EVALUATION OF DIAGRAMMATIC SIGNING AT CAPITAL BELTWAY EXIT 1

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A conventional sign on the westbound approach to exit 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. After the diagrammatic sign was installed, weaving maneuvers in the gore area decreased; partial weaves increased, but vehicle hesitations and stopping or backing were fewer; and accidents were reduced 35 percent during 11 months.

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

A 2-year project undertaken by the Virginia Highway Research Council will examine some major urban Interstate highway 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, interchange type, and 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

This experiment was undertaken to analyze the effect on motorists of a single diagrammatic sign and to determine procedures for a statewide testing program. Erratic maneuvers were classified for use in evaluating driver confusion in future studies. Certain diagrammatic signing principles were established that will provide guidelines for the long-range study. Because of manpower and time constraints, the scope of the study was limited to one problem interchange for flow in one direction.

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 examination 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 the paper.

Sponsored by Committee on Motorist Information Systems.

The analysis describes the effect of diagrammatic signing on erratic-driver movements at critical points in the interchange. From this analysis and related study, generalizations may be drawn to establish criteria for relatively confusion-free signing for high-speed interchanges.

STUDY LOCATION

Observation at exit 1 of the Capital Beltway just south of Alexandria, Virginia, has shown it to be a problem interchange that can be analyzed in terms of numerous parameters. Studies of the interchange by both the author and members of the Virginia Department of Highways have described the problem in terms of geometrics, speed data, accident data, and capacity characteristics.

Geometrics

Figure 1 shows a schematic of exit 1 as approached by westbound traffic. Unusual geometrics are characterized by the fact that the driver is confronted by a lane drop and then by 3 exit ramps leading from a collector-distributor road. The sight distance to the approach is severely limited by a bridge abutment, as shown in Figure 2.

Speed Data

Based on the results of a speed study conducted by the Traffic and Safety Division of the Virginia Department of Highways, the 85th percentile speed on the approach during the morning and evening peak hours is about 45 mph. This relatively low speed is due to the heavy traffic volume and weaving conditions that exist at those times. During off-peak hours, the 85th percentile speed increases to around 65 mph.

The Traffic and Safety Division examined warrants to explore the possibility of changing speed limits. It was concluded that no applicable warrant exited and that new speed limits would be difficult to enforce and would have a questionable effect on the accident rate.

Accident Data

During the period from January 1, 1968, through March 31, 1970, there were 240 accidents in which 4 persons were killed and 136 injured; measurable property damage was more than $184,000. Figure 3 shows a collision diagram for the vicinity of the first gore, in which there were 38 accidents, 1 fatality, 25 injuries, and property damage amounting to approximately $28,000.

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 sideswipe 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 paper 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 relations. Freeway capacity charts were used to determined that the design capacity of the upstream approach (the Woodrow Wilson Bridge) was approximately 2,600 vehicles/hour in the westbound direction. The design capacity in this instance was based on level of service A, i.e., a speed of approximately 65 mph and freedom of driver movement. The maximum capacity is reached at level of service E and is approximately 5,000 vehicles/hour. Peak-hour volumes exceeding 4,700 vehicles/hour were recorded during the study, and that fact explains the speed reduction to around 45 mph during peak periods.

Figure 1. Capital Beltway westbound at exit 1 just south of Alexandria.

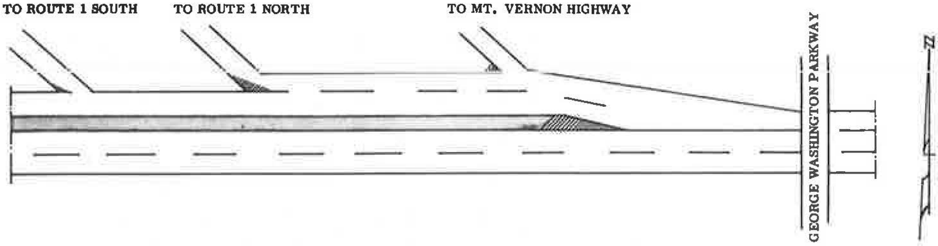
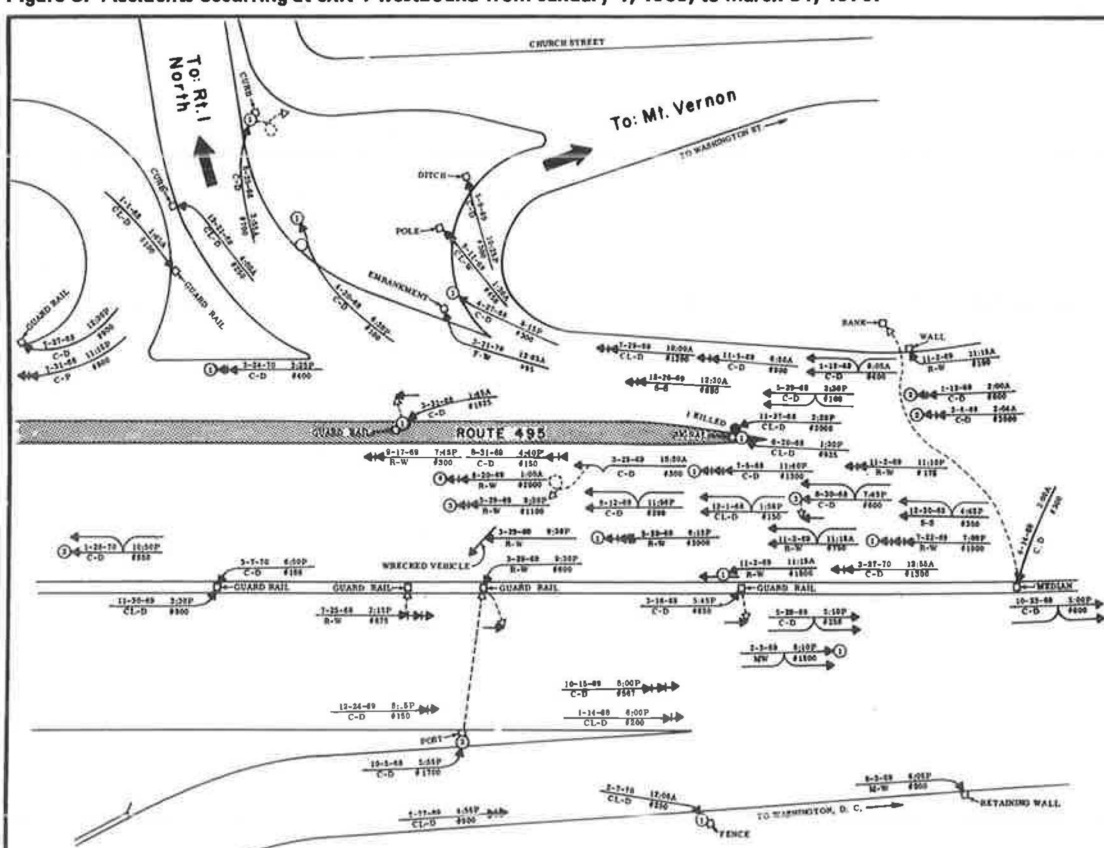


Figure 2. Limited sight distance on the approach to exit 1.

Figure 3. Accidents occurring at exit 1 westbound from January 1, 1968, to March 31, 1970.



From the analysis given above, it would appear that much of the problem at exit 1 can be attributed to the high volume-to-capacity ratio. However, 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.

PROCEDURE

The effects of diagrammatic signing on driver behavior were determined by the use of the "comparative erratic maneuver" method of analysis. The study area was divided into zones as shown in Figure 4, and erratic vehicle movements were recorded for each zone. A time-lapse camera was focused on zone 3, for this was thought to be the most critical zone because of the short weaving section located within it. Data for zones 1 and 2 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:

Maneuver	Type
Weaves (as shown in Fig. 4)	1
Weaves (over gore areas)	1a
Hesitations (slow to approximately 15 mph)	2
Stopping or backing or both	3
Partial weaves	4

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 ended as late as 5:00 p.m. Data for the "before" traffic characteristics were collected during the late fall and early spring. On March 29, 1971, the conventional sign on the approach to exit 1 was replaced by a diagrammatic sign. Observations were then undertaken to evaluate the traffic characteristics resulting from the change in signing. Figure 5 shows both the conventional sign and the new diagrammatic sign.

The standard for the diagrammatic sign is similar to those recommended by Serendipity, Inc. (1), and utilizes 20-in. route-name lettering and 36-in. shields to comply with AASHO standards for Interstate highway signing. The 14- by 19½-ft size is the maximum allowable on the existing overhead structure.

The variables measured directly were erratic maneuvers, traffic volume, and time of day. Because of 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 both in volume, as shown in Figure 6, and in 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 1 during a period of 19 days. In this period, 56,326 vehicles were observed during 47 half-hour intervals before the installation of the new sign, and 91,423 vehicles were observed during 73 half-hour intervals after the installation. An average of 9.03 percent of all vehicles passing the interchange made erratic maneuvers, thereby affording an adequate sample size for analyzing the behavioral patterns of motorists.

The traffic characteristics of the before and the after conditions were compared in terms of different patterns of erratic maneuvers. The erratic maneuvers observed as statistically comparable variables are given in Table 1. The relation of the variable, the observed mean for the before and the after conditions, the statistical tests, and their significance are given in this table.

Data given in Table 1 lead to the conclusion that, although the tourist traffic did not significantly increase the mean traffic volume, it did increase the total weave-to-volume

Figure 4. Exit 1 zone and weave designations.

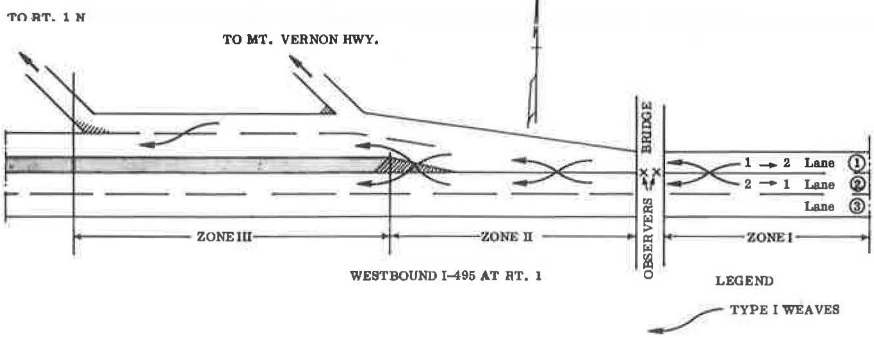


Figure 5. Conventional and diagrammatic signs at exit 1.

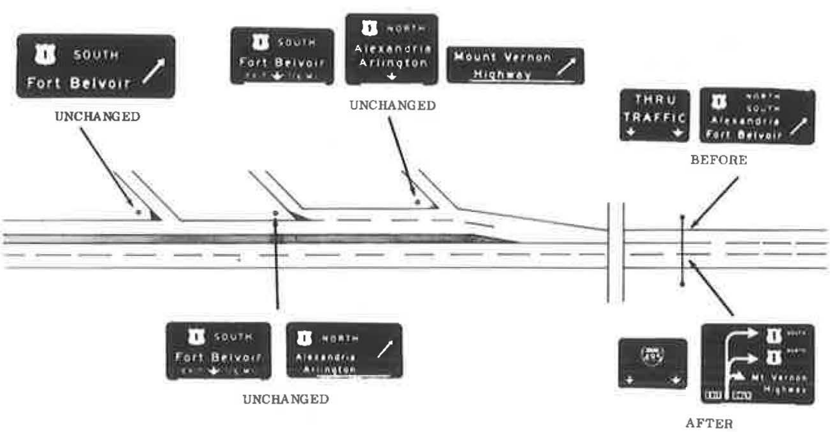


Figure 6. Seasonal traffic trend.

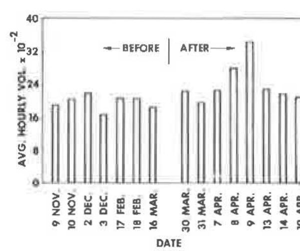


Table 1. Statistical comparison of variables—study period data.

Variable	Mean		Significance Test		Population Change
	Before	After	t	F	
Volume, vehicles/½ hour	1,198.38	1,298.87	1.06	1.13	Not significant
Weaves/volume, × 10^2					
Total, all traffic	8.22	9.84	3.08[a]	1.36	Higher
Total, rush-hour traffic	9.90	7.52	2.17[a]	2.20[a]	Lower, less variable
Gore, all traffic	81.60	69.20	1.63	2.56	Not significant
Gore, rush-hour traffic	98.20	65.50	4.53[a]	2.43[a]	Lower, less variable
Zone 1, all traffic	59.01	67.63	1.91	1.55	Not significant
Zone 2, all traffic	9.48	12.92	4.46[a]	1.04	Higher
Zone 3, all traffic	15.14	18.17	2.38[a]	1.30	Higher
1-2, all traffic	30.37	40.33	3.34[a]	1.87	Higher
Weaves/total weaves, × 10^2					
Gore, all traffic	10.03	6.77	4.84[a]	2.29[a]	Lower, less variable
Gore, rush-hour traffic	9.85	7.08	3.73[a]	2.47[a]	Lower, less variable
Zone 1, all traffic	69.53	68.79	0.36	2.44[a]	Less variable
Zone 2, all traffic	12.52	13.58	2.05[a]	1.63	Higher
Zone 3, all traffic	17.93	17.61	0.18	1.25	Not significant
1-2, all traffic	35.00	37.15	1.16	1.89	Not significant

[a]Significant value. $\alpha = 0.05$.

ratio. However, the data show 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 after the new sign was installed despite the influx of tourist traffic. The increased seasonal traffic was due to the spring tourist attractions 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.

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

A comparison of gore weave-to-volume ratios and volume regression analysis plots shown in Figure 8 for the before and the 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 data shown in the figure would imply. The line for the after condition is deceptively high because of increased weaving of tourist traffic and the fact that most of the data points reflect the low-volume condition. Furthermore, observations of high-volume (rush-hour) conditions during this study and prior research on the Beltway by Shepard (2) show weave-to-volume ratios to be much lower during these times. The gore weave-to-volume ratios during rush periods for this study were as follows:

Time	Before	After
a. m.	3.37	2.79
	3.70	1.43
	3.45	3.66
	2.74	3.38
p. m.	6.61	5.68
	6.95	7.19
	6.71	6.02
Avg	5.08	4.66

The effect of the sign change on weaving by zone is also given in Table 1. 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 because of the tourist traffic, a slight decrease in the percentage of weaves in zone 1 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 percent for the entire interchange during the after study period, yet the zone 1 weave-to-total weave ratio decreased by 0.38 percent indicating that many motorists did weave before entering the study area. Increased erratic maneuvers in zones 2 and 3 were generally consistent with the increase in volumes due to the increase in tourist traffic.

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 percent per unit traffic volume yet increased only 2.15 percent 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 nonexiting 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 2 gives a summary of 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 1 weaves. The earlier separate treatment of gore weaves showed a significant reduction in the after study.

Figure 7. Regression analyses results.

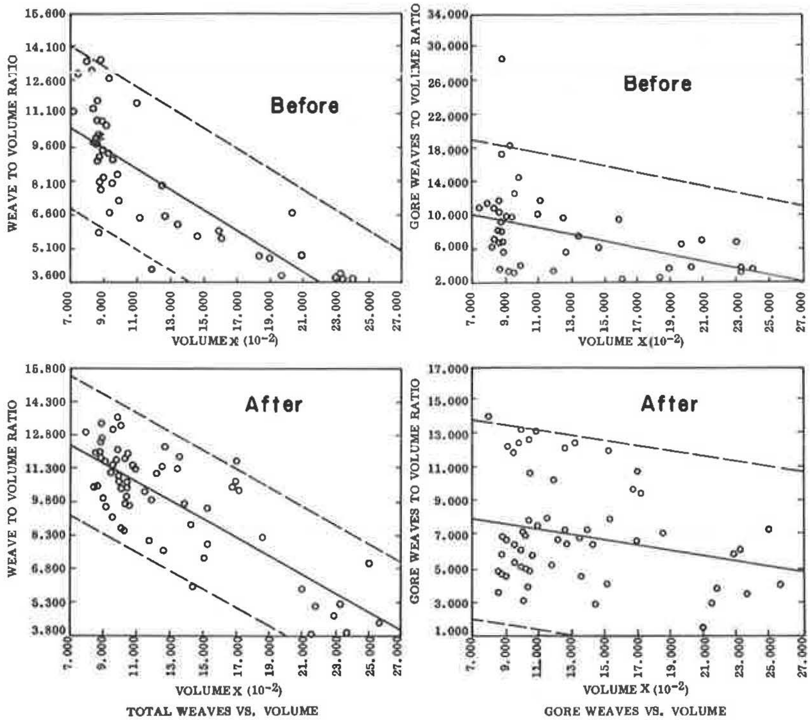


Figure 8. Gore weaves and volume.

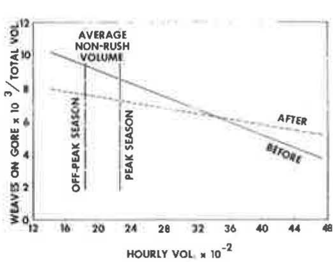


Table 2. Erratic maneuvers by type and zone.

Type	Zone	Number		Avg per Vehicle (× 10⁻³)		Change (percent)
		Before	After	Before	After	
1	1	2,881	5,741	51.15	62.79	+22.8
	2	476	1,038	8.45	11.35	+34.3
	3	541	732	9.61	8.01	-16.6
Total		3,898	7,511	69.21	82.16	+18.7
2	2	10	48	0.18	0.53	+194.4
	3	3	14	0.05	0.15	+200.0
Total		13	62	0.23	0.68	+195.7
3	2	24	28	0.43	0.31	-27.9
	3	21	29	0.37	0.32	-13.5
Total		45	57	0.80	0.62	-22.5
4	2	9	20	0.16	0.22	+37.5
	3	178	695	3.16	7.60	+190.5
Total		187	715	3.32	7.82	+135.5
Total maneuvers		4,143	8,345	71.55	91.28	+27.6
Total volume		56,324	91,423			+38.4

Table 3. Comparison of variables–March data.

Variable	Mean		Significance
	Before	After	
Avg volume, vehicles/½ hour	1,198.38	1,257.42	–
Weaves/volume, × 10²			
Total, all traffic	8.94	8.71	–
Gore, all traffic	107.00	49.70	t, F
Gore, rush-hour traffic	126.00	56.00	t, F
Weaves/total weaves, × 10²			
Gore, all traffic	11.66	6.11	t
Gore, rush-hour traffic	12.03	5.66	t

The average erratic maneuver per vehicle increased more than 27 percent in the after phase, largely because of the increased weaving by tourists. A substantial increase was seen in the number of vehicles that slowed down in zones 2 and 3 and that made partial weaves in zones 3; however, a favorable trade-off is evidenced by a 22.5 percent reduction in the number of vehicles that stopped or backed. It is also noteworthy that type 1 weaving was reduced by 16.6 percent in the critical zone 3.

The increased hesitations and partial weaving may be attributed in part to initial driver confusion on seeing the unfamilar diagrammatic sign. Despite the higher percentage of erratic maneuvers in the after phase, the trade-off among 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, because the magnitude of increased erratic maneuvers exceeded that of the reduced, a conclusion that the trade-off 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 2 days of data collection before installation of the sign and during the 2 days immediately after installation. Table 3 gives the results of the analysis, which denote the immediate reduction of weaves over the gore area.

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 weaving by tourists 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-to-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 nonrush-hour periods of traffic. This is consistent with the fact that driver habits during peak-hour conditions at urban interchanges are less dependent on signs. More drivers are familiar with the interchange, for many of them are daily commuters.

As a further aid in determining the effect of the diagrammatic sign, driver opinions were sampled. Because of a manpower shortage, continuous driver interviews throughout the study were not possible. However, driver attitudes were sampled at random intervals by interviews with confused motorists who had stopped on the shoulder or who asked for directions at a nearby service station. In most cases, lost motorists were looking for Beltway exits other than exit 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 1 is due to poor orientation to the area.

A valid comparison of accident data between the before and the after conditions is not possible because insufficient time has elapsed since erection of the diagrammatic sign to develop an after-period accident history. However, it is noteworthy that accident data before the installation of the diagrammatic sign revealed an accident rate of more than 1 per month on the approach. For the 11 months following the installation, there has been a 35 percent reduction in accidents.

An overview of the analysis shows an attempt to contrast motorist behavioral patterns between the before and the 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 after 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.

CONCLUSIONS

The combined effects of general acceptance by motorists evidenced through improved advance warning and of initial confusion of motorists 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 after the installation of the sign. Nevertheless, significant results in terms of erratic driver behavior could be seen through comparison of the before and the after studies.

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

1. A significant reduction of weaves over the gore area indicates a safer interchange as a result of improved advance warning provided by the diagrammatic sign;
2. A lesser increase of zone 1 maneuvers relative to total maneuvers implies that much traffic did weave before entering the study area, and a reduction of zone 3 weaves indicates that drivers did benefit from the geometric information provided by the sign;
3. The effect of the sign on the type of maneuver is seen by a trade-off between increased hesitations and partial weaves coupled with decreased stopping and backing movements, and this result is indicative of a safer interchange because hesitations and partial weaves are less dangerous than stopping and backing;
4. Informal driver interviews indicated that much of the problem at exit 1 stems from poor orientation to the area, yet motorists felt that diagrammatic signs convey much needed information and encouraged further research; and
5. Insufficient time has elapsed since erection of the sign for a valid statistical comparison of accident data, but in 11 months of sign usage the accident rate has been reduced by 35 percent.

REFERENCES

1. Berger, W. G. Criteria for the Design and Deployment of Advance Graphic Guide Signs. Serendipity, Inc., Arlington, Va., Sept. 1970.
2. Shepard, F. D. Evaluation of Certain Signing on the Capital Beltway. Virginia Highway Research Council, Charlottesville, Jan. 23, 1969.