EVALUATION OF DIAGRAMMATIC SIGNING AT CAPITAL BELTWAY EXIT NO. 1

by

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SUMMARY

Much research to eliminate driver confusion at high-speed interchanges is being directed toward the application of diagrammatic signing. In this study, one conventional sign on the westbound approach to Exit No. 1 of the Capital Beltway was replaced by a diagrammatic sign to determine the effect of the new sign on driver behavior. Before and after phases of the study evaluated the effects of the sign in terms of erratic maneuvers, which were classified into the following types: weaving (across solid line and gore area), hesitating, stopping/backing and partial weaving. The analysis of each maneuver within designated zones throughout the interchange revealed the numbers of maneuvers at critical points.

The significant findings are as follows:

1. A significant decrease in weaving maneuvers took place over the gore area after installation of the diagrammatic sign, which indicates a safer condition than existed before the sign was installed.

2. A tradeoff is seen in the increased partial weaves and vehicle hesitations accompanied by fewer vehicles stopping or backing after the installation of the sign. Much of the increased maneuvering could be attributed to tourist traffic, yet the total effect of the tradeoff is probably a safer condition.

3. Statistical tests showed more consistent patterns of driver behavior following the sign installation.

4. During the four months the diagrammatic sign has been utilized, no accidents have been reported on the approach, which denotes a considerable reduction in the accident rate.

General conclusions are that diagrammatic signs can be initially confusing to motorists because their use on major routes is still practically nonexistent. However, driver interviews indicated a favorable reaction to this type of signing and future research was encouraged.

This research served as a pilot study for planned statewide tests of disgrammatic signs by the Virginia Highway Research Council. In the future study, an attempt will be made to correlate laboratory findings to the results of field studies.

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INTRODUCTION

Methods to eliminate motorists' confusion at high-speed interchanges are needed on high volume interstate highway sections. The signing of these roads poses particular problems due to the close interchange spacing, the multiplicity of exits, and the large number of intersecting arterials. At present, so much confusion exists at numerous interstate interchanges throughout all states that research is needed to establish criteria for evaluating signing at these locations.

A two-year project undertaken by the Virginia Highway Research Council will examine most major urban interstate interchanges throughout the state. Data will be taken at all interchanges and driver behavior will be examined for the possible determination of the effects of variables such as geometrics and interchange type, as well as signing. This report presents the results of a pilot study of one intersection undertaken to assist in the design of the long-range project.

PURPOSE AND SCOPE

As stated, this experiment served as a guide to determine procedures for the statewide testing program. It developed a classification of erratic maneuvers which can be used to evaluate driver confusion in future studies. Certain diagrammatic signing principles were established which will provide guidelines for the long-range study. The scope of the study was limited to one problem intersection for flow in one direction, due to manpower and time constraints.

METHOD OF APPROACH

The "comparative erratic maneuver" technique consists of observing, recording, and analyzing arbitrarily defined erratic movements to compare driver behavior for various signing schemes. The study area was divided into several zones and data were collected for each zone. A review of accident data covering a $2\frac{1}{2}$-year period prior to the study was used to designate accident prone points within the study area and to help establish the study zones. Thus, one objective of the study became the reduction of erratic maneuvers at the most accident prone points of the interchange.

The variables included in the analysis were erratic maneuvers, type and location of maneuver, traffic volumes, time of day, and a variation in signing. Data were collected by manual recording and by time-lapse photographic equipment. A description of the study procedure is found in a later section of this report.

TABLE 1

ACCIDENTS AT EXIT NO. 1

January 1, 1968 to March 31, 1970	
Total Accidents	240
Persons Killed	4
Persons Injured	136
Property Damage	$184,812

Accident statistics reveal some very interesting facts, but the conclusions regarding causes must be largely subjective. Of primary concern in this study is the large number of side-swipe and rear-end collisions at the first gore area approaching the exit. These accidents appear to be the result of driver confusion caused by a lack of advance notice of the lane drop. Based on this supposition, this report places major emphasis on erratic maneuvers at that location.

Capacity Characteristics

Volume counts taken in 1970 indicate that there are some 81,000 vehicles passing the intersection every day. Unfortunately, ramp volume counts for the exits are not available.

A study was made to examine the existing volume-to-capacity relationships. Using freeway capacity charts, the design capacity of the upstream approach (the Woodrow Wilson Bridge) was determined to be approximately 2,600 vehicles per hour in the westbound direction. The design capacity in this instance was based upon Level of Service A, i.e., a speed of approximately 65 mph and freedom of driver movement. The maximum capacity is reached at a Level of Service E and is approximately 5,000 vehicles per hour. Peak hour volumes exceeding 4,700 vehicles per hour were recorded during the study, which fact explains the speed reduction to around 45 mph during peak periods.

From the above analysis it would appear that much of the problem at Exit No. 1 can be attributed to the high volume-to-capacity ratio. However, it may be noted that only about 20 percent of the accidents occur during peak hours, which fact warrants a study of signing effectiveness with respect to relating the unusual geometric conditions to the motorists' actions.

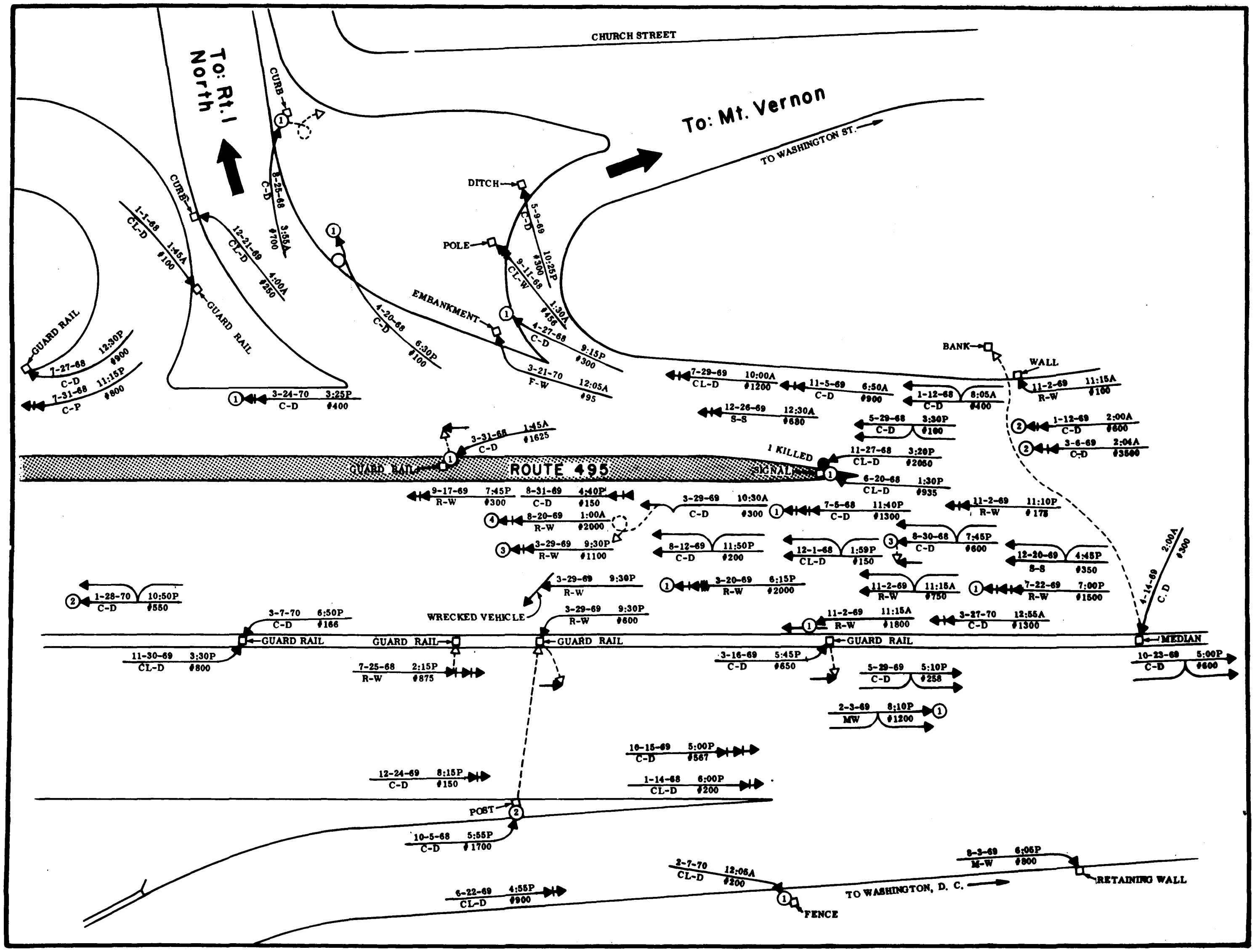

Figure 3. Diagram of accidents occurring at Exit No. 1 westbound during the period January 1, 1968 – March 31, 1970.

PROCEDURE

To determine the effects of diagrammatic signing on driver behavior, the "comparative erratic maneuver" method of analysis was used. The study area was divided into zones as indicated in Figure 4, and erratic vehicle movements were recorded for each zone. A time-lapse camera was focused on Zone III, since this was thought to be the most critical zone due to the short weaving section located within it. Data for Zones I and II were collected manually by observers stationed on the Washington Street Bridge in the positions shown in Figure 4. The designation of erratic maneuvers used in this study was as follows:

Type I — Weaves (as designated in Figure 4)

Type IA — Weaves (over gore areas)

Type II — Hesitations (slow to approximately 15 mph)

Type III — Stopping and/or backing

Type IV — Partial weaves

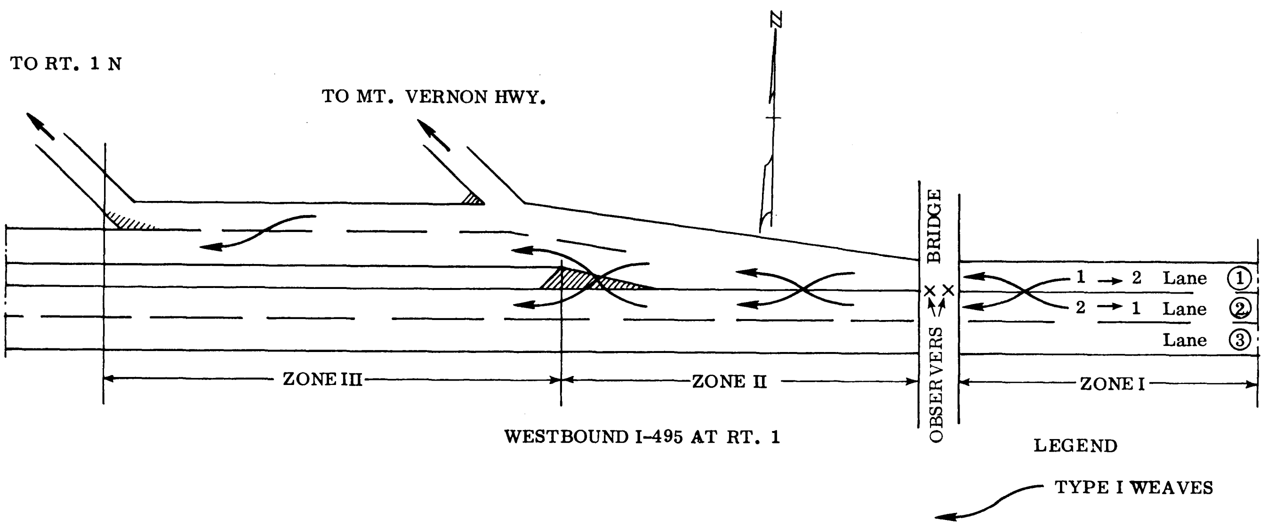

Figure 4. Exit No. 1, zone and weave designations.

Volume and erratic maneuver data were recorded at random times throughout the day for half-hour intervals. Observations started as early as 7:00 a.m. and as late as 4:00 p.m. Data were collected during the late fall and early spring to evaluate the before traffic characteristics. On March 29, 1971, the conventional sign on the approach to Exit No. 1 was replaced by a diagrammatic sign. Observations were then undertaken to evaluate the traffic characteristics resulting from the change in signing. Figure 5 depicts both the conventional signing of the before phase and the new diagrammatic sign of the after phase.

The diagrammatic sign is similar to standards recommended by Serendipity, Inc., and utilizes 20" route name lettering and 36" shields to comply with AASHO standards for interstate signing. The 14' - 0" by 19' - 6" size is the maximum allowable on the existing overhead structure.

The variables measured directly were erratic maneuvers, traffic volume, and the time of day. Due to a manpower shortage and high traffic volumes, it was impossible to record all license plate designations or otherwise to directly measure the effect of seasonal traffic variations. The effect of seasonal traffic was evidenced by an overall increase in both volume, as shown in Figure 6, and total weaves. However its significance as a variable can be considered nonexistent based on findings of the statistical tests, which are described in a following section.

ANALYSIS

The analysis was based on observations of traffic at Exit No. 1 during a period of 19 days. In this period, 56,326 vehicles were observed during 47 half-hour intervals before installation of the new sign, and 91,423 vehicles were observed during 73 half-hour intervals following the installation. An average of 9.03% of all vehicles passing the interchange made erratic maneuvers, thereby affording an adequate sample size for analyzing behavioral patterns of motorists.

The traffic characteristics of the before and after conditions were compared in terms of different patterns of erratic maneuvers. The erratic maneuvers observed as statistically comparable variables are shown in Table 2. The variable, the observed mean for the before and after condition, the statistical tests, and their significance are all related in this table.

Inspection of Table 2 leads to the conclusion that although the tourist traffic did not significantly increase the mean traffic volume, it did increase the total weave-to-volume ratio. However, Table 2 shows that fewer motorists (per unit volume) did weave across the gore. This, in itself, attests to the fact that a safer condition existed at the interchange following installation of the new sign despite the influx of tourist traffic. The increased seasonal traffic was due to the spring tourist attraction in the Washington, D. C. area. It should be emphasized that a significant reduction of erratic movements in the gore area indicates a reduction of driver confusion in this critical area.

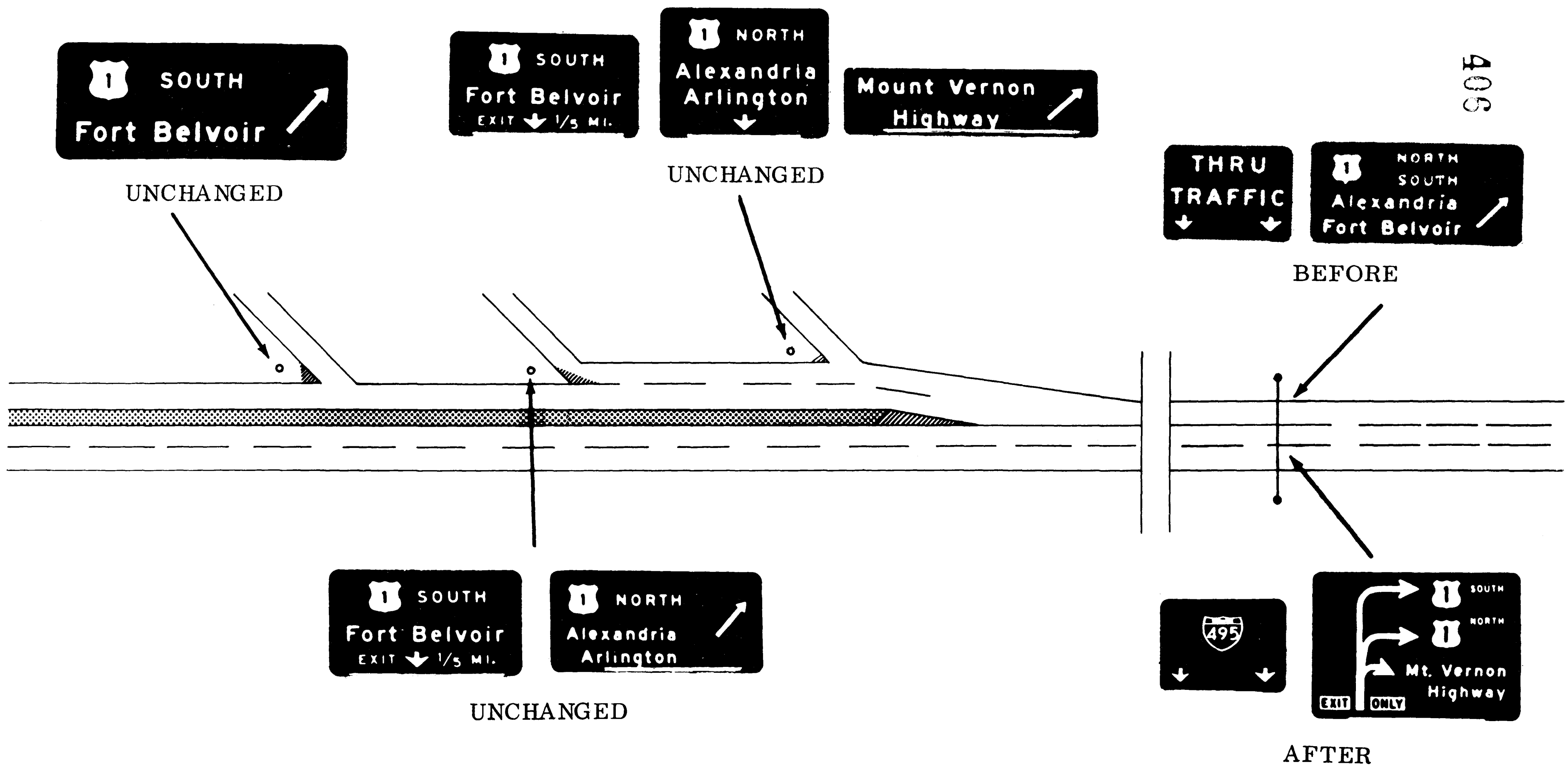

Figure 5. I-495 W at Exit No. 1, signing for before and after conditions.

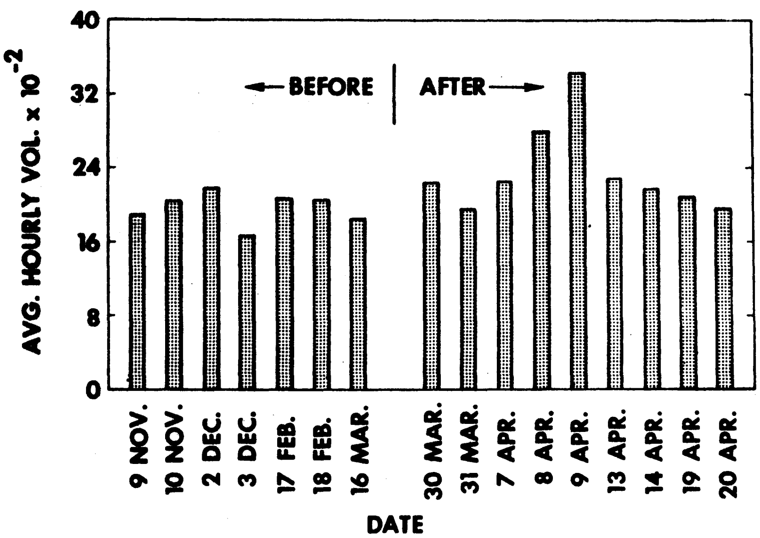

Figure 6. Observed seasonal trend.

A regression analysis of weave-to-volume ratio versus volumes further illustrated the change in traffic behavior between the before and after conditions. Figure 7 depicts computer printouts of the regression analyses, showing both the points and a linear fit. Although the coefficients of correlation are relatively low (approximately 0.75) the analysis is not without meaning.

A comparison of gore-weave/volume ratios-to-volume plots shown in Figure 8 for the before and after conditions indicates that a safer condition existed when the traffic volume was under 3,400 vehicles per hour. The average observed non-rush hour volumes for seasonal and off-seasonal conditions, also shown in the figure, indicate that the safer conditions existed most of the time.

It is highly doubtful that the upper volume range actually does exhibit a higher percentage of gore weaves as the figure would imply. The after line in the figure is deceptively high due to increased weaving of tourist traffic and the fact that the majority of data points reflect the low volume condition. Furthermore, observations of high volume (rush hour) conditions made during both this study (see Table 3) and prior research on the Beltway show weave-to-volume ratios to be much lower during these times.

The effect of the sign change on weaving by zone may also be seen in Table 2. The weaving in each zone is expressed both as a fraction of the total volume and as a percentage of the total weaves. Although the overall percentage of vehicles weaving was higher due to the tourist traffic, a slight decrease in the percentage of weaves in Zone I indicates that the new sign offered the needed advance warning for the interchange. The total weave-to-volume ratio showed an increase of 1.62% for the entire interchange during the after study period, yet the Zone I weave-to-total weave ratio decreased by .38%, indicating that many motorists did weave before entering the study area. Increased erratic maneuvers in Zones II and III were generally consistent with the increase in volumes due to the increase in tourist traffic.

TABLE 2

STATISTICAL COMPARISON OF APPROPRIATE VARIABLES

Variable	Non-Rush Hour	All Traffic	Mean		Significance Test		Population Change
			Before	After	t	F	
Volume (veh/1/2 hour)		x	1,198.38	1,298.87	1.06	1.13	not significant
Total Weaves/Volume x 10^2		x	8.22	9.84	3.08*	1.36	higher
Total Weaves/Volume x 10^2	x		9.90	7.52	2.17*	2.20*	lower, less variable
Gore Weaves/Volume x 10^3		x	8.16	6.92	1.63	2.56	not significant
Gore Weaves/Volume x 10^3	x		9.82	6.55	4.53*	2.43*	lower, less variable
Gore Weaves/Total Weaves x 10^2		x	10.03	6.77	4.84*	2.29*	lower, less variable
Gore/Weaves/Total Weaves x 10^2	x		9.85	7.08	3.73*	2.47*	lower, less variable
Zone I Weaves/Volume x 10^2		x	59.01	67.63	1.91	1.55	not significant
Zone II Weaves/Volume x 10^2		x	9.48	12.92	4.48*	1.04	higher
Zone III Weaves/Volume x 10^2		x	15.14	18.17	2.38*	1.30	higher
Zone I Weaves/Total Weaves x 10^2		x	69.53	68.79	0.36	2.44*	less variable
Zone II Weaves/Total Weaves x 10^2		x	12.52	13.58	2.05*	1.63	higher
Zone III Weaves/Total Weaves x 10^2		x	17.93	17.61	0.18	1.25	not significant
Total 1 — 2 Weaves/Volume x 10^2		x	30.37	40.33	3.34*	1.87	higher
Total 1 — 2 Weaves/Total Weaves x 10^2		x	35.00	37.15	1.16	1.89*	not significant

*Significant value. $\alpha = 0.05$

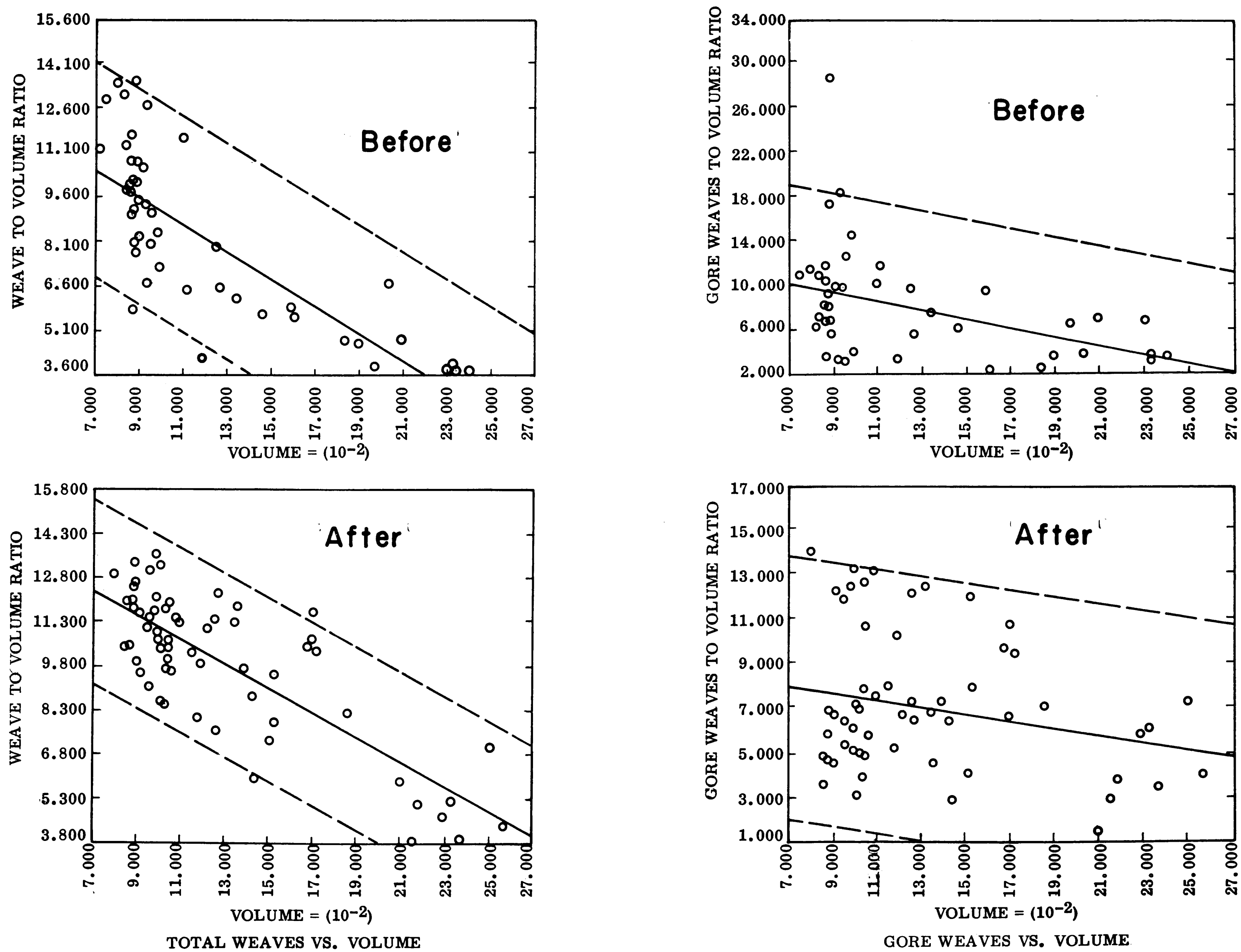

Figure 7. Regression analyses results.

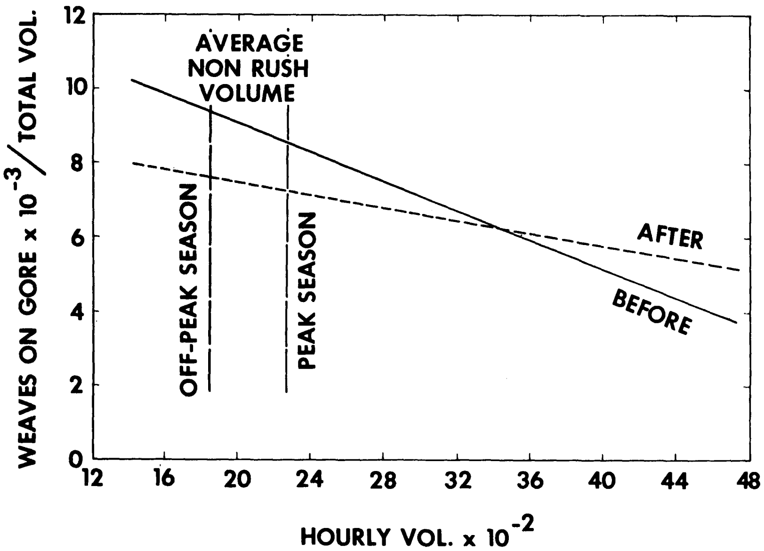

Figure 8. Weaves over gore area as a function of volume.

TABLE 3

GORE WEAVES/VOLUME FOR RUSH PERIODS

Before		After	
AM	PM	AM	PM
3.37 3.70 3.45 2.74	6.61 6.95 6.71	2.79 1.43 3.66 3.38 3.89	5.68 7.19 6.02
Avg. = 5.08		Avg. = 4.66	

The total number of vehicles weaving across the solid line pavement marking into the mainstream of traffic increased significantly during the after period. This maneuver, designated as a "1 — 2 Weave", increased about 33% per unit traffic volume, yet increased only 2.15% with the total observed erratic maneuvers. This further indicates that tourists benefited from the advance warning provided by the new sign, and that a relatively high percentage of non-exiting tourist traffic did weave in advance of the interchange. Inference is thereby made that were the new sign not in place, many tourists would not have weaved until reaching the gore area, thereby creating an additional hazard.

Table 4 summarizes erratic maneuvers by type and by zone. For the purpose of the analysis by type, the weaves over the gore area were included with the Type I weaves. The earlier separate treatment of gore weaves showed a significant reduction in the after study.

TABLE 4

ERRATIC MANEUVERS BY TYPE AND ZONE

	Number Observed		Avg. per Vehicle x 10 - 3		
	Before	After	Before	After	Percent Change
Total Type I	3,898	7,511	69.21	82.16	+ 18.7
Type I in Zone I	2,881	5,741	51.15	62.79	+ 22.8
Type I in Zone II	476	1,038	8.45	11.35	+ 34.3
Type I in Zone III	541	732	9.61	8.01	- 16.6
Total Type II	13	62	.23	.68	+195.7
Type II in Zone II	10	48	.18	.53	+194.4
Type II in Zone III	3	14	.05	.15	+200.0
Total Type III	45	57	.80	.62	- 22.5
Type III in Zone II	24	28	.43	.31	- 27.9
Type III in Zone III	21	29	.37	.32	- 13.5
Total Type IV	187	715	3.32	7.82	+135.5
Type IV in Zone II	9	20	.16	.22	+ 37.5
Type IV in Zone III	178	695	3.16	7.60	+190.5
Total	4,143	8,345	71.55	91.28	+ 27.6
Total Volume	56,324	91,423			

Explanation of Type: Type I — Weaving
Type II — Hesitating
Type III — Stopping/backing
Type IV — Partial Weaving

The total erratic maneuver average per vehicle showed an increase of over 27% in the after phase, due largely to increased weaving by tourists. A substantial increase was seen in the number of vehicles which slowed down in Zones II and III and which made partial weaves in Zone III; however, a favorable tradeoff is evidenced by a 22.5% reduction in the number of vehicles that stopped or backed. It is also noteworthy that Type I weaving was reduced by 16.6% in the critical Zone III.

The increased hesitations and partial weaving may be attributed in part to initial driver confusion upon seeing the unfamiliar diagrammatic sign. Despite the higher percentage of erratic maneuvers in the after phase, the tradeoff between types of behavior would probably be indicative of a safer condition. The stopping/backing erratic maneuver that was reduced can be seen to be more dangerous than the partial weaving and hesitating types, which were increased. The driver has more control over his vehicle during the weaving and hesitating than during the stopping/backing maneuvers. However, since the magnitude of increased erratic maneuvers exceeded that of the reduced, a conclusion that the tradeoff yielded a safer condition would be somewhat speculative.

To isolate the effect of seasonal traffic, a partial analysis was made of data collected during the month of March. Included in this limited sample were observations made during the two days of data collection prior to installation of the sign and during the two-day period immediately following installation. Table 5 shows the results of the analysis, which denote the immediate reduction of weaves over the gore area.

TABLE 5

RESULTS OF ANALYSIS OF MARCH DATA

		Mean		Significance
		Before	After	by
Avg. Volume (Veh. per 1/2 hr.)	all traffic	1,198.38	1,257.42	–
Total Weaves/Volume $\times 10^2$	all traffic	8.94	8.71	–
Gore Weaves/Volume $\times 10^3$	all traffic	10.70	4.97	t, F
Gore Weaves/Volume $\times 10^3$	non rush	12.60	5.60	t, F
Gore Weaves/Total Weaves $\times 10^2$	all traffic	11.66	6.11	t
Gore Weaves/Total Weaves $\times 10^2$	non rush	12.03	5.66	t

Unlike the results for the entire study period, those here show a slight reduction in the total weave-to-volume ratio. This reduction follows by virtue of the nulled seasonal effect of increased tourists weaving combined with the confusion-reducing effect of the sign. Significant reductions in gore weaves compared both to volume and to total weaves are verified by statistical tests. The F-test used in analyzing the gore-weave/volume ratios indicates that driver behavior was less variable following the sign installation. The reduction of gore weaves is seen to be most significant during the non-rush periods of traffic. This is consistent with the fact that driver habits during peak hour conditions at urban interchanges are less dependent upon signs. More drivers are familiar with the interchange since many of them are daily commuters.

To further aid in determining the effect of the diagrammatic sign, driver opinions were sampled. Due to a manpower shortage continuous driver interviews throughout the study were not possible. However, driver attitudes were sampled at random intervals by interviewing confused motorists who had stopped on the shoulder or who asked for directions at a nearby filling station. In most cases, lost motorists were looking for Beltway exits other than Exit No. 1. Prior trip planning and better use of road maps would have eliminated most of the reported driver confusion problems. Motorists were shown pictures of the diagrammatic sign, and their general response indicated that the sign, although initially confusing, contained much helpful information. The only conclusion drawn from the driver interviews was that much of the current driver confusion at Exit No. 1 is due to poor orientation to the area.

A valid comparison of accident data between the before and after conditions is not possible since insufficient time has elapsed since erection of the diagrammatic sign to develop an after period accident history. However, it is noteworthy that prior accident data revealed an accident rate of about 10 per month at Exit No. 1, and for the four months following installation of the diagrammatic sign there have been no reported accidents.

An overview of the analysis shows an attempt to contrast motorist behavioral patterns between the before and after conditions in terms of erratic maneuvers. A statistical analysis of erratic maneuvers as a function of total volume has revealed a higher percentage of weaves following installation of the diagrammatic sign. However, the increased weave-to-volume ratios can be attributed primarily to seasonal traffic differences as evidenced in the analysis of the March data.

Summary of Data Analysis

The findings of this study may be summarized as follows:

1. There was a significant reduction of weaves over the gore area from 8.16 to 6.92 weaves per thousand vehicles passing the interchange after installation of the sign.

2. Zone I and Zone III weaves relative to total weaves decreased .74% and .32% respectively; while Zone II weaves as a percentage of total weaves increased 1.06%.

3. There was a distinct tradeoff between increased hesitations and partial weaves (+196% and +135% respectively) coupled with decreased stopping/backing movements (-22%) after installation of the diagrammatic sign.

4. Significant values of the statistical F-test have indicated more consistent patterns of behavior following installation at the new sign.

5. Informal driver interviews revealed that much of the problem at Exit No. 1 stems from poor orientation to the area.

6. Insufficient time has elapsed since erection of the sign for a valid comparison based on accident data as the before study encompassed a 27-month period. However, there appears to be a significant reduction in accidents in the four months of sign usage as none have been reported.

CONCLUSIONS

The combined effects of general motorists' acceptance evidenced through improved advance warning and of motorist's initial confusion due to lack of familiarity with diagrammatic signing were reflected in this study. An influx of seasonal traffic due to spring tourist attractions in the Washington, D. C. area was also partially responsible for an increased percentage of erratic maneuvers following installation of the sign. Nevertheless, significant results could be seen through comparison of the before and after studies in terms of erratic driver behavior.

Specific conclusions which may be derived from this study are as follows:

1. A significant reduction of weaves over the gore area indicates a safer interchange resulting from improved advance warning provided by the diagrammatic sign.

2. A higher reduction of Zone I maneuvers relative to total maneuvers implies that much traffic did weave before entering the study area. A similar reduction of Zone III weaves indicates that drivers did benefit from the geometric information provided by the sign.

3. The effect of type of maneuver after sign installation is seen by a trade-off between increased hesitations and partial weaves coupled with decreased stopping and backing movements. This result is indicative of a safer interchange since hesitations and partial weaves are less dangerous than stopping and backing.

4. Significant values of the statistical F-test showed the patterns of behavior to be more consistent following the installation of the new sign.

5. Informal driver interviews indicated that much of the problem at Exit No. 1 stems from poor orientation to the area, yet motorists felt that diagrammatic signs convey muchly needed information and further research was encouraged.

6. Insufficient time has elapsed since erection of the sign for a valid comparison based on accident data; however, there appears to be a significant reduction in accident rate as there have been no accidents reported in four months of sign usage.

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