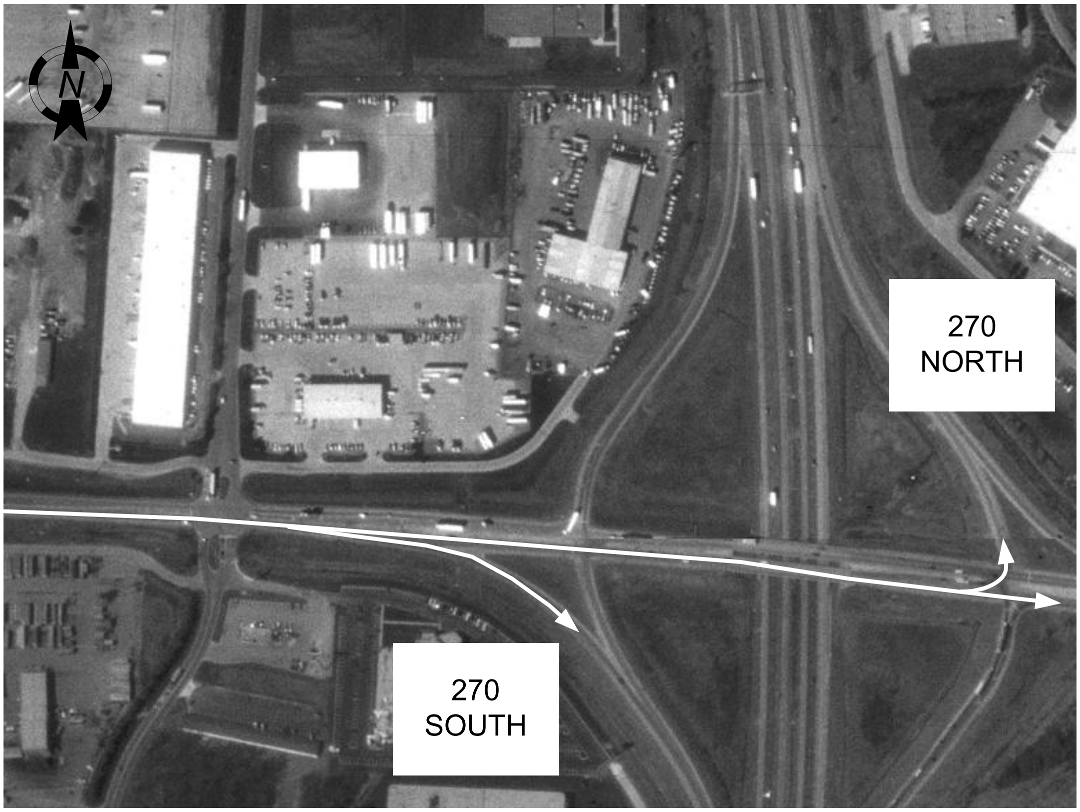
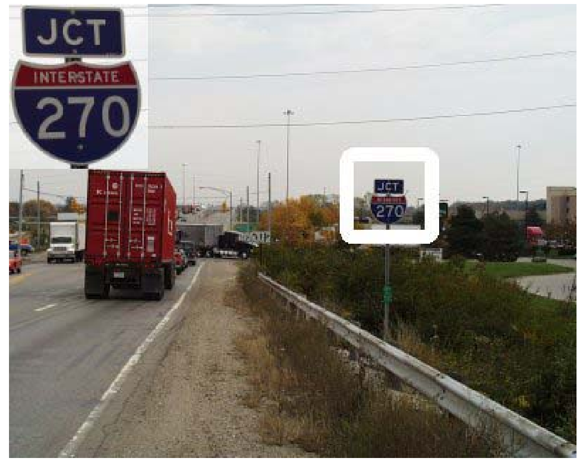
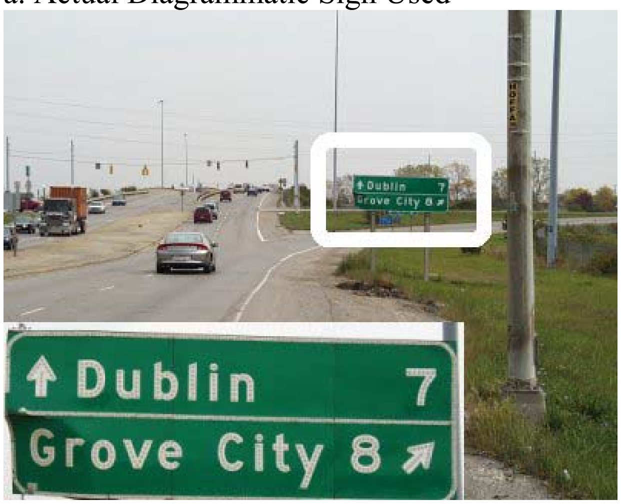


Figure 19. Aerial View of the Roberts Road (Eastbound) Interchange Site with I 270

a. Actual Diagrammatic Sign Used



b. JCT 270 0.3 Miles Ahead of First Gore



c. Destination Sign 0.08 Miles Ahead of Gore

d. Trailblazer Assembly at First Gore

e. Trailblazer Assembly on Bridge Prior to Second Gore

f. Trailblazer Assembly at Second Gore

Figure 20. Roberts Road (Eastbound) Interchange with I 270

3.5 Hilliard Rome Road (Southbound) Interchange with I 70

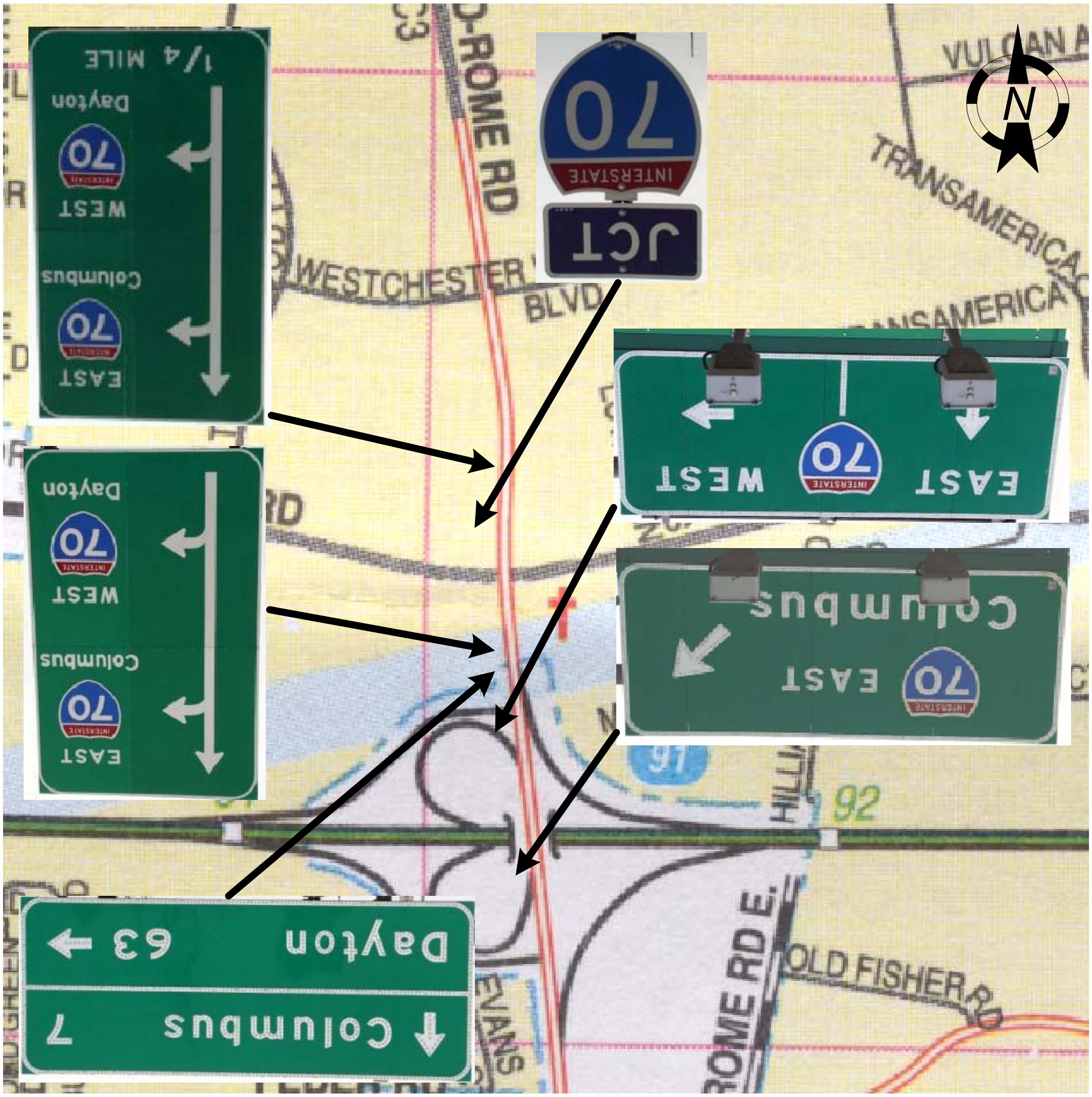


Figure 21. Map View of the Hilliard Rome Road (Southbound) Interchange Site with I 70

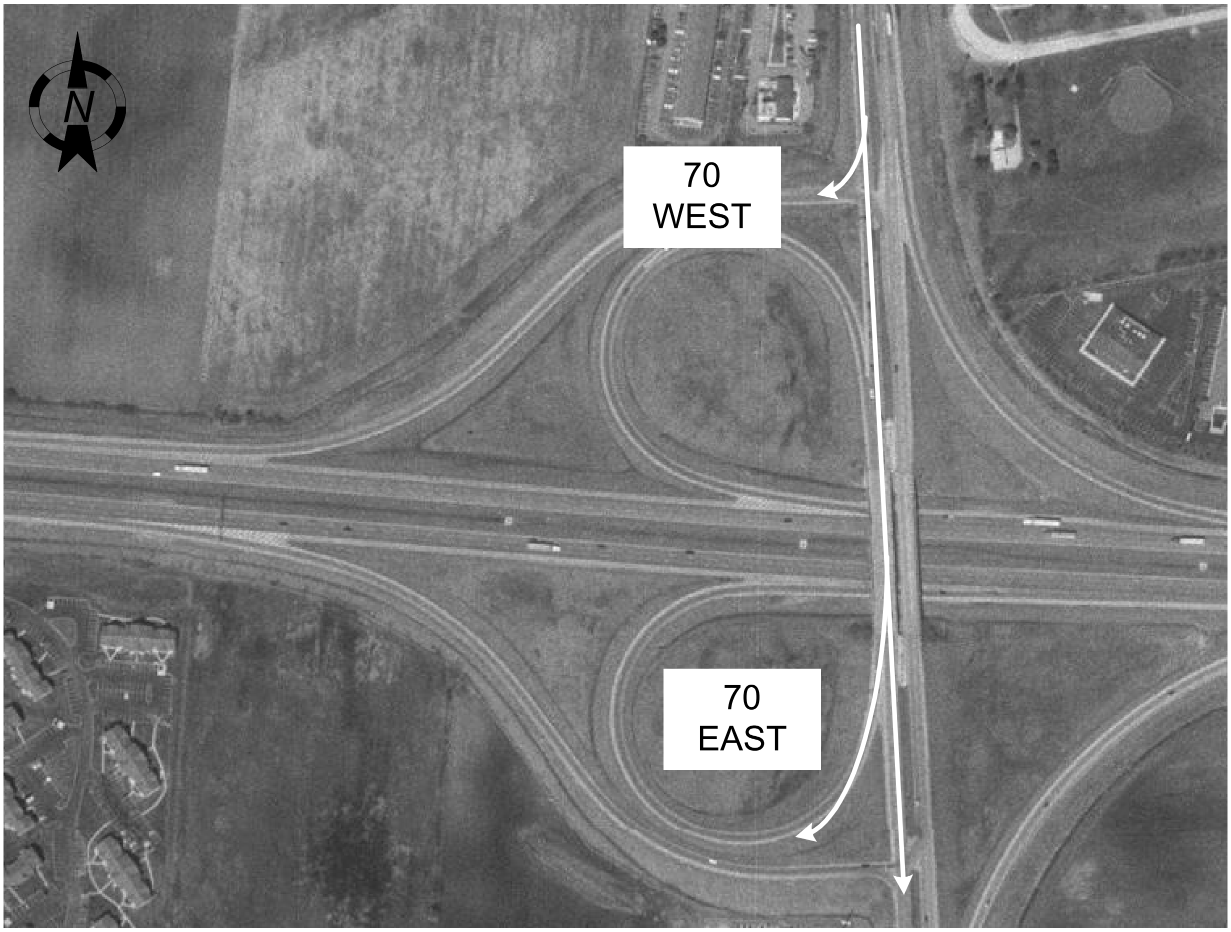
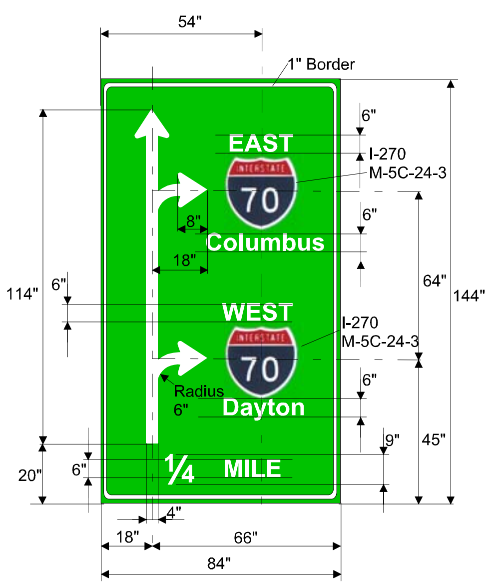
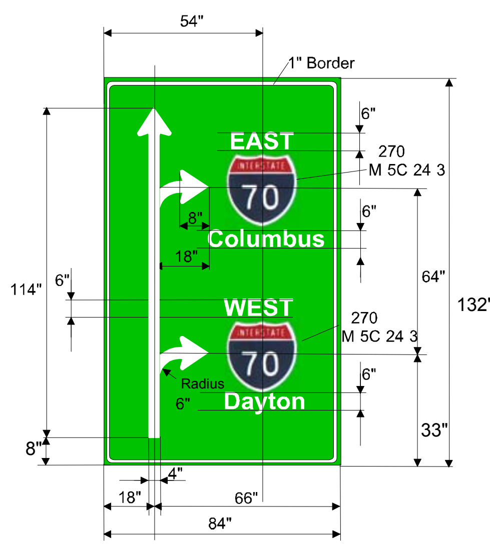


Figure 22. Aerial View of the Hilliard Rome Road (Southbound) Interchange Site with I 70



a. Dimensions of Sign at ¼ Mile



b. Dimensions of Sign at 121 m (400 ft)

Figure 23. Dimensions of Ground Mounted Diagrammatic Signs at Hilliard Rome Road (Southbound) Interchange with I 270

a. Actual Diagrammatic Sign at ¼ Mile

b. Trailblazer Assembly 0.2 Miles Ahead of Gore

c. Actual Sign Diagrammatic Sign

d. Shoulder Destination Sign and Cantilever Sign

e. Cantilever Sign

Figure 24. Hilliard Rome Road (Southbound) Interchange with I 270

3.6 Plain City Georgesville Road (SR 142) Southbound with I 70

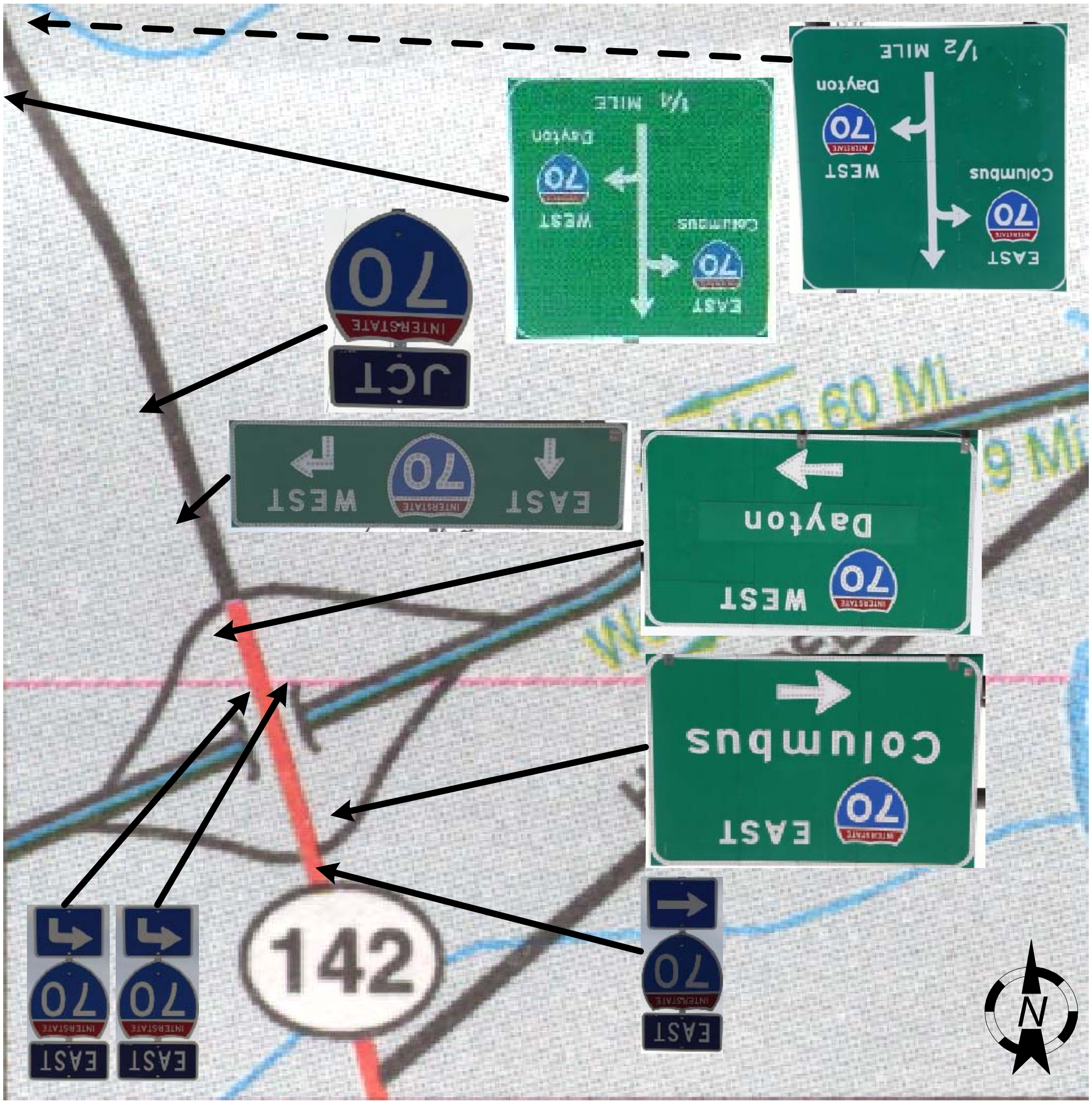


Figure 25. Map View of the Plain City Georgesville Road (Southbound) Interchange Site with I 70

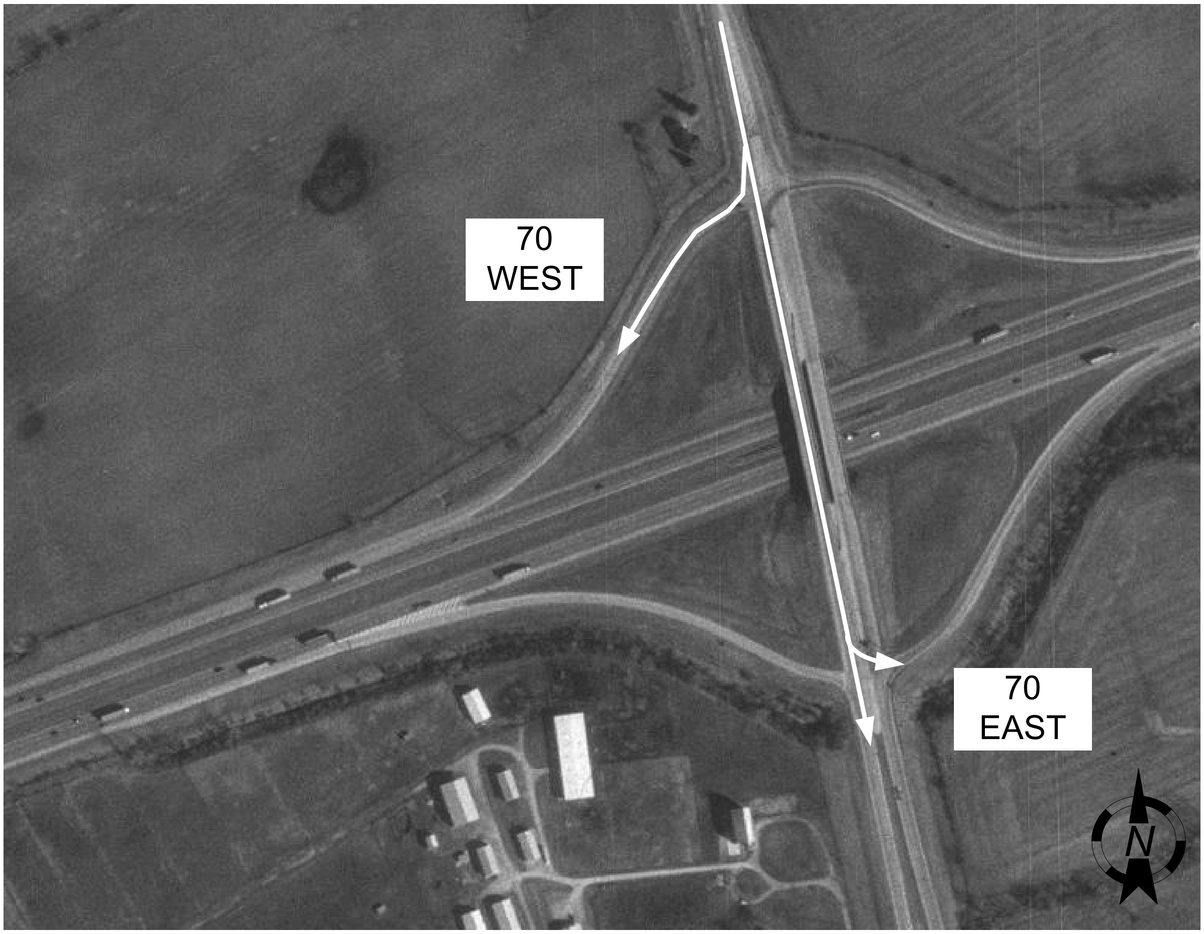


Figure 26. Aerial View of the Plain City Georgesville Road (Southbound) Interchange Site with I 70

a. Shoulder Mounted Diagrammatic Sign ½ Mile Ahead of Interchange

b. Shoulder Mounted Diagrammatic Sign ¼ Mile Ahead of Interchange

c. JCT 70, East West Guide Sign, and Cantilever Overhead Sign at First Gore

d. Trailblazer Assemblies on Bridge to Second Gore

e. 70 East and Cantilever Overhead Sign at Second Gore

Figure 27. Plain City Georgesville Road (Southbound) Interchange Site with I 70

4 TRAFFIC FLOW VIDEO ANALYSIS

One particular concern when introducing novel guide signing techniques such as diagrammatic signs centers around the effects on traffic flow. Considering that the target interchanges for diagrammatic signing are usually at or near capacity, and exhibit tremendously high traffic volumes (ADT), one has to ensure that any new sign design does not disrupt, in any way, shape, or form, the traffic flow at the interchanges. In this study, we elected to use unobtr`usive video cameras in the approach area to determine the traffic flow conditions during the before and during the after condition. The goal of the video data acquisition for the before condition was to obtain detailed data of the traffic characteristics along three selected (unidirectional) freeway interchange approaches equipped with conventional, preexisting guide signs. The following interchanges were studied in this fashion:

1. Brice Road and I-70
2. SR 315 and I-270
3. Georgesville and I-270

The following traffic characteristics (measures of effectiveness, MOE) were quantified in this task:

1. Traffic volume
2. Interchange throughput
3. Vehicle speeds
4. Number of vehicles per lane
5. Headway gaps

Multiple overhead video cameras (three per approach direction) were used to cover a substantial portion of the approach zones. Cameras were installed in aluminum boxes with plexiglass viewports for weather and vandal proofing. The cameras were installed at the interchange site using existing poles (lamp poles, utility poles, etc.). A separate utility pole had to be installed at SR 315 due to a lack of adequate existing poles. Note: all camera support posts were breakaway or behind a guardrail. The cameras were aimed downward to obtain a top-down view that minimized obstruction of traffic lanes by large vehicles.

After the cameras were installed, the video data was collected for three days at each interchange. The cameras recorded their respective scenes on 8 mm cassette tapes from approximately 8:00 AM until 8:00 PM. Because of capacity limits of the cassettes, new cassettes had to be inserted in each camera every two hours. All cassettes were labeled with the following information: cassette number, camera box number, interchange location, date, and time. A total of three spreadsheets, one for each intersection, were created. These spreadsheets contained information on camera location, time interval, additional information regarding cassette condition, and remarks.

The goal of the data acquisition for the after condition was to obtain detailed data of the traffic characteristics along the same three selected (unidirectional) freeway interchange approaches observed in the before condition. During the after condition the interchanges were equipped with the experimental diagrammatic guide signs along with the existing guide signs.

4.1 Data analysis

The data, stored on 8 mm video tapes, was analyzed in the laboratory using MOBILIZER-PC, a software-based traffic classification and counting system. Intersections were analyzed at each of the three camera locations for the before and after conditions during three, two-hour time periods:

- Morning (8:00AM-10:00AM)
- Afternoon (11:00AM-1:00PM)
- Evening (4:00PM-6:00PM)

Note: The above times served as an analysis guideline, because of technical difficulty actual analysis times differed slightly. Only daytime video footage was analyzed because Mobilizer PC could not handle the multiple reflections of the car headlamps on the pavement during nighttime. Figure 28 shows a screen shot of the Mobilizer PC geometry definition module for the first camera location at Brice Road. The geometry defines the outline of the individual traffic lanes and specifies measurement lines (lines horizontally across the street) for Mobilizer PC to be able to determine the distance a vehicle travels in the perspective view of the video image. The size of typical vehicles can be entered in this definition also, so that Mobilizer PC can automatically classify vehicles based upon their overall length.

Figure 28. Mobilizer PC Geometry Definition at the First Camera Location, Brice Road

Figure 29 shows five vehicles being tracked as they enter the tracking area at the first camera location of the Brice Road interchange.

Figure 29. Mobilizer PC Vehicle Tracking at First Camera Location of Brice Road

The MOBILIZER-PC system uses video inputs from a camera or VCR. The system has three major components: a digitizer board, the TN Detection Module, and the Data Association Tracking Module. The digitizer board is a hardware component, installed in the PC to allow digitizing of the video stream. The TN Detection Module is a software component, which detects vehicles on the roadway. The Data Association Tracking Module is a software component, which tracks vehicles detected by the TN Detection Module and removes false alarms. As the system processes the video, it provides displays of detected and tracked vehicles as well as aggregated statistics, which are stored in a data file. The vehicles are tracked throughout the defined field of view, and tracking boxes are displayed around the vehicles. The data files generated by the MOBILIZER-PC system were converted to Microsoft Excel format for analysis purposes.

4.2 Results

At each of the videotaped interchanges (SR 315, Brice Road, Georgesville Road) data was gathered at three locations, with location one being farthest from the gore and location three being closest to the gore. At each location, separate data was collected for each of the individual lanes with regard to headway gaps, speed, and lane changes. For each lane at the defined locations, data was summarized in cumulative distributions, probability density functions, and correlation scatter plots. The three interchanges were videotaped and analyzed during the before condition (preexisting guide signing only) and the after condition (preexisting signing plus diagrammatic signs). Figure 30 to Figure 35 show the schematic layout of the two interchanges.

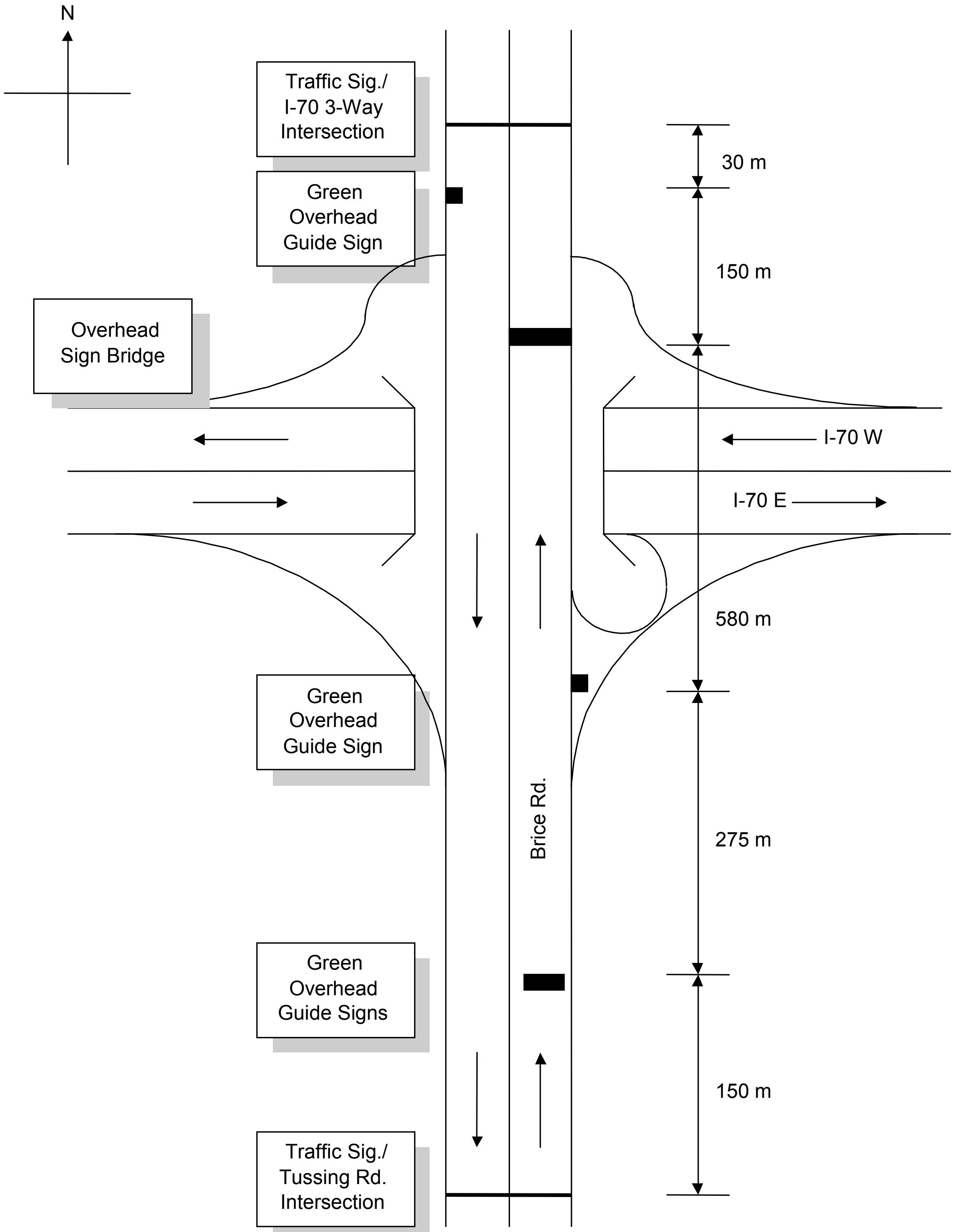


Figure 30. Brice Road Interchange with I 70, Signing During the Before Condition.

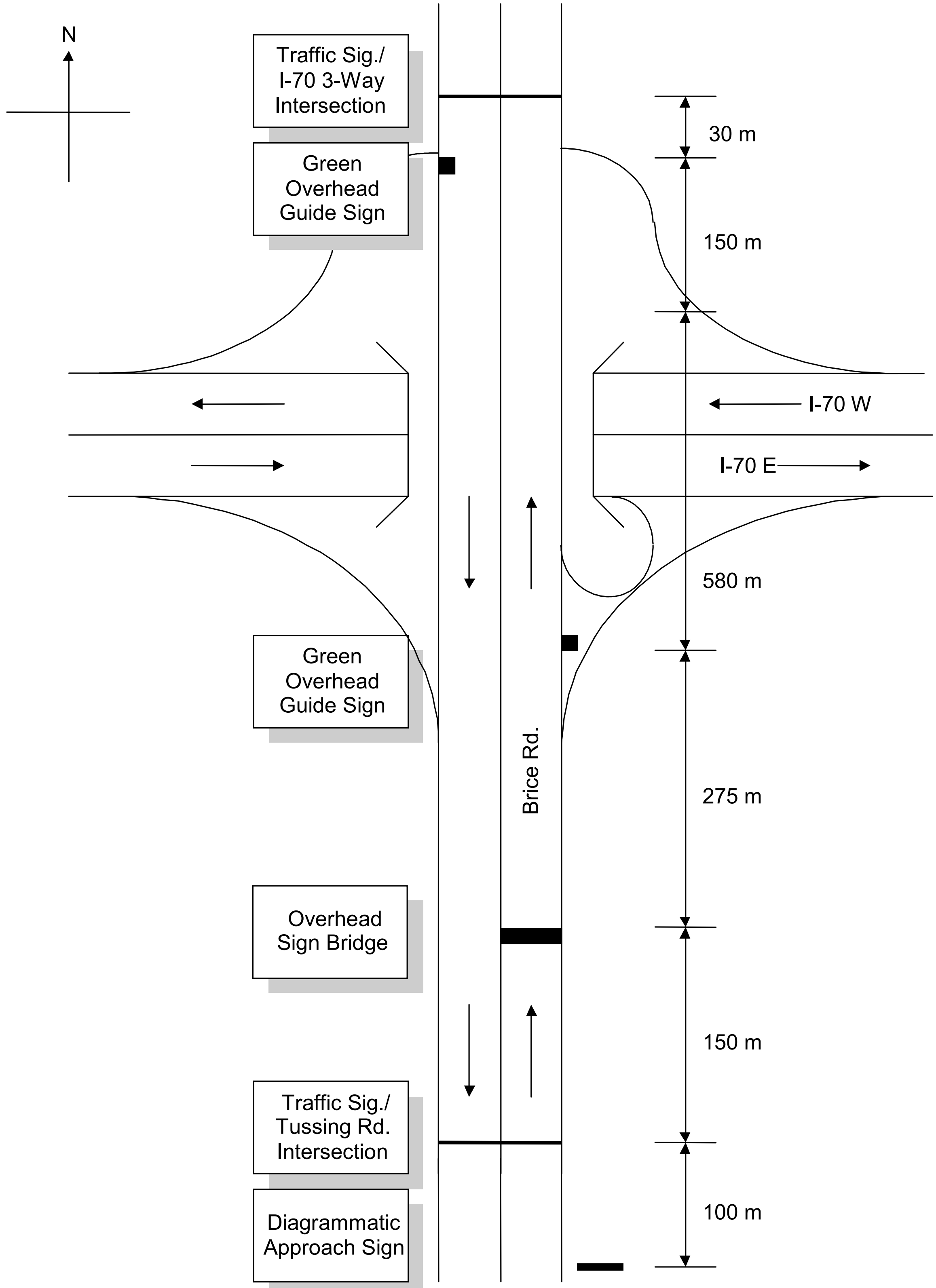


Figure 31. Brice Road Interchange with I 70, Signing During the After Condition.

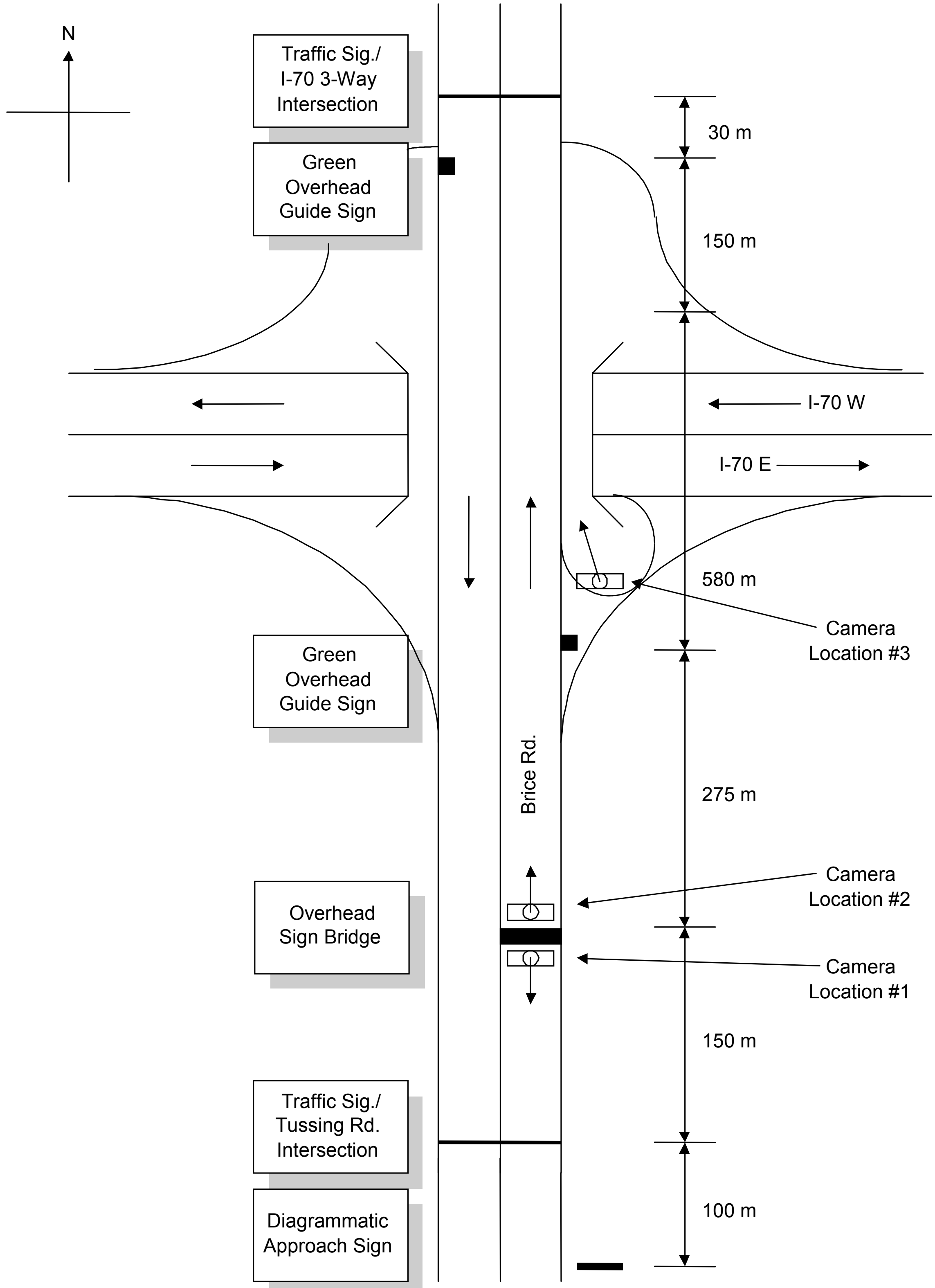


Figure 32. Brice Road Interchange with I 70, Camera Locations.

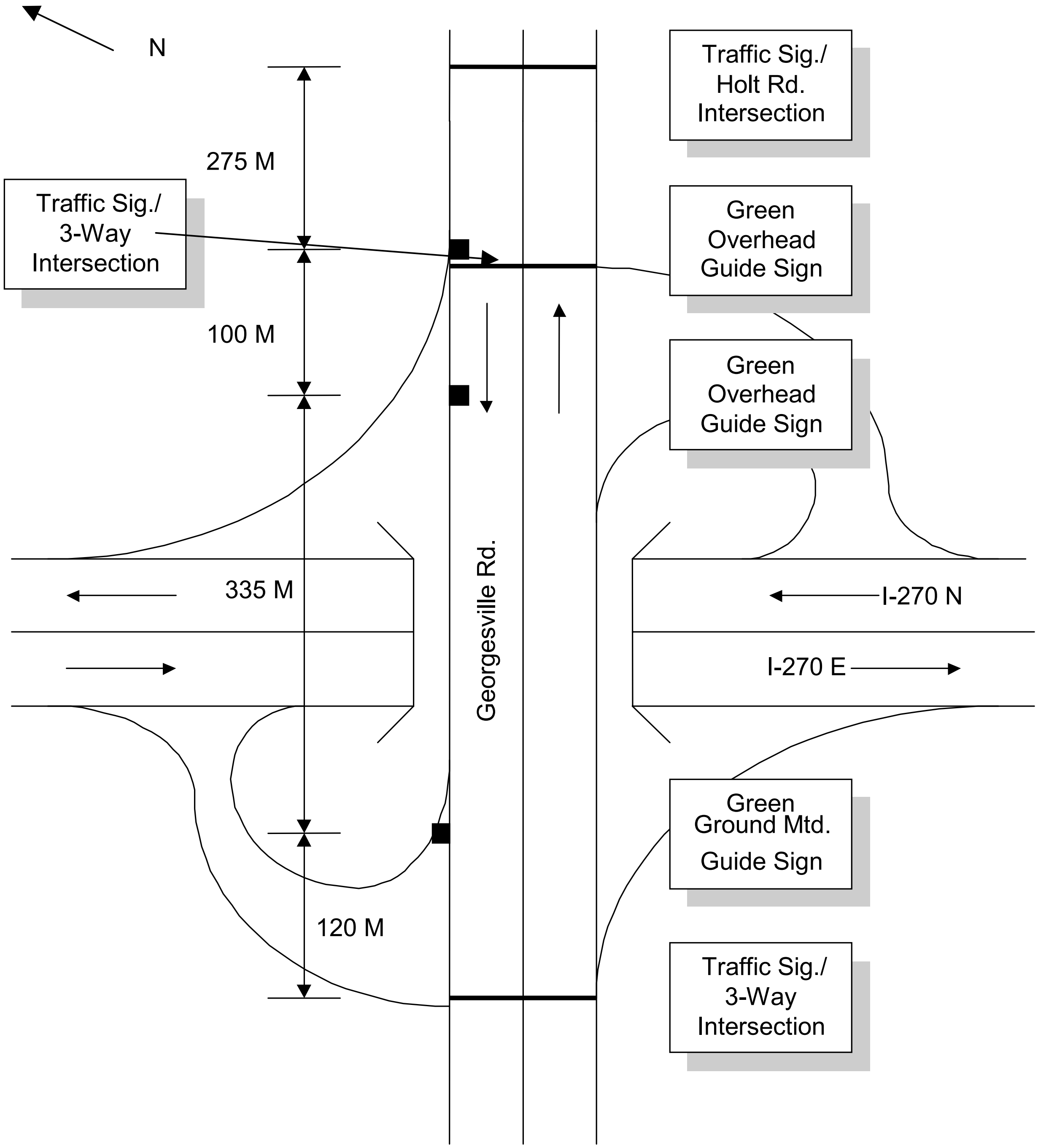


Figure 33. Georgesville Road Interchange with I 270, Signing During the Before Condition

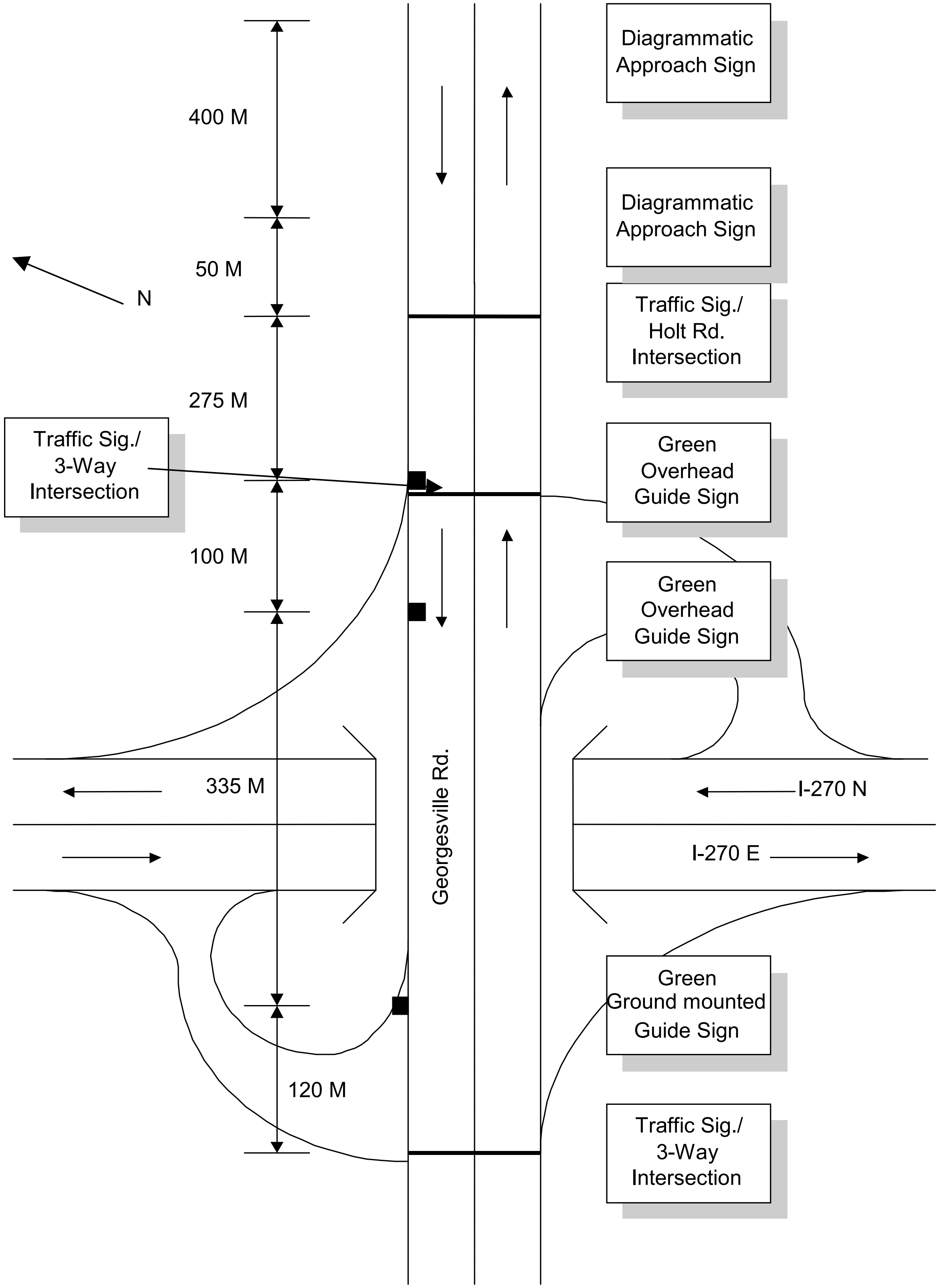


Figure 34. Georgesville Road Interchange with I 270, Signing During the After Condition.

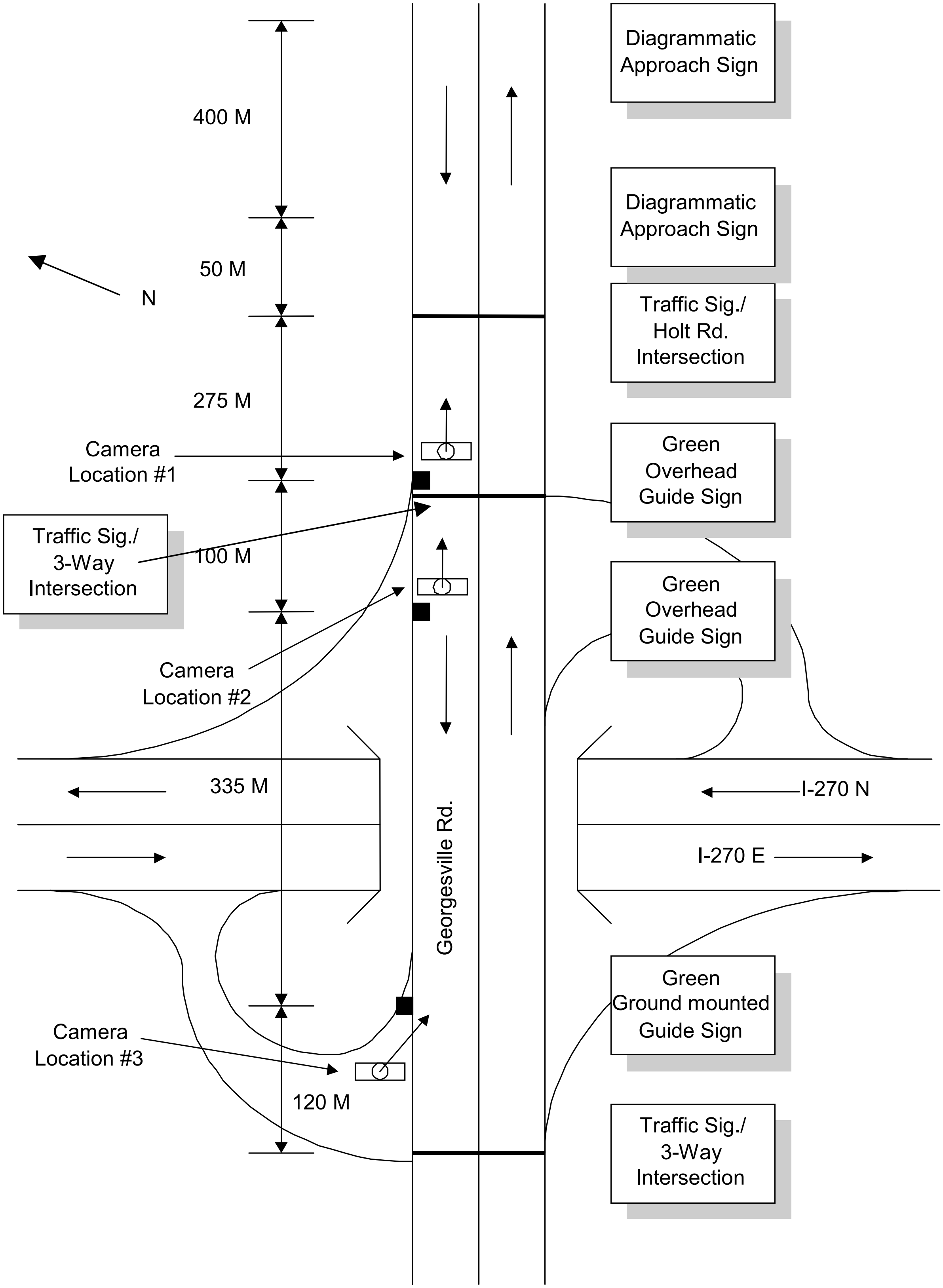


Figure 35. Georgesville Road Interchange with I 270, Camera Locations

Only data for the Brice Road interchange is shown, since the resulting data looked very similar for the three test interchanges. Cumulative percentages as a function of speed are shown in Figure 36, Figure 37, and Figure 38 for camera locations one, two, and three respectively. Graphically, the after condition distributions tend to show a shift to the left in both lanes, indicating a decrease in the vehicle speed. Also, the average speed in each lane at each camera location decreased in the after condition. Further, Table 1 shows that each of the differences in average speed are statistically significant at $\alpha = 0.05$.

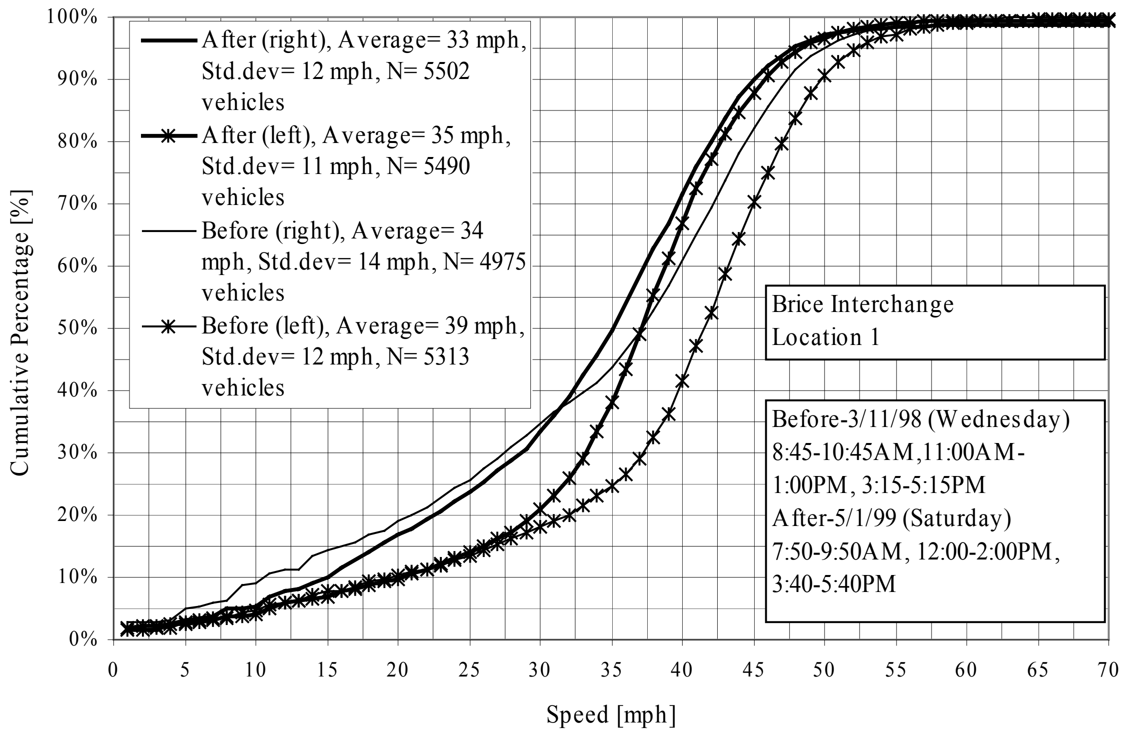


Figure 36. Cumulative Percentage as a Function of Speed, Brice Interchange, Location One.

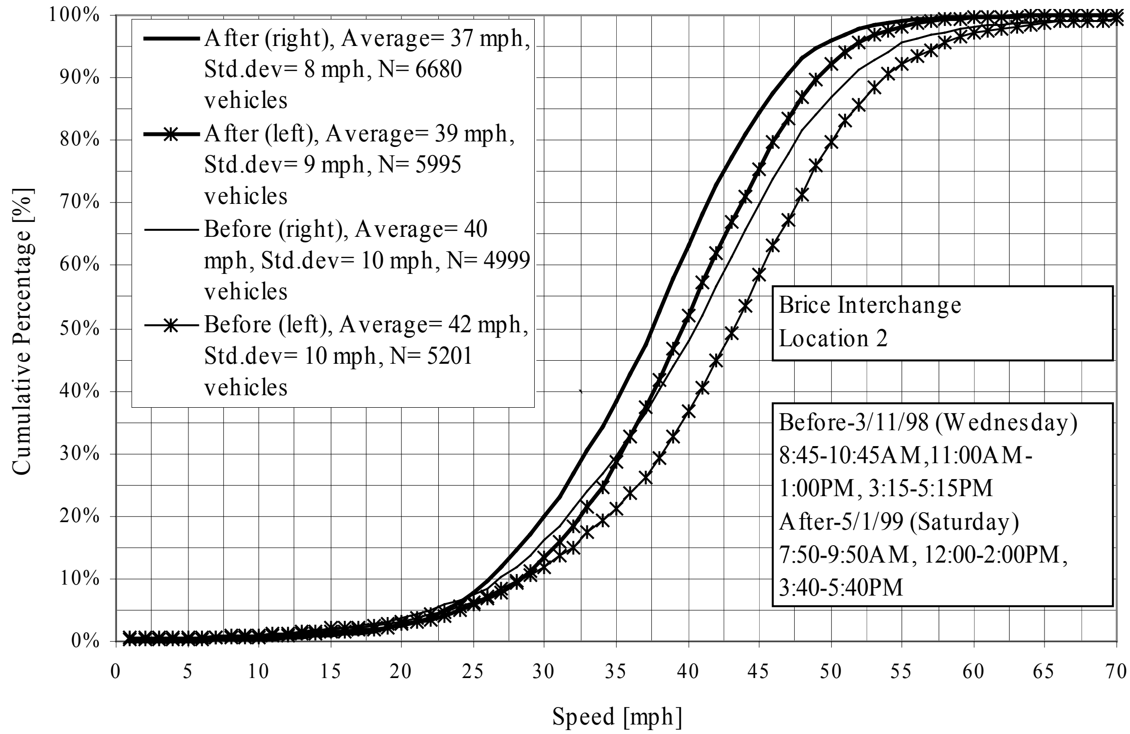


Figure 37. Cumulative Percentage as a Function of Speed, Brice Interchange, Location Two.

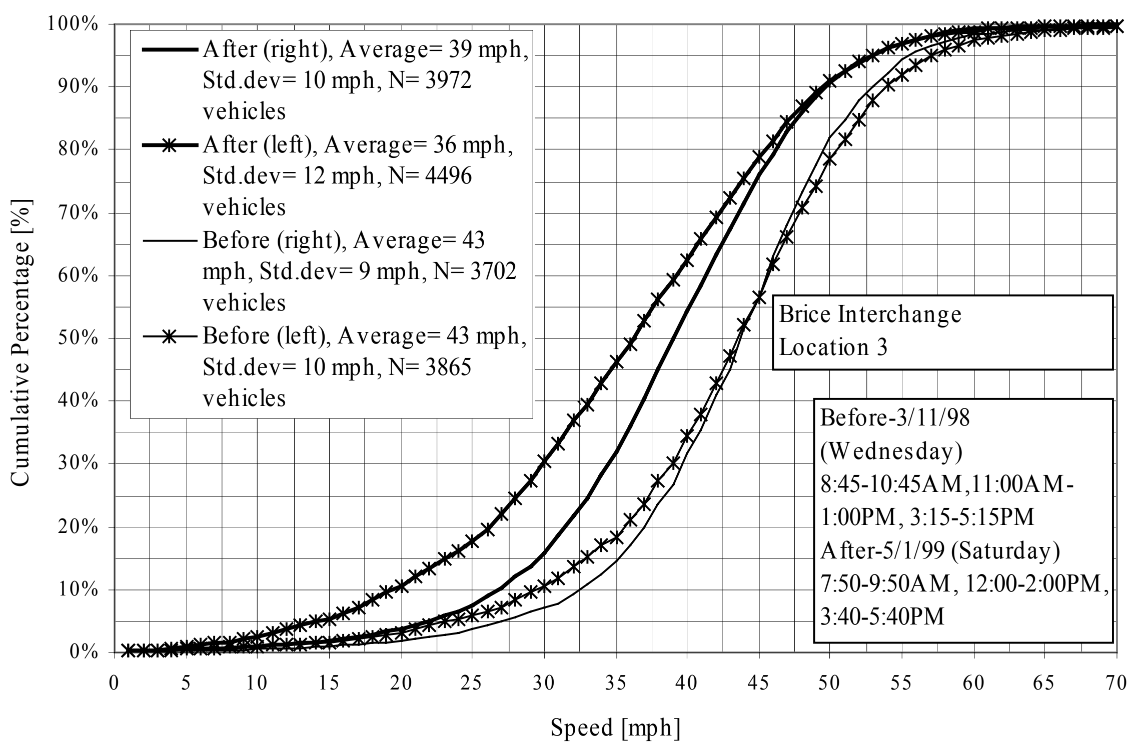


Figure 38. Cumulative Percentage as a Function of Speed, Brice Interchange, Location Three.

Table 1. Test of Hypothesis that the Before and After Mean Speeds are Equal at Brice Road Interchange.

Location 1	Right Lane	Left Lane
t-value	3.5084	15.7715
P-value	0.0005	0.0000
Conclusion	Reject	Reject
Location 2		
t-value	14.5987	15.8733
P-value	0.0000	0.0000
Conclusion	Reject	Reject
Location 3		
t-value	20.7922	29.4333
P-value	0.0000	0.0000
Conclusion	Reject	Reject

A similar comparison was conducted with respect to headway gap. Figure 39, Figure 40, and Figure 41 illustrate the cumulative percentages as a function of headway gap for camera locations one, two, and three, respectively. Again, the after condition distributions appear to be shifted to the left. The average headway gap in each lane at each location decreased, with all but one difference showing statistical significance as indicated in Table 2.

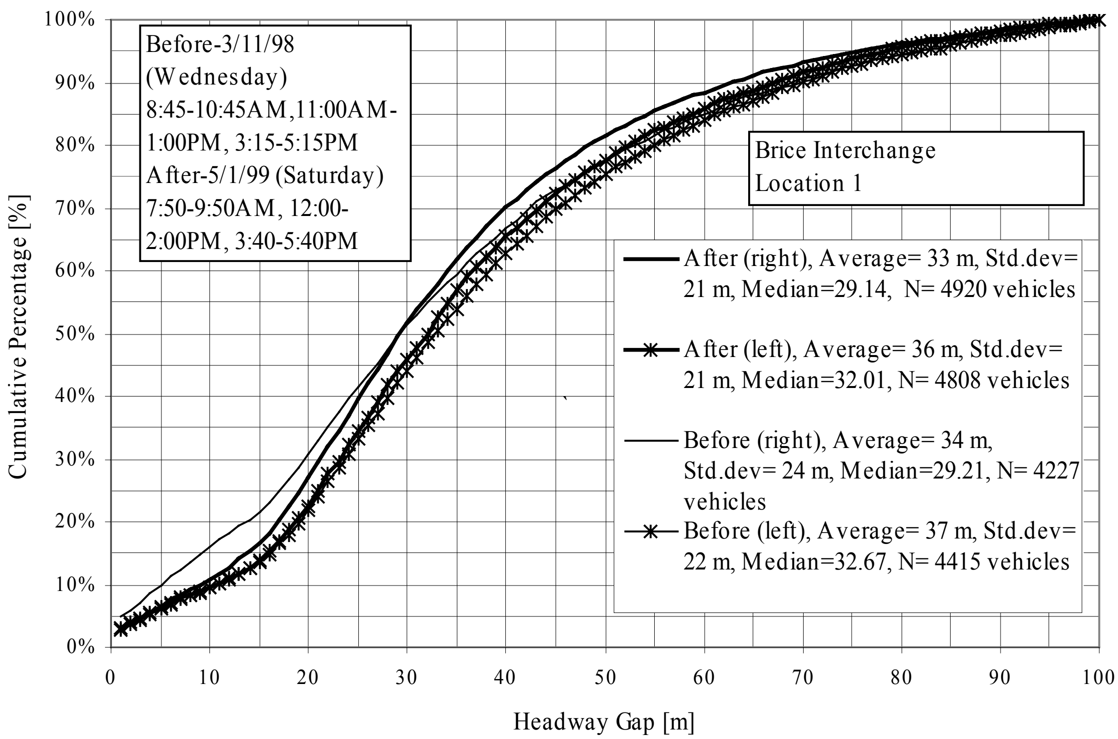


Figure 39. Cumulative Percentage as a Function of Headway Gap, Brice Interchange, location one.

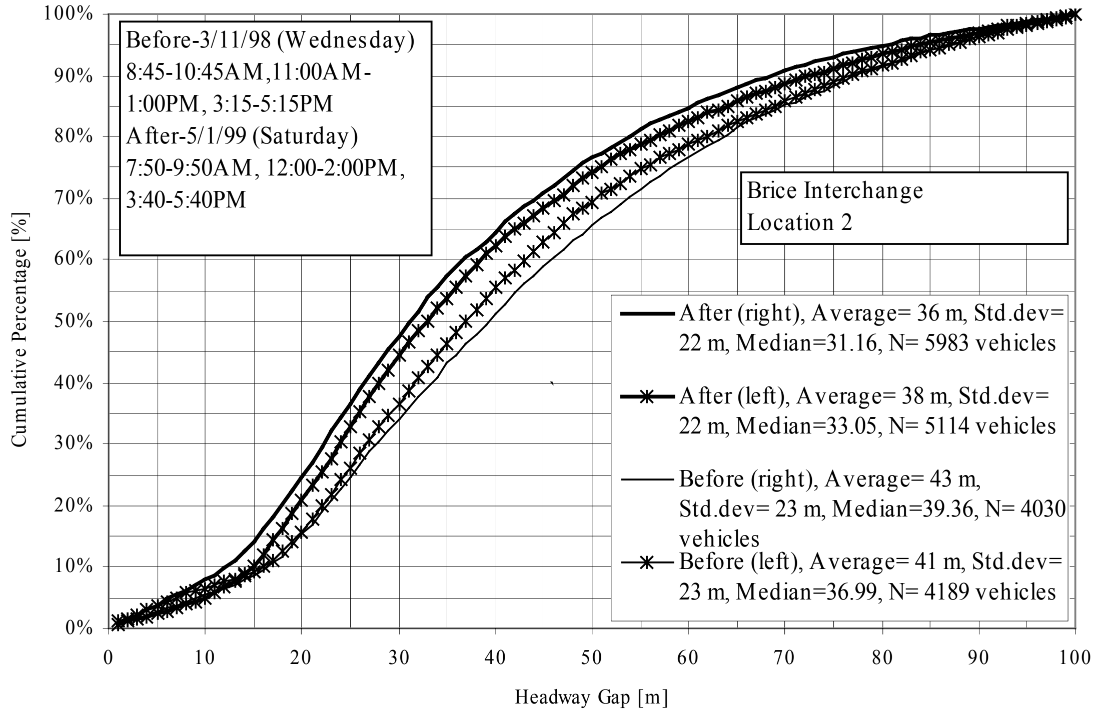


Figure 40. Cumulative Percentage as a Function of Headway gap, Brice Interchange, Location Two

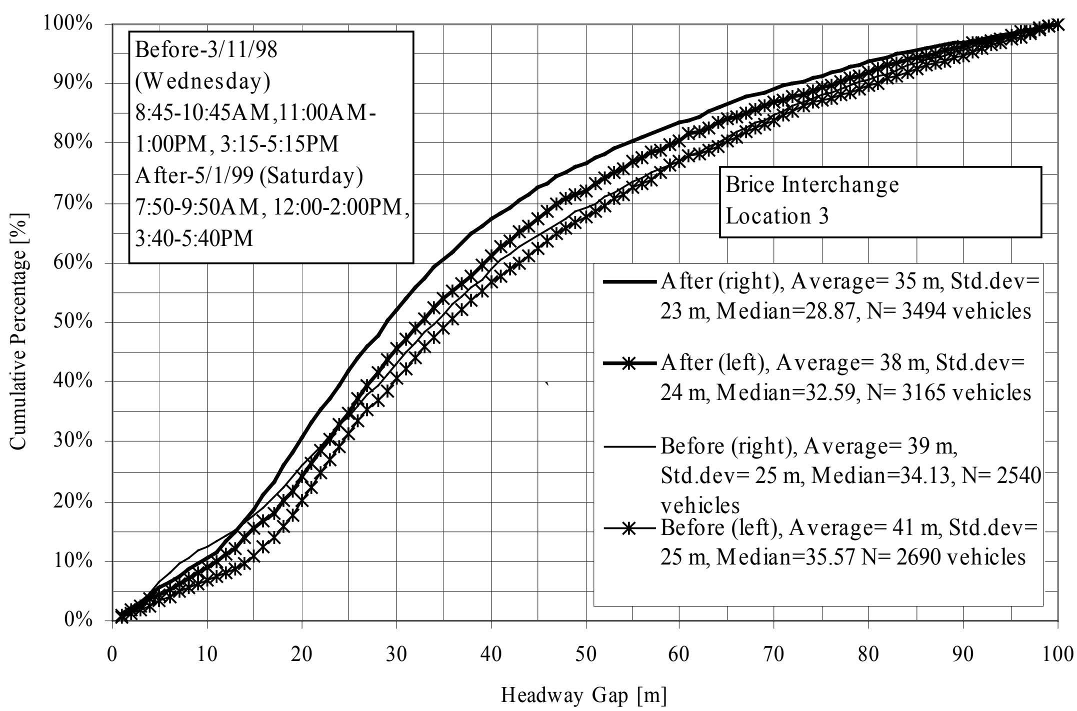


Figure 41. Cumulative Percentage as a Function of Headway gap, Brice Interchange, Location Three.

Table 2. Test of Hypothesis that the Before and After Mean Headway Gaps are Equal at the Brice Road Interchange.

Location 1	Right Lane	Left Lane
t-value	1.3858	2.9043
P-value	0.1658	0.0037
Conclusion	Fail to Reject	Reject
Location 2		
t-value	14.9315	6.5651
P-value	0.0000	0.0000
Conclusion	Reject	Reject
Location 3		
t-value	6.6326	4.8298
P-value	0.0000	0.0000
Conclusion	Reject	Reject

Overall, for the three interchange sites that were videotaped, it was found that under the after condition (diagrammatic signs present), the vehicle speeds were statistically significantly reduced, the vehicle headway gaps were shorter, and the vehicle throughput was statistically significantly higher.

These findings suggest that the diagrammatic entrance ramp approach signs did not hamper the throughput of vehicles at the experimental interchanges. In fact, an increase in throughput was observed. However, caution must be given when making conclusions about differences in flow from the before and the after conditions. The observed fluctuations in traffic volume or vehicle speeds may be only partially due to the effectiveness of the diagrammatic signs. It is well possible that factors such as for example the day of the week or road construction on nearby roads may have affected driver behavior in the observed areas. The primary use of the data obtained with the help of Mobilizer PC is to have some assurance that the diagrammatic signs did not disrupt traffic flow and to provide headway gap information for use in the theoretical calculations made in section 8.

5 ODOT/FHWA EVALUATOR FIELD SURVEY OF THE EXPERIMENTAL GUIDE SIGNING SYSTEMS (AFTER CONDITION)

A total of 13 ODOT/FHWA traffic engineering personnel were recruited to critically evaluate the design, application, and placement of the diagrammatic entrance ramp approach signs at the sites described in section 3. The passenger evaluators were driven through the test sites along the approach on the multilane arterial, and their task was to concentrate on the application and placement of all guide signing, trailblazer assemblies, lane alignment arrows, etc. The vehicles with the evaluators were parked on the shoulder or on a nearby parking lot, after the pass through the interchange along the multilane arterial. The evaluators were then given enough time to complete a questionnaire consisting of the five following questions:

1. In your opinion, how helpful is the information provided by the diagrammatic entrance ramp approach signs that are installed in addition to the existing signing at this site?
   - □ Very helpful
   - □ Helpful
   - □ Somewhat helpful
   - □ Marginally helpful
   - □ Not helpful, existing signing is sufficient
   - □ Other
2. How many diagrammatic entrance ramp approach signs should be used for this approach and what are the best advance distances?
   - □ None, existing signing is sufficient
   - □ One
   - □ Two
   - □ Three
   - □ More
   - □ Other
3. Keeping in mind space and cost considerations, is the right road shoulder the most appropriate lateral location at this particular approach?
   - □ No diagrammatic entrance ramp approach signs needed, existing signs are sufficient
   - □ Yes, the right road shoulder is the most appropriate lateral installation location at this approach
   - □ Yes, but where space is available an additional sign should also be installed on the median
   - □ No, where space is available the signs should be installed on the median only
   - □ Other
4. In what situations do you think will the benefits of the diagrammatic entrance ramp approach signs be greatest at this site?
   - □ No benefits
   - □ In light traffic
   - □ In moderate traffic that is still flowing
   - □ In heavy bumper-to-bumper traffic
   - □ During daytime
   - □ During nighttime
   - □ In situations where large vehicles may obstruct some traffic signs

□ Other

5. From how far ahead could you recognize all features on the ground mounted diagrammatic entrance ramp approach signs at this approach?
   □ Well from far enough
   □ From far enough
   □ Just barely from far enough
   □ Just barely from not far enough
   □ Clearly not from far enough
   □ Other

Six of the evaluators visited the test sites in the order of Brice Road, SR 315, Roberts Road, Hilliard Rome Road, Plain City Georgesville Road (SR 142), and Georgesville Road. The remaining seven evaluators visited the test sites in the reverse order. The evaluator responses were compiled into a frequency count that is shown in Table 3 and Figure 42 to Figure 46.

Table 3. ODOT/FHWA Evaluator Responses to Five Questions Regarding the Application and Placement of Diagrammatic Entrance Ramp Approach Signs

		Sites					
Question	Choices	Plain City, SR 142	Hilliard Rome	Roberts Road	SR 315	Brice Road	Georgesville Road
Q1: In your opinion, how helpful is the information provided by the diagrammatic entrance ramp approach signs that are installed in addition to the existing signing at this site ?	Very helpful	2	4	6	9	3	6
	Helpful	5	6	5	3	6	4
	Somewhat helpful	2	0	2	0	4	1
	Marginally helpful	0	2	0	1	0	2
	Not helpful, existing signing is sufficient	3	1	0	0	0	0
	Other	0	0	0	0	0	0
Q2: How may diagrammatic entrance ramp approach signs should be used for this approach and what are the best advance distances ?	None, existing signing is sufficient	4	1	0	0	0	0
	One	3	6	9	7	7	6
	Two	5	6	4	6	4	7
	Three	0	0	0	0	0	0
	More	0	0	0	0	0	0
	Other	0	0	0	0	2	0
Q3: Keeping in mind space and cost considerations, is the right road shoulder the most appropriate lateral location at this particular approach ?	No diagrammatic entrance ramp approach signs needed, existing signs are sufficient	5	1	0	0	1	1
	Yes, the right road shoulder is the most appropriate lateral installation location at this approach	8	12	13	11	12	12
	Yes, but where space is available an additional sign should alo be installed on the median	0	0	0	2	0	0
	No, where space is available the signs should be installed on the median only	0	0	0	0	0	0
	Other	0	0	0	0	0	0
Q4: In what situations do you think will the benefits of the diagrammatic entrance ramp approach signs be greatest at this site ?	No benefits	5	1	1	1	1	1
	In light traffic	4	2	4	4	2	5
	In moderate traffic which is still flowing	5	9	9	9	7	8
	In heavy bumper-to-bumper traffic	4	4	7	6	7	5
	During daytime	4	7	6	7	5	7
	During nighttime	6	10	10	9	9	9
	In situations where large vehicles may obstruct some traffic signs	2	4	4	3	4	4
	Other	1	1	1	2	1	1
Q5: From how far ahead could you recognize all features on the ground mounted diagrammatic entrance ramp approach signs at this approach ?	Well from far enough	6	2	2	3	2	3
	From far enough	5	8	9	6	7	7
	Just barely from far enough	1	3	2	4	3	3
	Just barely from not far enough	0	0	0	0	0	0
	Clearly not from far enough	0	0	0	0	1	0
	Other	0	0	0	0	0	0

Figure 42 shows the evaluator responses to question 1. This question focused on the overall usefulness of diagrammatic entrance ramp approach signs on each of the test sites evaluated. Generally, the evaluators considered the diagrammatic signs to be very helpful or helpful. Only few evaluators thought that the diagrammatic signs would be helpful on Plain City Georgesville (SR 142), and Brice Road. The Plain City Georgesville Road (SR 142) installation is unsuitable for diagrammatic signs, because the approach has a very low traffic volume, and is essentially a rural two-lane road. The Brice Road diagrammatic sign installation was considered to be only somewhat helpful, because the preexisting guide signing was already excellent (overhead sign bridge). The SR 315 fared very well because this approach is quite counterintuitive for an unfamiliar driver. Figure 43 indicates that most evaluators think that one or two diagrammatic guide signs are sufficient. The placement of ½ mile and ¼ mile in advance of the interchange (first gore) was generally considered to be adequate, as long as no major cross streets exist between the diagrammatic sign and the first gore of the interchange. Figure 44 shows the evaluator questionnaire responses for question 3, which focused on the lateral placement of the diagrammatic guide signs. Generally, for those evaluators who thought that diagrammatic guide signs are useful, it can be seen that the right road shoulder was considered to be the most appropriate sign location. No clear opinion crystallized regarding the most appropriate traffic situation that would call for the deployment of diagrammatic guide signs (Figure 45). Figure 46 shows that most evaluators felt that the guide sign designs were visible and legible enough for the intended application. Overall, it seems that ground mounted diagrammatic guide signs should not be used in situations where low traffic volumes exist, in situations that are essentially two lane rural approaches with lane extensions only in the immediate interchange area, and in situations where the preexisting guide signing is already about ½ to ¼ mile in advance of the interchange and conveys unambiguous guide information. Ground mounted diagrammatic guide signs are best suited in approaches that are counterintuitive to unfamiliar drivers. The application of two right shoulder mounted diagrammatic guide signs located ½ mile and ¼ mile prior to the first gore of the interchange seems to be a reasonable use of resources for the evaluators who participated in this study.

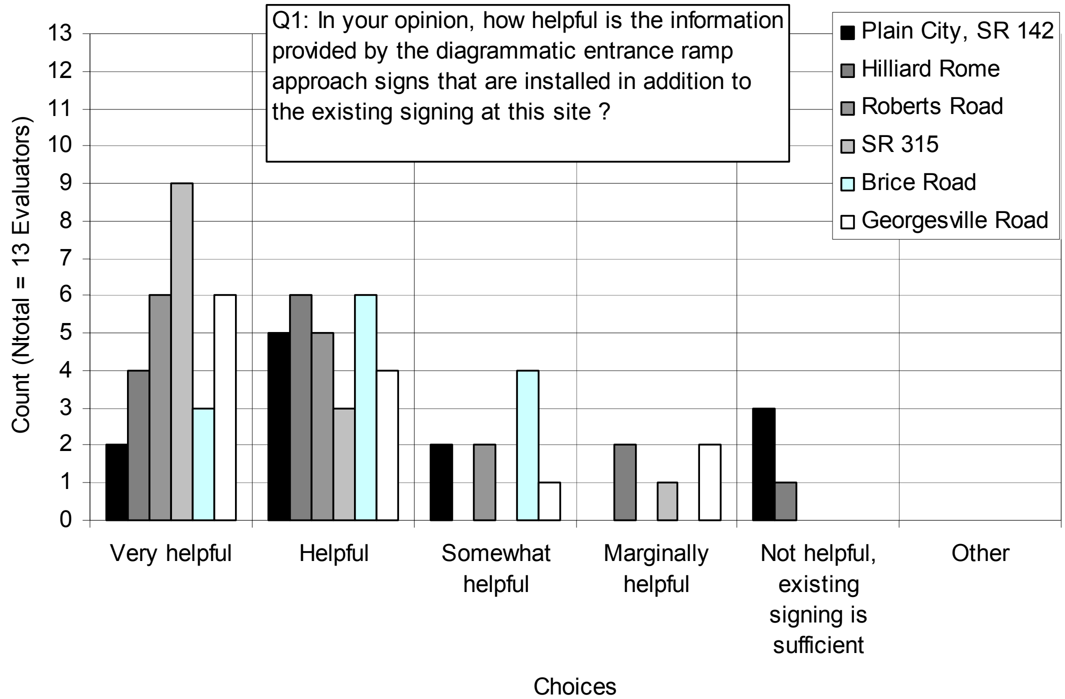


Figure 42. Question Number 1, ODOT/FHWA Evaluator Responses

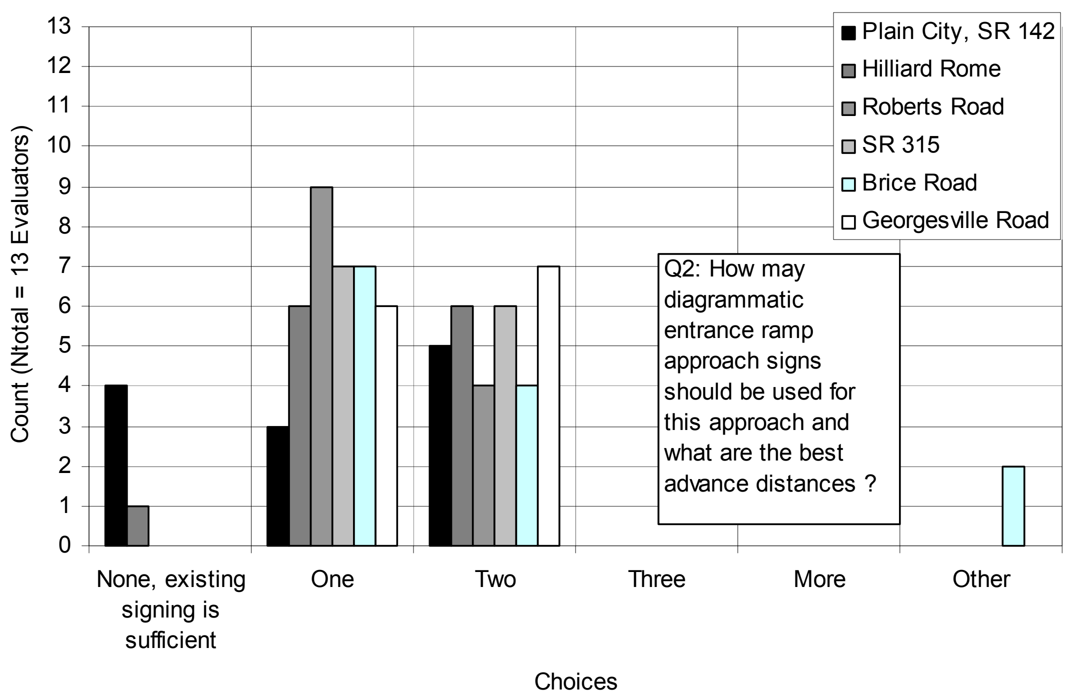


Figure 43. Question Number 2, ODOT/FHWA Evaluator Responses

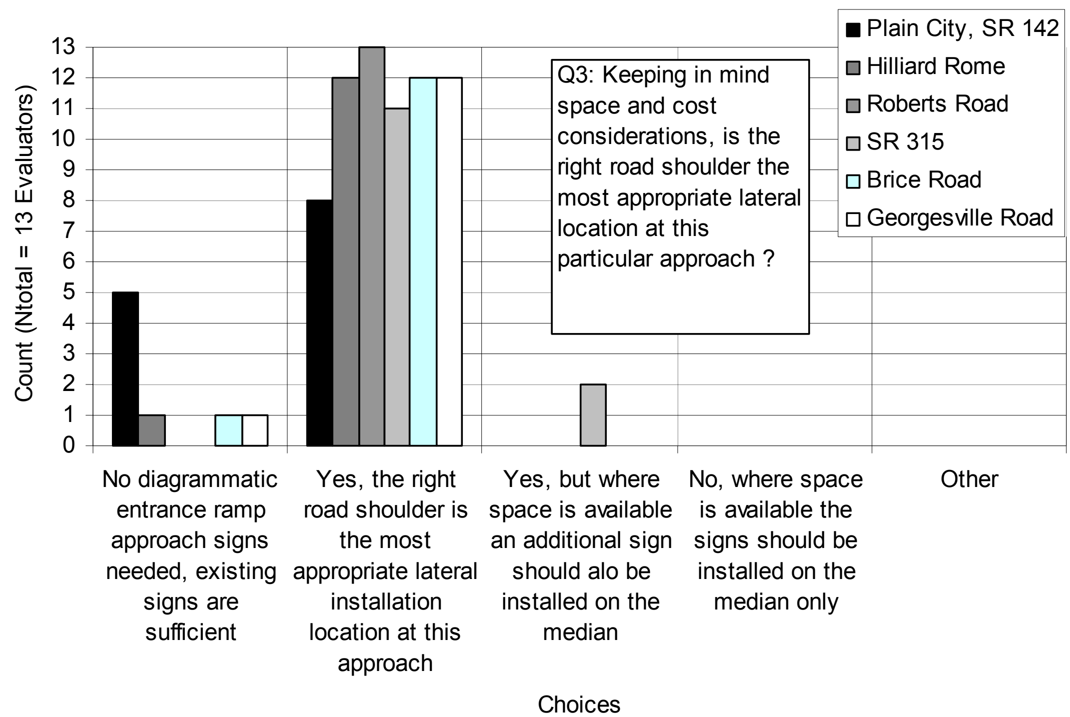


Figure 44. Question Number 3, ODOT/FHWA Evaluator Responses

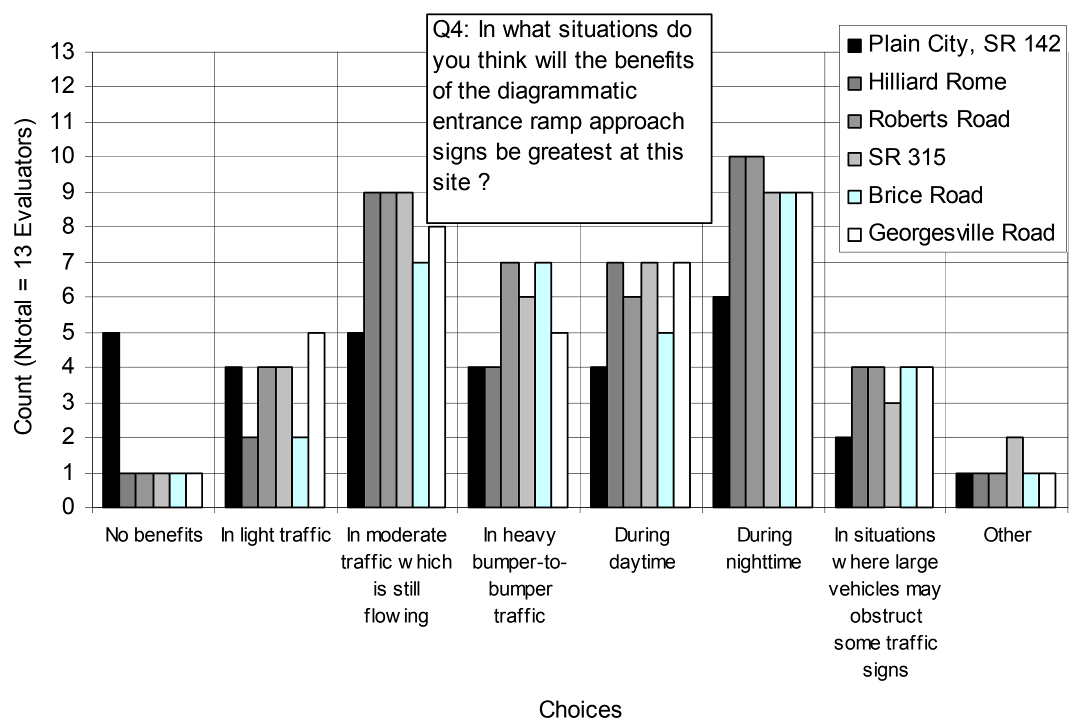


Figure 45. Question Number 4, ODOT/FHWA Evaluator Responses

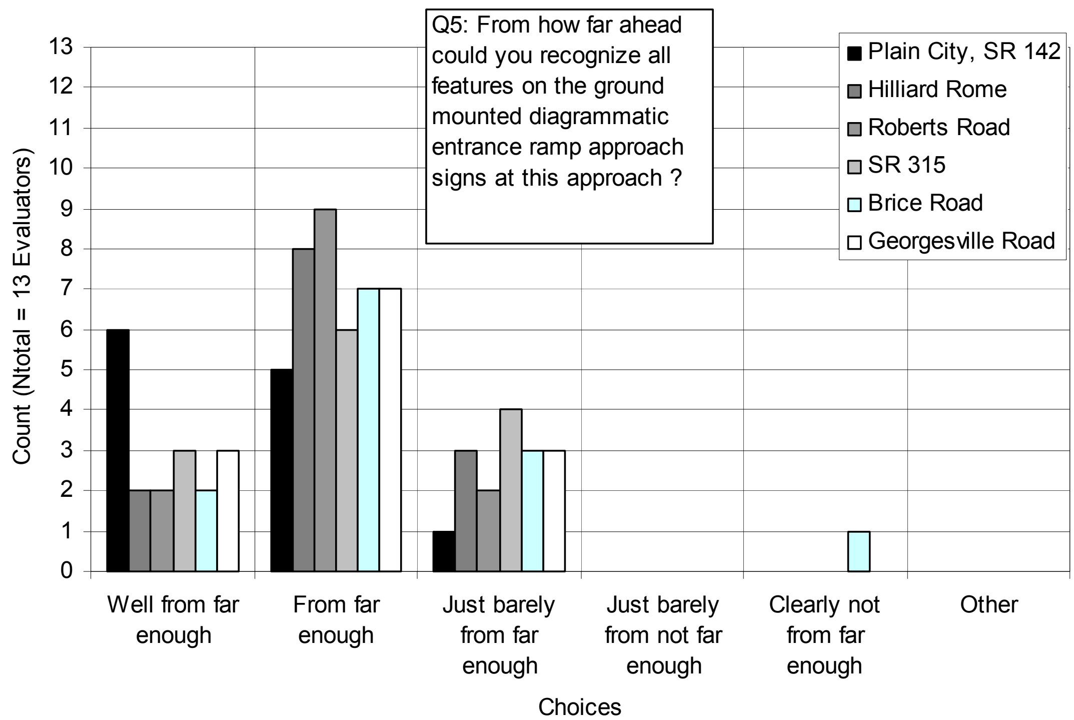


Figure 46. Question Number 5, ODOT/FHWA Evaluator Responses

6 EVALUATION OF THE EXPERIMENTAL GUIDE SIGNING SYSTEMS USING 20 UNFAMILIAR DRIVERS IN AN EXPERIMENTAL INSTRUMENTED VEHICLE

A total of 21 and 19 unfamiliar test drivers were recruited under the before and after condition, respectively, to further evaluate the usefulness of the diagrammatic entrance ramp approach signs for unfamiliar drivers. Approximately half of the subjects visited the test sites in the order of Brice Road, SR 315, Roberts Road, Hilliard Rome Road, Plain City Georgesville Road (SR 142), and Georgesville Road. The remaining subjects visited the test sites in the reverse order.

A screening questionnaire was designed to determine the familiarity of the subjects with the Greater Columbus area. Care was taken in the design of the questionnaire to ensure that the subjects did not detect the actual objective of the experiment. None of the questions directly addressed issues of familiarity with the Greater Columbus area, however, the questionnaire revealed enough information about each subject for us to be reasonably sure that the subjects were not familiar with the Greater Columbus area. An exit interview that was administered after the experiment then probed fairly deeply into the familiarity of the subjects with the interchanges they had just visited. None of the subjects had to be excluded due to familiarity. Also, the reader should note, that for reasons of familiarity, none of the subjects who were recruited for the before condition were allowed to participate in the after condition, or in any other test driving tasks in this study.

The subjects were staged on parking lots well in advance of the interchanges. A passenger experimenter was present in the vehicle at all times to give instructions. After the subjects completed their consent form paperwork, they were allowed to start driving and to merge with the traffic on the multi lane arterials leading to the corresponding freeway interchanges. Typically, this occurred about three miles in advance of the corresponding interchange. The experimenter told the subjects to find their way to a specific freeway entrance ramp, for example to I 270 Northbound. The experimenter made sure that the subjects always started out in the wrong lane for accessing the freeway in the direction given by the experimenter.

The vehicle was equipped with a forward-looking video camera, a Distance Measuring Instrument (DMI), and with an audio recording system. The variable of interest was the distance to the first gore at which the subject realized that he or she was in the wrong lane and a lane change had to be performed. All runs were performed at night because this allowed for more efficient driving as the selected interchanges often experience massive travel time delays during the daytime.

Figure 47 to Figure 52 show the cumulative distributions of the lane change occurrences for each one of the interchanges used in the study. The positive effect of the diagrammatic signs that were located in advance of the interchanges is quite striking. With the exception of the Plain City Georgesville (SR 142) interchange (Figure 52), all distributions clearly show that the lane change from the wrong lane to the correct lane was initiated much earlier under the after condition. The Plain City Georgesville (SR 142) interchange is simply not suited for diagrammatic entrance ramp approach signs located in advance of the interchange, because the approach to this interchange is a two-lane rural road.

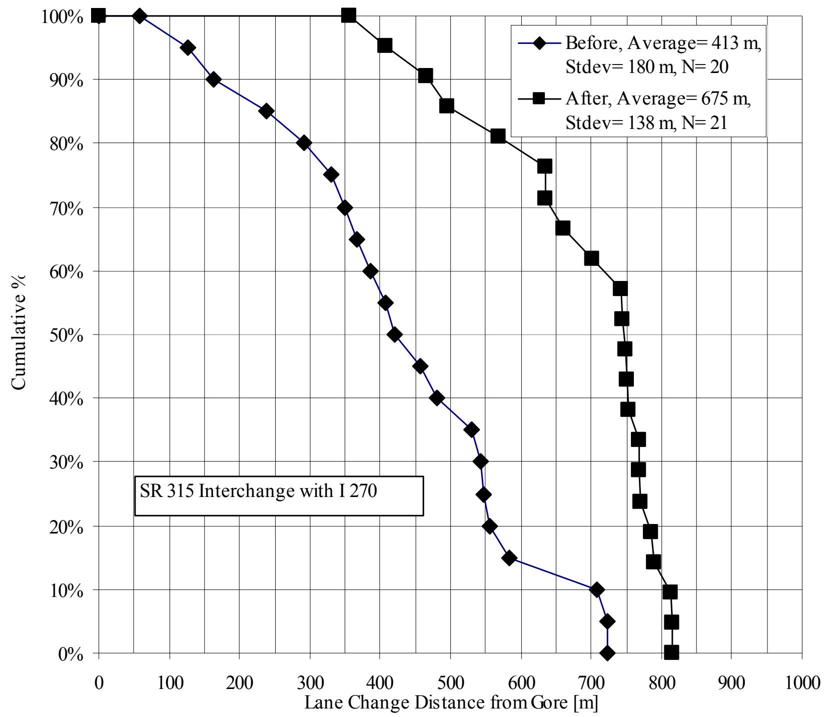


Figure 47. SR 315 Southbound Interchange with I 270, Lane Change Distance to Gore

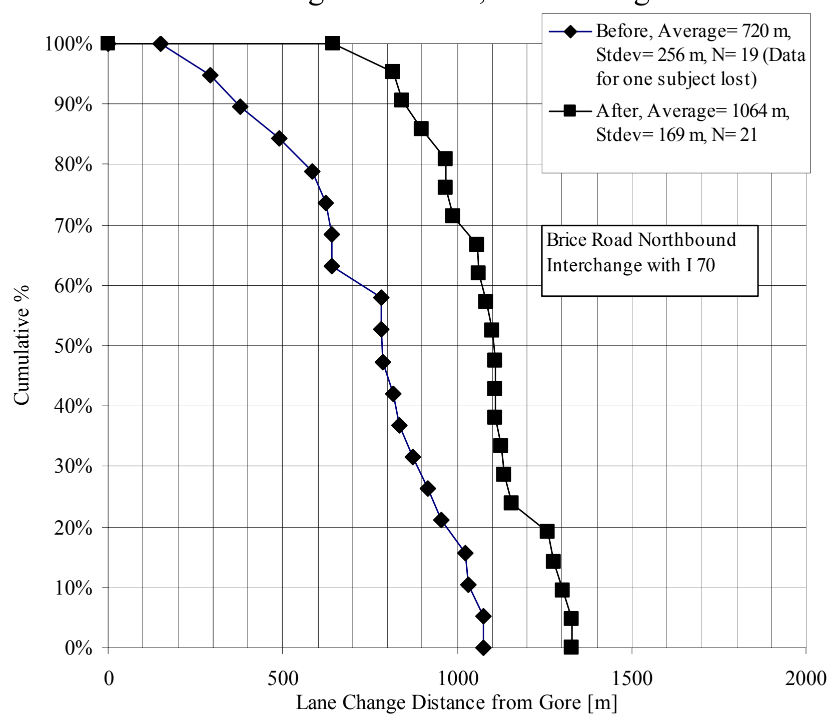


Figure 48. Brice Road Northbound Interchange with I 70, Lane Change Distance to Gore

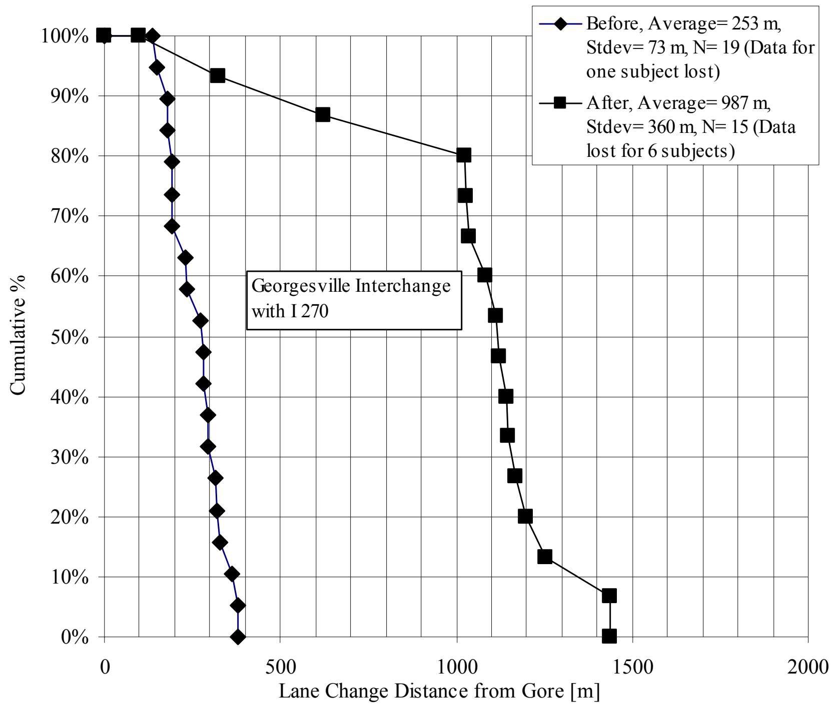


Figure 49. Georgesville Road Interchange with I 270, Lane Change Distance to Gore

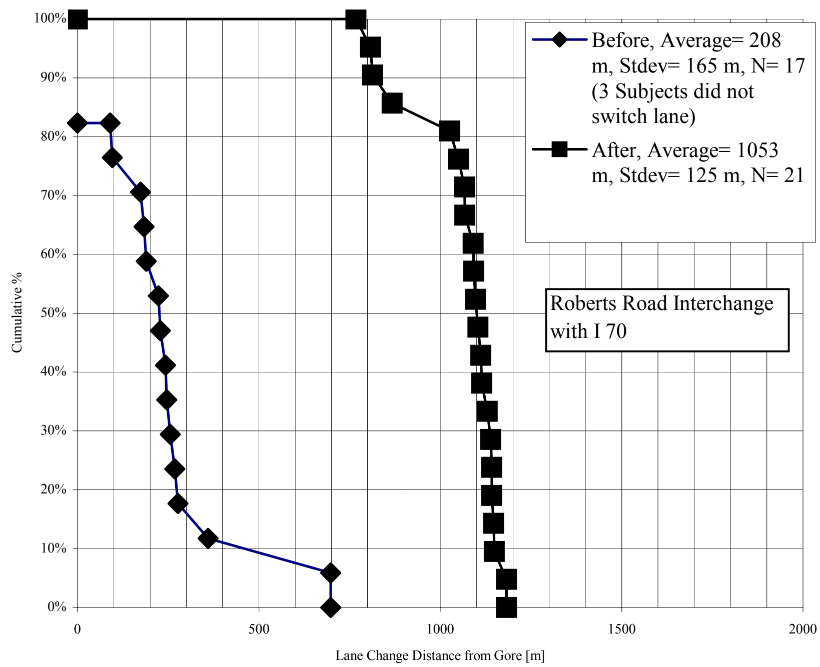


Figure 50. Roberts Road Interchange with I 270, Lane Change Distance to Gore

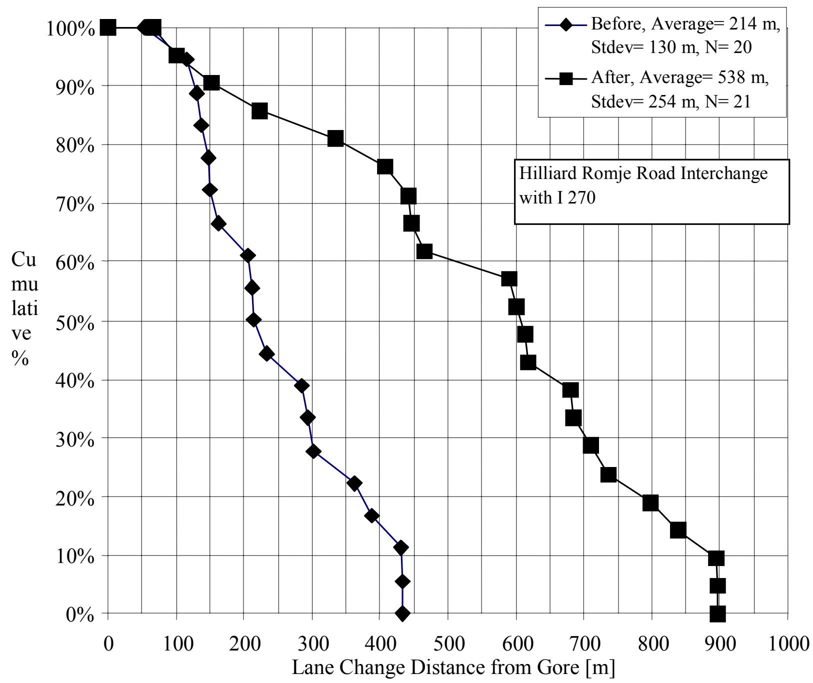


Figure 51. Hilliard Rome Road Interchange with I 270, Lane Change Distance to Gore

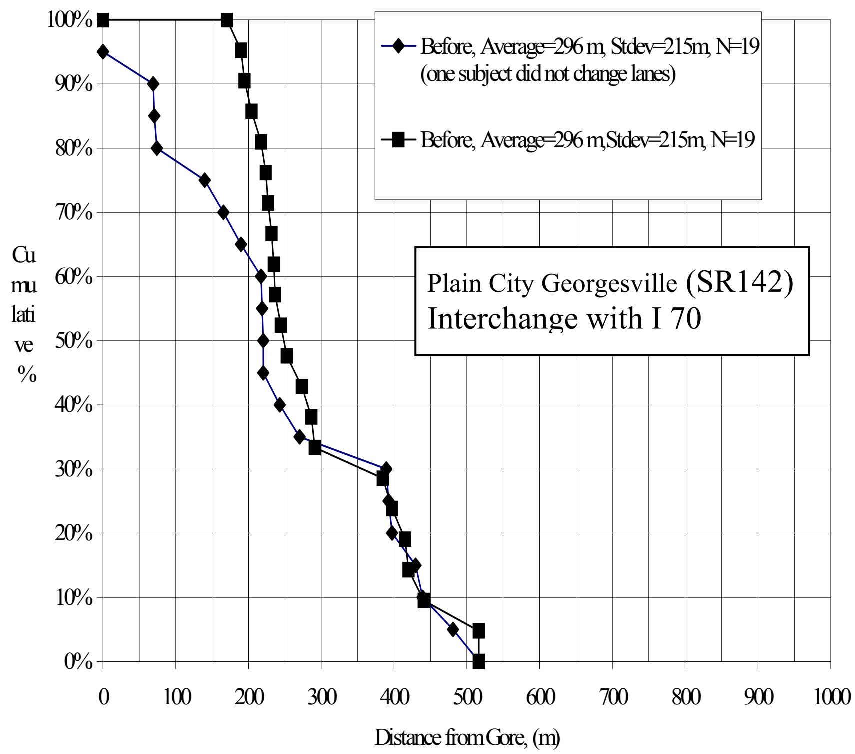


Figure 52. Plain City Georgesville Road (SR 142) Southbound Interchange with I 70, Lane Change Distance to Gore

Figure 53 shows the combined lane change distances for all interchanges. Again, the after condition (diagrammatic signs present), clearly shows a substantial, statistically highly significant ($t_{0.025,215}$=10.1, $P < 0.0001$) improvement in terms of lane change distance.

Overall, for the test driver experiment, it can be concluded that the diagrammatic entrance ramp approach signs located in advance of the interchange are excellent tools to convey lane choice information to unfamiliar motorists approaching a highway-freeway interchange.

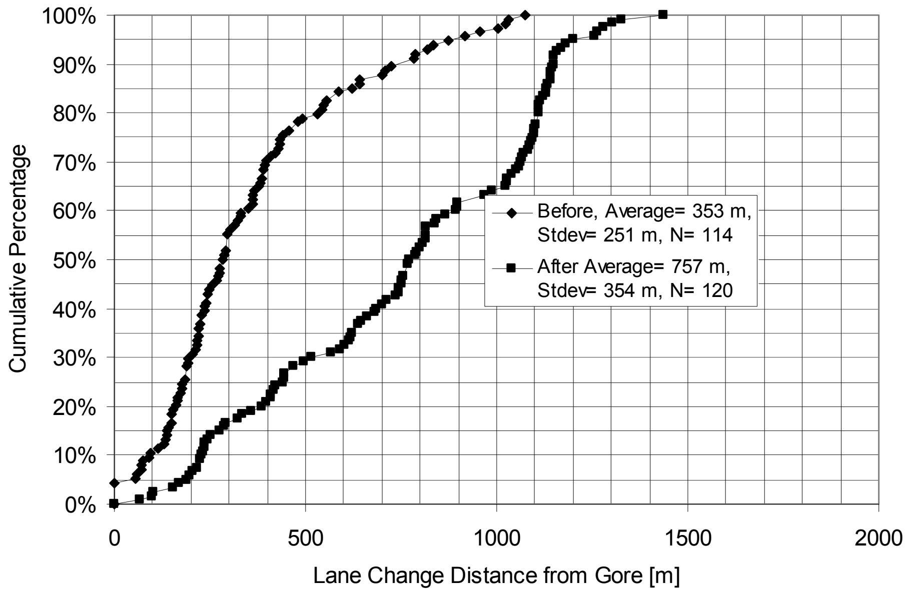
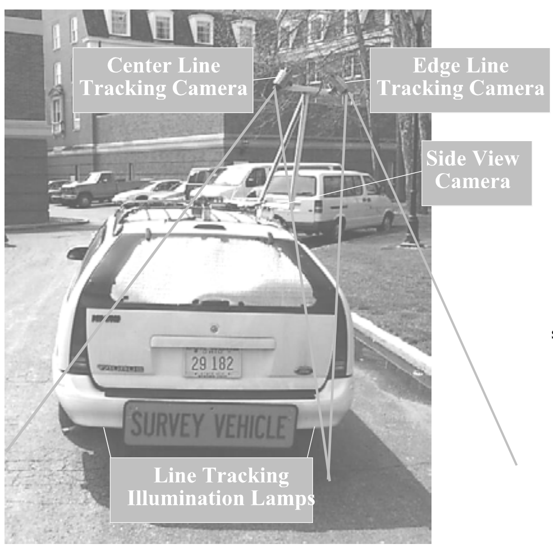


Figure 53. Lane Change Distance to Gore, Combined for All Interchanges used in Study

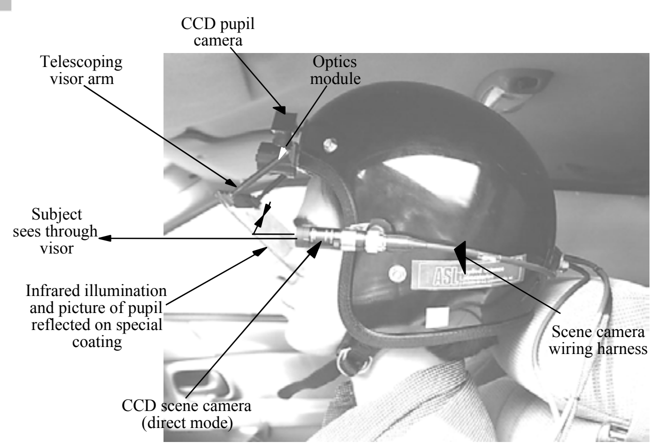
7 EYE SCANNING BEHAVIOR

7.1 Subjects and Apparatus

Six male subjects were recruited to participate in the study. All subjects, between the ages of 22-42, were unfamiliar with the Columbus, Ohio area (site of the experimental interchanges) and had a valid US driver's license. One subject wore contacts during the eye scanning runs. However, this did not adversely affect the ASL 4000 eye tracking system performance. Subjects were advised that they were in command of the vehicle and were responsible for their actions while operating the vehicle. They were informed that the experimental aim was to determine how drivers dealt with the traffic and/or road situations in urban settings. Also, they were instructed to drive as normally as possible, obey all speed limits, and navigate the vehicle safely to the experimental destinations. Each subject made five total eye scanning runs, one run through each of the six experimental interchanges equipped with the diagrammatic signs. All runs were performed during nighttime due to a restriction of the ASL eye scanning system.



a. Experimental Vehicle, 1994 Ford Taurus Wagon with Lane Tracking and Side View Cameras



b. ASL 4000 Eye Scanning Helmet

Figure 54. Experimental Vehicle and Eye Scan Equipment Used in the Present Study

7.2 Data Acquisition and Analysis

Staging and calibration was always performed on a parking lot area near each corresponding interchange site. Each subject was newly calibrated prior to performing a run through an interchange site. The video data from the eye scanning runs were recorded on 8mm cassettes. Recording of the eye scanning video and digital data was always begun well in advance of the diagrammatic signs (the signs were not visible when recording began), and were continued until the driver exited the vehicle back at the staging area. No clues as to the exact nature of the study, whatsoever, were given to the subject prior to, during, and after the experiment.

The analysis focused on the looking behavior of the subjects in the vicinity of the diagrammatic entrance ramp approach signs. A separate analysis was conducted for each diagrammatic sign location and for each subject. The first look and last distance to each diagrammatic sign was carefully extracted from the video records. Also, looking behavior was analyzed with regard to number and duration of looks to each diagrammatic sign.

The initial step of the data analysis was to determine the relative location of each diagrammatic sign in question with respect to the mileage counter shown on the video record. The exact longitudinal location of each diagrammatic sign thus became the origin of the longitudinal coordinate system for each video record. The distances at which looks to the diagrammatic signs were performed always related to the origin of the corresponding diagrammatic sign. Once the origin of a diagrammatic sign for a given video record (subject) was found, the video was stepped back and paused at the point, where the diagrammatic sign came into the field of view for the first time, at a long distance ahead. The looks during the approach were analyzed frame by frame. Each sign of interest had a virtual boundary (Figure 55) that extended the sign dimensions by approximately 15% in each direction. A fixation to a diagrammatic guide sign was defined as the duration from when the gaze crosshairs entered the virtual boundary to when the gaze crosshairs exited the virtual boundary. One or two frames where the crosshairs were outside the virtual boundary did not terminate a fixation, provided that the crosshairs immediately returned to the inside of the boundary. In most cases, a fixation ends in an unambiguous saccade away from the sign (virtual boundary) to another object (usually the road environment).

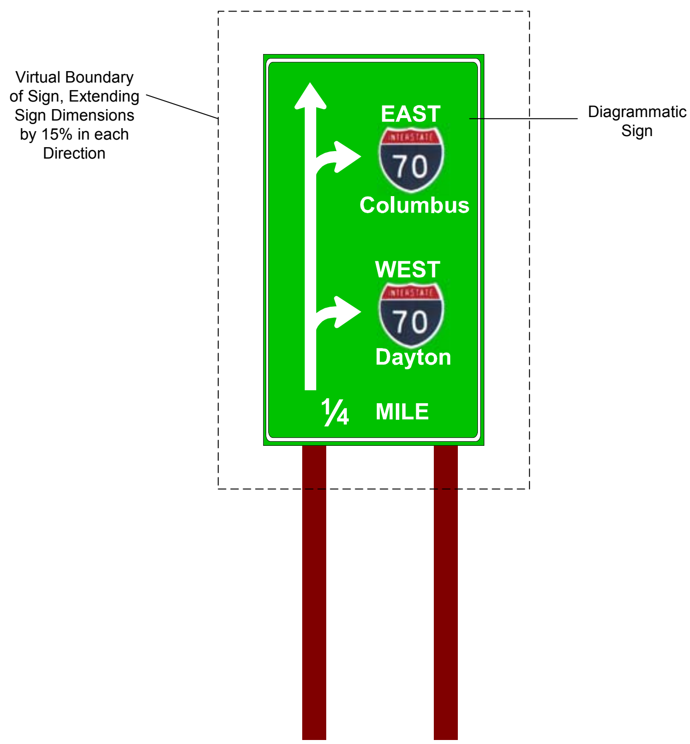


Figure 55. Virtual Boundary Used for Analysis of Eye Fixation Video Records

An automatic analysis was not possible, because the head movements were not tracked and thus, the eye tracker coordinate system was constantly moving with the subject's head. However, even if head movements were tracked, one could still not perform a completely automatic analysis, because the ASL proprietary algorithm that determines the begin and end of a fixation does not consider moving objects such as a traffic sign seen from a moving car. The x,y gaze coordinates constantly change during an approach to a sign, even during a definite fixation of the sign. This coordinate change is due to smooth pursuit eye movements that are necessary to keep the sign fixated. With present technology, there seems to be no better way than to analyze the video record frame by frame.

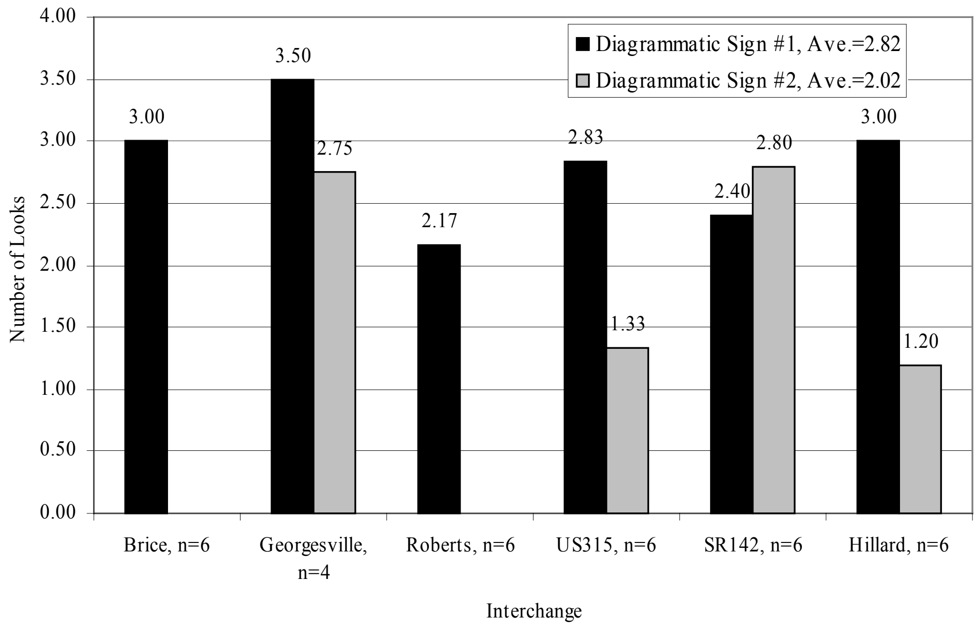
When a look began the numbers from the mileage counter and the frame counter were recorded. In addition, these same observations were made when the look ended. This procedure was repeated for each look the driver made while approaching the signs. The total duration of each look was calculated by subtracting the beginning frame count from the ending frame count and converting this number (total frames associated with the look) into seconds. Also, the distances at which each look began were calculated by subtracting the number on the mileage counter when the look began from the determined location of the sign. This data was recorded separately for each interchange in Microsoft Excel format.

7.3 Results

Because the diagrammatic entrance ramp approach signs were novel and different in appearance from the traditional trailblazer assemblies, particular interest was given to the number of looks that drivers made to the diagrammatic signs, the distance at which the first and last looks occurred, and the duration of the first and last looks. Traffic signs that elicit more than about four looks may be considered distractive to an unacceptable extent.

The average number of looks for each diagrammatic sign is shown in Figure 56. Overall, the average number of looks to the first diagrammatic sign of the approaches was 2.82 and 2.02 for the second diagrammatic sign (where present) of the approaches. This average number of looks indicates that the diagrammatic signs are noticed, and that they do not unduly distract a driver.

The average look duration to the diagrammatic signs is illustrated in Figure 57 for the first diagrammatic sign in each approach, and Figure 58 for the second diagrammatic sign (where present) in the approaches. Overall, the average first look durations were 0.74 seconds and 0.66 seconds for the first and second diagrammatic signs, respectively. The average last look durations were 0.68 seconds and 0.62 seconds for the first and second diagrammatic signs, respectively. These look durations fall well within the range of acceptance, and compare well with the sign reading times given by Zwahlen in [17]. The observed sign reading times indicate a normal level of information processing and do not appear to be unduly long.



(Note: not all interchanges contained two diagrammatic signs.)

Figure 56. Average Number of Eye Fixations Per Diagrammatic Sign.

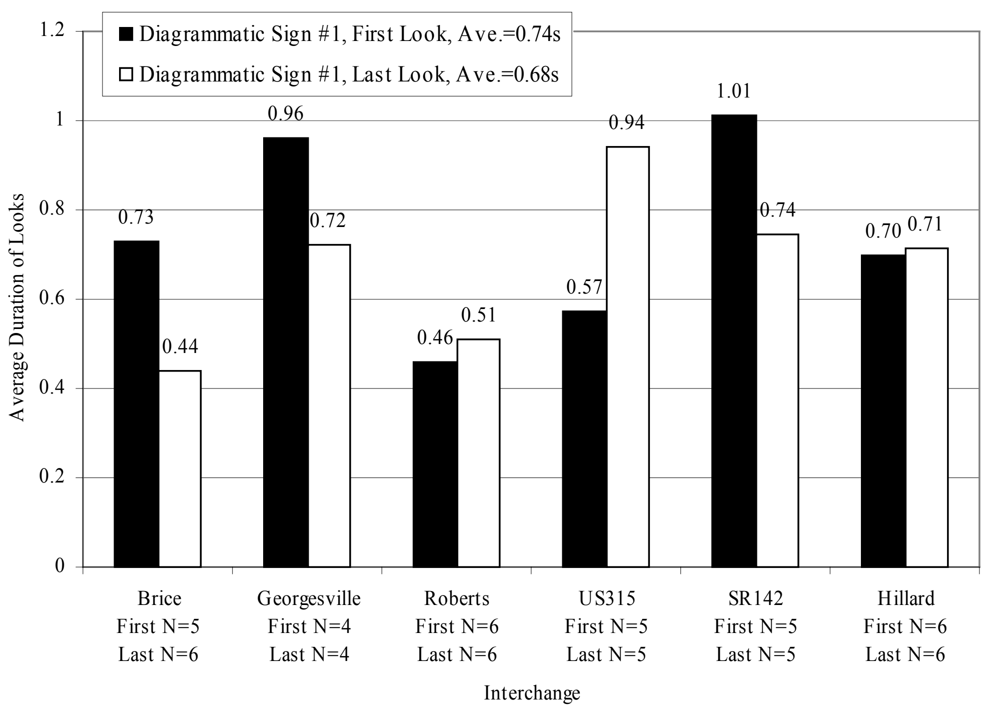


Figure 57. Average Duration of Eye Fixation [seconds] at the First Diagrammatic Sign of each Interchange.

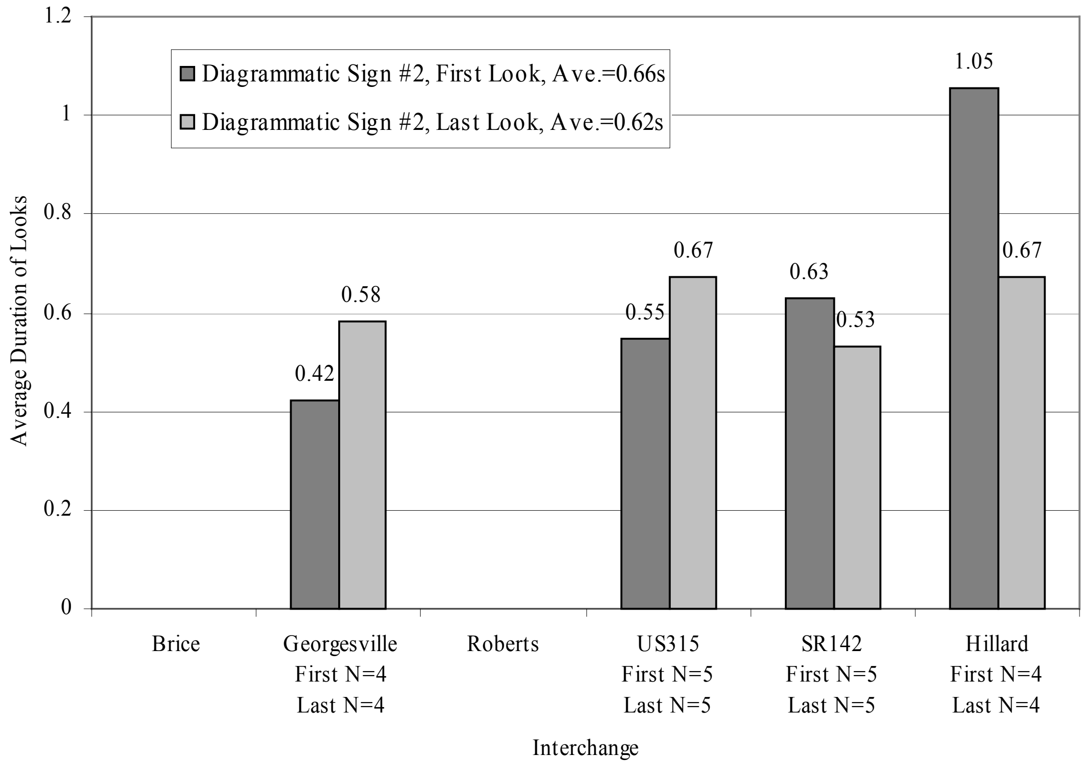


Figure 58. Average Duration of Eye Fixation at the Second Diagrammatic Sign (Where Present) of each Interchange.

The first and last look distances are important dependent variables. With the help of the first look distance, one can determine, approximately where a driver starts to extract visual information provided by a diagrammatic guide sign. The last look distance indicates, approximately where a driver no longer pays attention to the sign. A diagrammatic sign must be designed and placed in such a way as to become completely visible and legible between the first look distance and the last look distance. The box plots shown in Figure 59 and Figure 60 give a graphical representation of the first and last look distances for the experimental interchanges and the overall look behaviors.

Figure 59 shows that the overall median first look to the first diagrammatic sign of the approaches occurs 123m prior to reaching the diagrammatic sign, and that the last look occurs 48m prior to the sign. The overall median first look distance to the second sign in the approaches (Figure 60) is 104m, somewhat shorter than the corresponding distance at the first sign. The second diagrammatic sign of the approach serves, most likely, as a confirmation to the first sign. Thus, less processing is expected and also quantitatively observed (second sign has shorter average fixation durations and lower average number of looks).

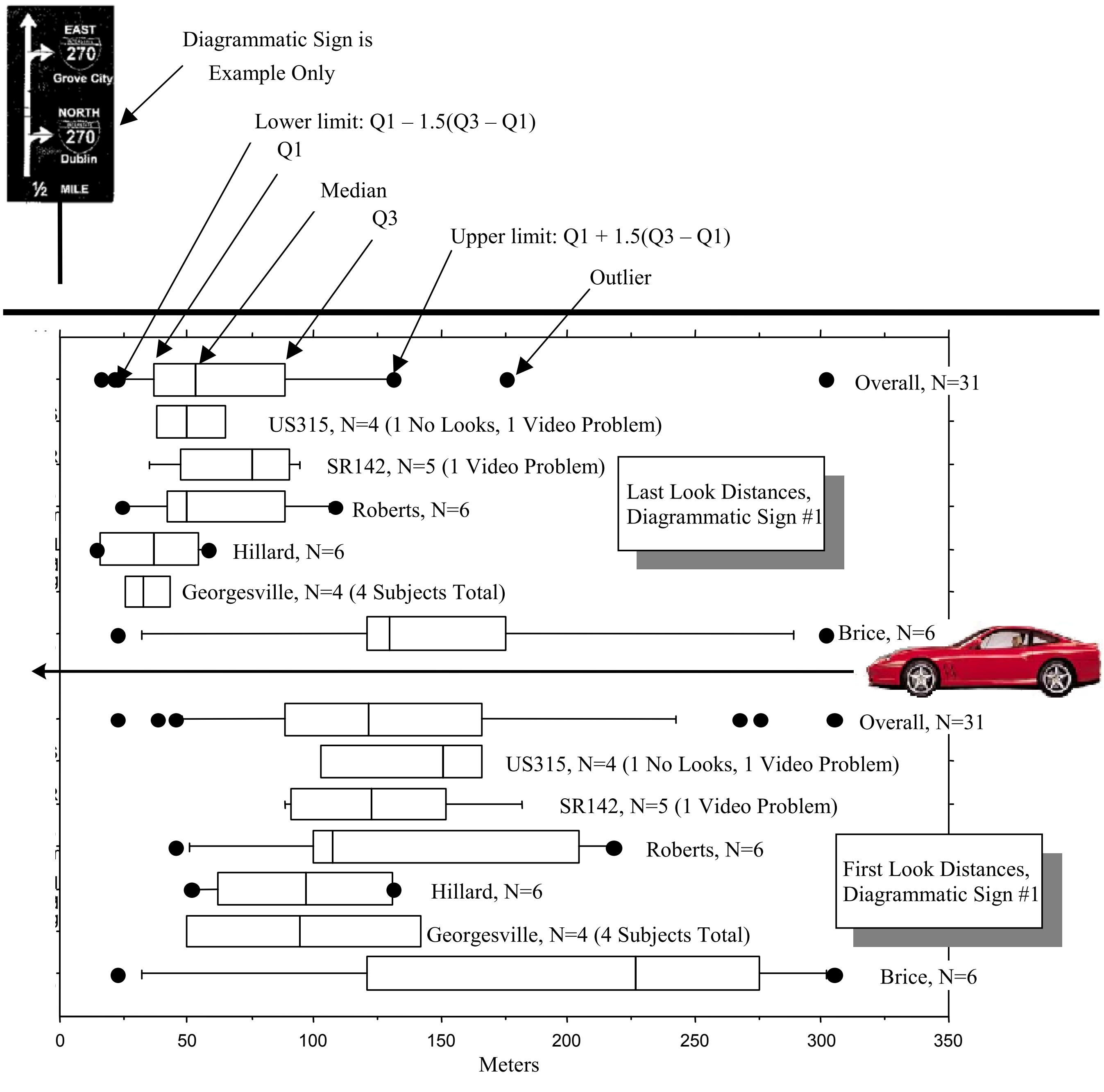


Figure 59. Box Plots of Look (Fixation) Distances, Diagrammatic Sign #1

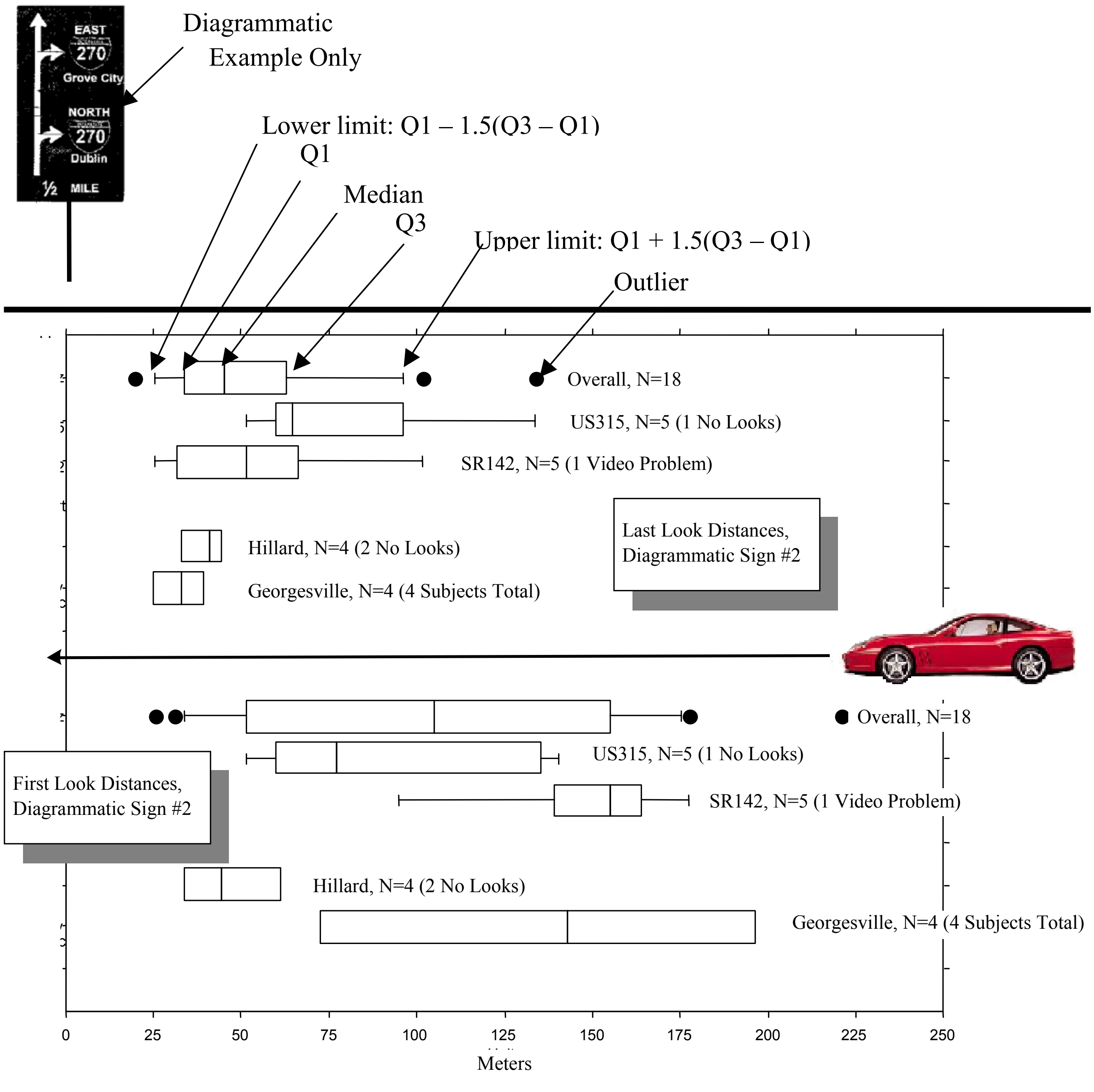


Figure 60. Box Plots of Look (Fixation) Distances, Diagrammatic Sign #2.

8 THEORETICAL LANE CHANGE PROBABILITIES

The main goal of a diagrammatic entrance ramp approach sign is to give unfamiliar drivers adequate advance guidance information to select the proper lane on a multi-lane arterial leading to a freeway entrance. The main purpose of this analysis was to investigate the probabilities of making a successful lane change during the before condition (without diagrammatic signs) and the after condition (with diagrammatic signs). It is evident, that the advance location of the diagrammatic signs, combined with their fairly long legibility distances, will allow unfamiliar drivers to initiate a lane change much earlier than would be possible with preexisting trailblazer assemblies that are located in the interchange area. Assuming very heavy traffic conditions at or near capacity, an unfamiliar driver needs every bit of advance guidance information to make his or her way across the lanes towards the desired freeway entrance. The increased lane change opportunity distance (LCOD) for making a required lane change when diagrammatic signs are used, translates in an increased probability that the lane change can actually be accomplished. Unfamiliar drivers will appreciate this.

8.1 Method

An analytical model was developed, assuming an unfamiliar driver who is approaching a freeway interchange in the wrong lane (similar to the test drivers used in section 5). This situation is depicted in

Figure 61. The unfamiliar driver (vehicle A) is faced with the dilemma of the freeway entrance lane blocked by vehicles moving nearly at the same speed. The unfamiliar driver needs to find an acceptable gap to merge with the stream of blocking vehicles prior to reaching the desired freeway entrance ramp gore. However, the unfamiliar driver in vehicle A cannot initiate the lane change attempt before he or she has read the diagrammatic entrance ramp approach sign. The distance from the point, where the diagrammatic sign is completely legible to the freeway entrance gore is called the Lane Change Opportunity Distance (LCOD). The goal of this analysis is to find the probability that the unfamiliar driver in vehicle A can locate an acceptable gap in the stream of blocking vehicles, prior to reaching the gore. Obviously, this probability will be much higher when guide signs are placed well in advance of the interchange than when only trailblazer assemblies at the interchange are used. The model was based on headway gap and speed data obtained from the Mobilizer PC video observation task (see section 2). Any simple analytic model like the one discussed above requires that the headways between the blocking vehicles in the real world are not serially autocorrelated. That is, the headway of vehicle i needs to be independent of the headway of vehicle i+1, i+2, etc. The independence of successive headway gaps was tested for the data obtained from the Mobilizer PC. A typical plot of the headway generated by vehicle i and the vehicle i+1 is shown in Figure 62. All data obtained from Mobilizer PC at the interchanges where the video cameras were deployed, indicates that successive headways were indeed independent and not serially autocorrelated. Therefore, it was possible to perform the closed form analytical analysis of the lane change probability under the before and after condition without the need for stochastic simulation.

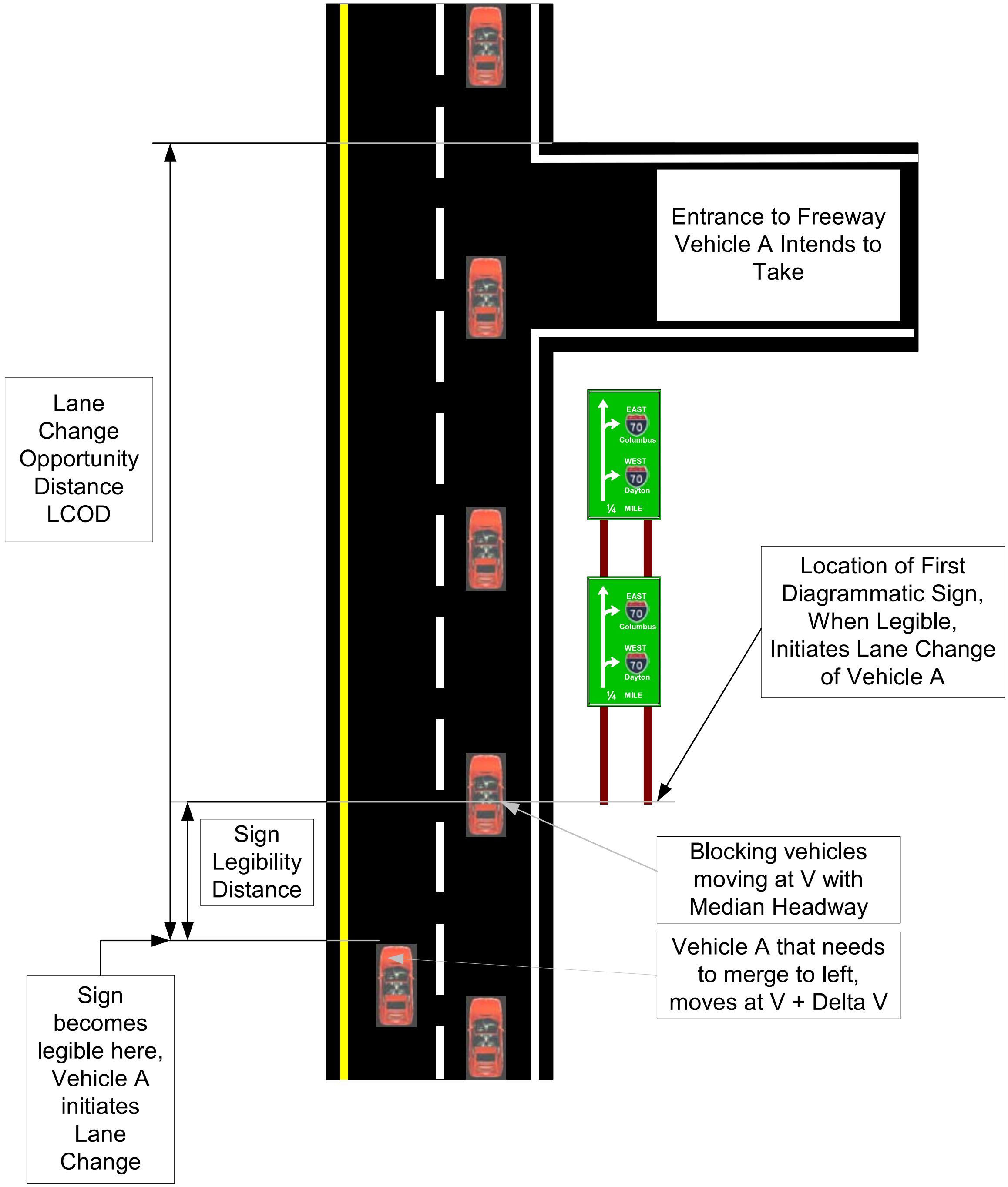


Figure 61. Model Used to Determine the Theoretical Lane Change Probability

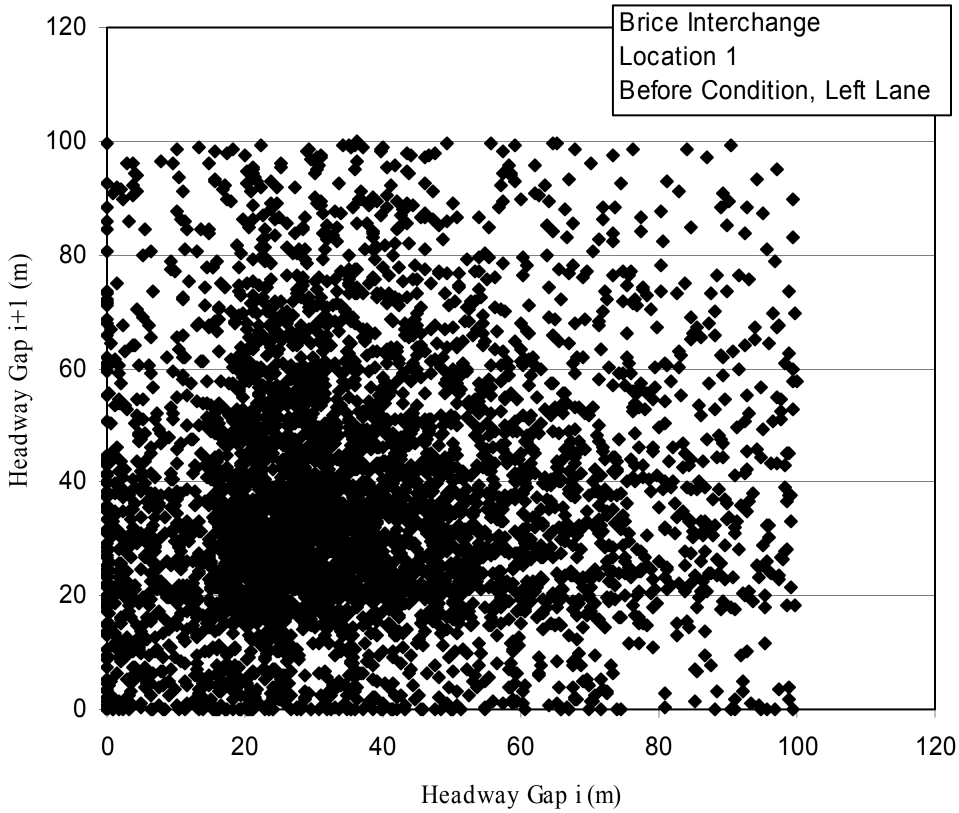


Figure 62. Typical Scatter Plot of Successive Headway Gaps.

The length of the roadway system in the model was based on the lane change opportunity distance (LCOD), the sum of the distance from the gore to the first guide sign of the approach and the legibility distance of the corresponding sign. The roadway model, consisting of two lanes moving in the same direction of travel, was split into two separate groups:

- Goal lane, the lane which merging drivers were attempting to gain access to
- Start lane, the lane where merging drivers began the approach

As previously noted, the headway behavior of the drivers in the goal lane was based on actual observed data from Mobilizer PC. The goal lane consisted of automobiles separated by the median observed headway gap, traveling at the observed median speed. The start lane consisted of a single automobile traveling at a given speed, which was in the range of plus/minus ten MPH of the speed of automobiles in the goal lane. The number of lane change opportunities, the number of gaps in the LCOD, was found by first computing the lane change opportunity time (LCOT), defined as

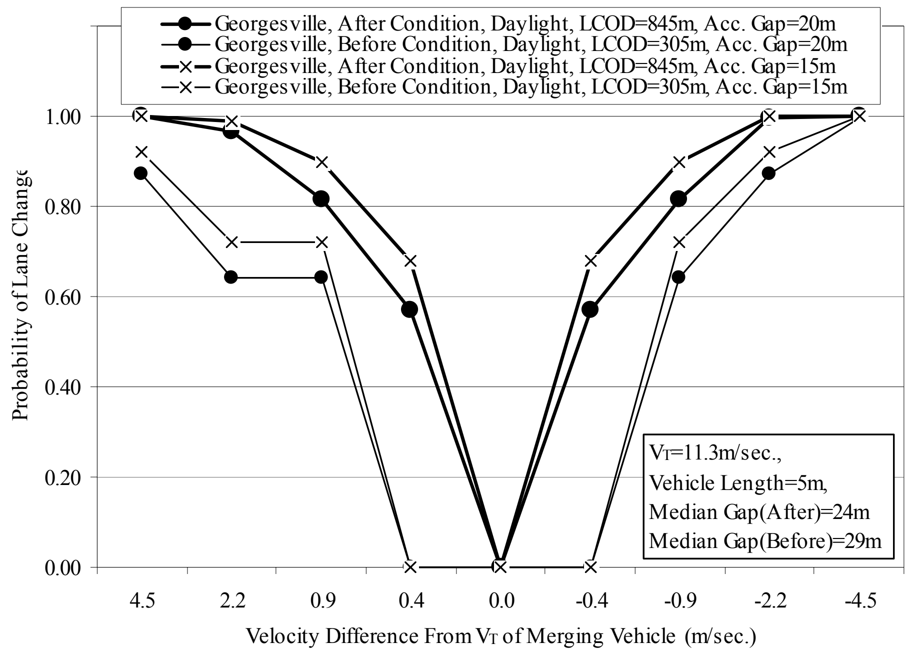
$$LCOT = \frac{LCOD}{V_T + \Delta V}$$

where V_T is defined as the speed of the automobiles in the goal lane and ΔV is defined as the difference in speed of the automobile in the start lane from the automobiles in the goal lane.

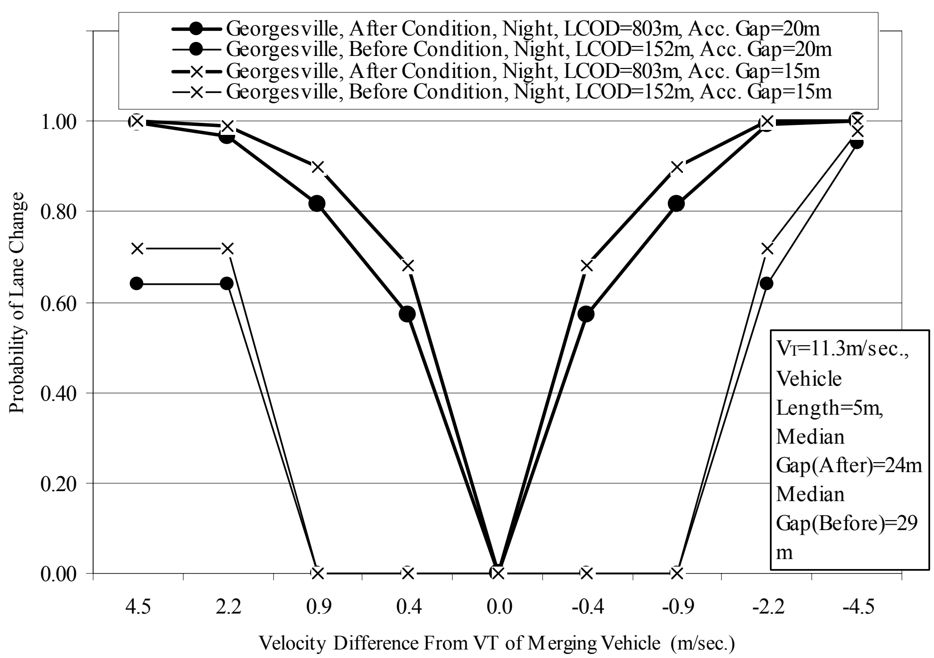
The LCOT represents the time available to the driver in the start lane to complete a merge into the goal lane. LCOT is the time from the instance the diagrammatic sign becomes legible to reaching the entrance ramp gore. The number of lane change opportunities will differ from the number of gaps in the LCOD because the automobiles in both lanes are moving toward the gore at nearly identical speeds. To find the number of lane change opportunities available to the driver in the start lane we must find the Adjusted LCOD (the distance that the automobile in the start lane gains or loses, relative to the adjacent automobiles in the goal lane prior to reaching the gore). Dividing the Adjusted LCOD by the sum of the given car lengths and the median headway gap and truncating, yields the number of lane change opportunities. Further, each individual driver in the merging vehicle has a threshold for an acceptable gap to attempt a merging maneuver. This acceptable gap was defined as a function of car lengths, ranging from one car length to four car lengths. From the headway gap data, obtained from Mobilizer PC, cumulative headway gap distributions were created. For each defined acceptable gap length, the cumulative distributions were used to find the probability that any headway gap in the roadway system will be smaller than this value. This probability raised to the power equals to the number of lane change opportunities yields the total probability that an acceptable gap will not be available to the driver in the start lane. Finally, subtracting this value from one yields the probability that a driver will find an acceptable merging gap based on the drivers speed and threshold of acceptable gaps.

8.2 Results

To compare the probabilities of making a successful lane change during each condition, graphs were created for Brice Road (one diagrammatic sign) and Georgesville Road (two diagrammatic signs). The graphs shown in Figure 63 and Figure 64 illustrate the probabilities associated with the before and after conditions at Georgesville and Brice Road, respectively. In each figure, the speed of the automobiles in the goal lane is $11.3 ms^{-1}$ (25 MPH). The relative speed difference between the vehicles in the goal lane and the merging vehicle is given along the abscissa of the graphs. Looking at both graphs, it is easy to see that the probability of a successful lane change is smallest if the vehicles in the goal lane and the merging vehicle are driving at the same speed (middle of the graphs). The advance location of the diagrammatic signs represents a major benefit in terms of raising the probability that a lane change can be successfully made. This theoretical quantification of a benefit for unfamiliar drivers corroborates very well the findings of the eye movement experiment and the experiment with the unfamiliar test drivers.

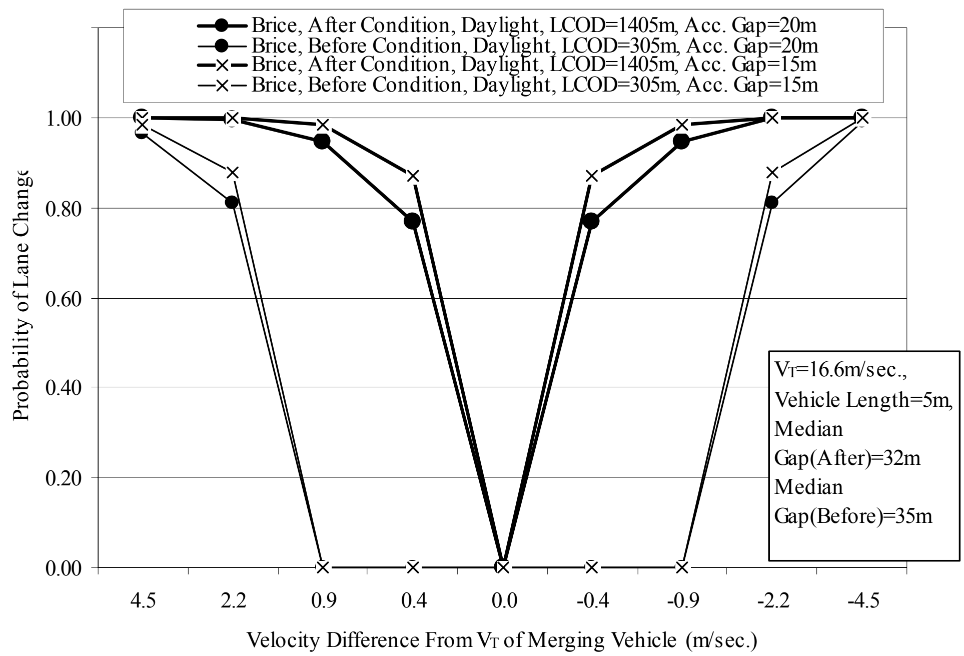


a. Daytime Condition, V_T of Vehicles in Goal Lane $11.3ms^{-1}$ (25 MPH)

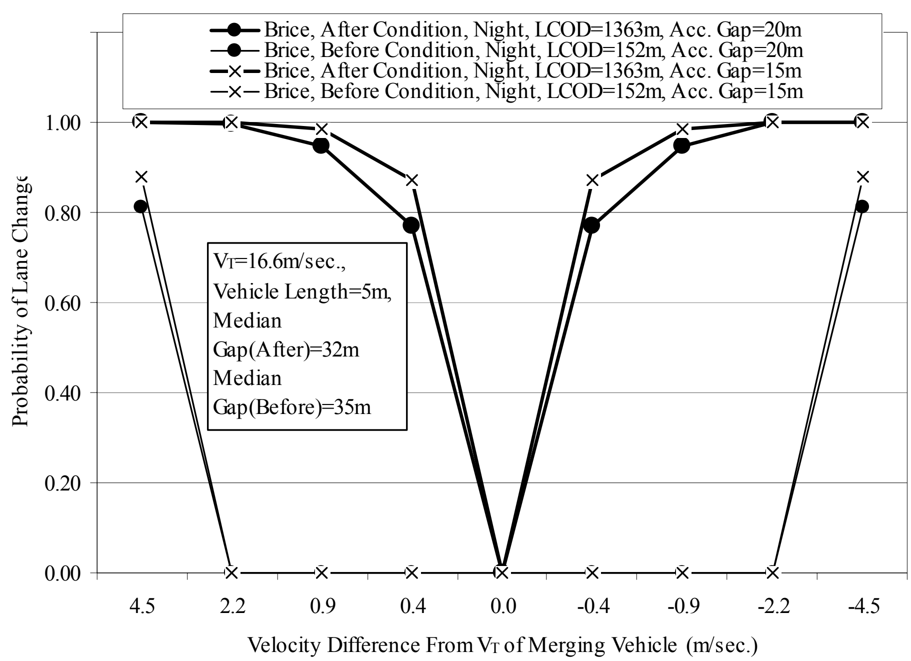


b. Nighttime Condition, V_T of Vehicles in Goal Lane $11.3ms^{-1}$ (25 MPH)

Figure 63. Probability of Making a Successful Lane Change During Before and After Conditions at Georgesville Road.



a. Daytime Condition, V_T of Vehicles in Goal Lane 11.3ms^{-1} (25 MPH)



b. Nighttime Condition, V_T of Vehicles in Goal Lane 11.3ms^{-1} (25 MPH)

Figure 64. Probability of Making a Successful Lane Change During Before and After Conditions at Brice Road.

9 DISCUSSION, CONCLUSIONS, AND APPLICATION GUIDELINES

Ground mounted diagrammatic signs as studied in this research are located on urban multi-lane arterials, well in advance of highway freeway interchanges. These diagrammatic signs provide unfamiliar drivers with more adequate advance navigational information than small trailblazer assemblies located at the interchange. Ground mounted diagrammatic signs should be used in addition to preexisting guide signs where the cost of overhead span type sign bridges cannot be justified and additional guidance to the motorist is desired. The literature review indicated that ground mounted diagrammatic guide signs have been used successfully in Europe for a long time. This research used several measures of effectiveness to determine the merit of similar diagrammatic signs in the US.

Three interchanges (SR 315 interchange with I 270, Georgesville Road interchange with I 270, Brice Road interchange with I 70) were videotaped under the before condition (preexisting guide signing) and under the after condition (preexisting guide signing plus ground mounted diagrammatic signs). The video streams were automatically analyzed using Mobilizer PC. The analysis indicated, that under the after condition (ground mounted diagrammatic signs present), the vehicle speeds were statistically significantly reduced, the vehicle headway gaps were shorter, and the vehicle throughput was statistically significantly higher. These findings suggest that the ground mounted diagrammatic entrance ramp approach signs did not hamper the throughput of automobiles at the experimental interchanges. In fact, an increase in throughput was observed.

A total of 13 ODOT/FHWA Traffic Engineering personnel were recruited to critically evaluate the design, application, and placement of the ground mounted diagrammatic entrance ramp approach signs at the sites used in this study. Overall, the vast majority of the evaluators considered these diagrammatic signs to be very helpful or helpful. Most evaluators felt that two right shoulder mounted diagrammatic signs (½ mile and ¼ mile advance placement) were desirable.

A total of 21 and 19 unfamiliar test drivers were recruited under the before and after condition, respectively, to further evaluate the usefulness of the ground mounted diagrammatic entrance ramp approach signs for unfamiliar drivers. The unfamiliar test drivers approached the interchanges in a vehicle that was equipped with an onboard video camera. At the beginning of each approach, the test drivers were set up in the lane farthest away from the lane that allowed access to the freeway in the desired direction. The dependent variable was the distance from the gore at which the unfamiliar drivers completed the lane change to access the entrance ramp to the freeway. Under the after condition (with ground mounted diagrammatic signs), the unfamiliar drivers were able to initiate the lane changes much earlier than under the before condition. Overall, for the test driver experiment, it can be concluded, that the ground mounted diagrammatic entrance ramp approach signs located in advance of the interchange are an excellent tool to convey lane choice information to unfamiliar motorists approaching a highway-freeway interchange.

Eye movement behavior was recorded for six unfamiliar subjects approaching the interchanges used in this study. The eye movement recordings were performed only under the after condition. The number of eye fixations and the fixation duration to the ground mounted diagrammatic signs were extracted from the eye scanning records. The analysis indicated that the ground mounted diagrammatic signs are noticed by the drivers and that the presence of these diagrammatic signs does not unduly distract them. The first diagrammatic sign in an approach is usually looked at somewhat longer and somewhat more often than the subsequent diagrammatic sign in the approach. This looking behavior is expected, because the second sign, in most cases, serves as confirmation of guidance information that was already conveyed by the first sign.

The theoretical probability that an unfamiliar motorist could complete a required lane change to access a freeway entrance was calculated using a simple closed form analytical model. The advance location of the ground mounted diagrammatic signs, combined with their fairly long legibility distances, will allow unfamiliar drivers to initiate a lane change much earlier than would be possible with preexisting trailblazer assemblies that are located in the interchange area. Assuming very heavy traffic conditions at or near capacity, an unfamiliar driver needs every bit of advance guidance information to make his or her way across the lanes towards the desired freeway entrance. The increased lane change opportunity distance (LCOD) for making a required lane change when ground mounted diagrammatic signs are used translates into an increased probability that the lane change can actually be accomplished. With little surprise, it was found that the advance location of the ground mounted diagrammatic signs represents a major benefit in terms of raising the probability that a lane change can be successfully made. This theoretical quantification of a benefit for unfamiliar drivers corroborates very well the findings of the eye movement experiment and the experiment with the unfamiliar test drivers.

Based on the results presented in this report, the use of ground mounted diagrammatic entrance ramp approach signs is recommended on multi-lane arterials leading up to a freeway interchange. Special consideration should be given where one or more of the following conditions exist:

1. An above average percentage of trucks or other large vehicles prevails. To further reduce the possibility of sign obstruction due to large vehicles, use two staggered (½ mile, ¼ mile) ground mounted diagrammatic signs.
2. An above average percentage of unfamiliar drivers is to be expected.
3. Where the upcoming interchange may be obstructed from direct view during the approach.
4. Where an above average percentage of lane change accidents and/or an above average percentage of accidents due to erratic last minute maneuvers exists.
5. For interchanges with an unconventional and/or confusing entrance ramp layout.

On two-lane crossroads (one lane in each direction), ground mounted diagrammatic entrance ramp approach signs are generally not necessary, but can be used if desired without any expected detrimental effects. The Plain City Georgesville interchange used in this study may serve as an example of such an interchange. Intermediate intersections existed at 4 of the 6 locations. This did not affect results. Signs actually performed in spite of this.

On multi-lane arterials where overhead span type sign bridges are in place, the use of ground mounted diagrammatic entrance ramp approach signs is generally not necessary. The sings on the sign bridge would usually be expected to provide adequate advance information to the motorist regarding entrance ramp configuration, but could be supplemented with ground mounted diagrammatic signs if desired. The Brice Road interchange is an example of an interchange with a sign bridge in place.

Regarding installation location of ground mounted diagrammatic signs, we recommend that two signs be used during a typical length approach. These diagrammatic signs should be located ½ mile and ¼ prior to the last point of the first gore, where a driver can still gain access to the freeway entrance ramp. Both ground mounted diagrammatic signs should be unobstructed and legible from a distance corresponding to a true preview time of 4.95 seconds (preview time of 3.0 seconds plus 2 fixations of 0.65 seconds duration plus 0.65 seconds for a fixation to the road between the sign fixations). At 45 MPH (72 km/h), this would require an unobstructed legibility distance of approximately 100m (328 ft). If possible, the sign should be legible at this distance. Also, if possible, the driver should have an unobstructed view of the ground mounted diagrammatic sign at 125m (median first look distance). However, the ground mounted diagrammatic signs need not be legible at that distance.

In situations where a very high percentage of large vehicles exists, ODOT may consider two ground mounted diagrammatic signs per longitudinal location (½ mile, ¼ mile), with one sign being installed on the right road shoulder and the other sign being installed on the median.

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