INTERIM REPORT

AN EVALUATION OF THE FOLLOWING TOO CLOSELY MONITOR SYSTEM ON A FOUR-LANE UNDIVIDED HIGHWAY

by

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Research Engineer

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

The FOLLOWING TOO CLOSELY (FTC) MONITOR system is an experimental device designed to measure vehicle gaps at a point along the highway and to advise the motorist, by means of a flashing message on a sign, that he is following the car in front of him too closely. On October 31, 1974, ten FTC monitors were installed at four sites on a 6-mile 4-lane undivided section of Route 1 in Woodbridge, Virginia. As the FTC system is a new concept in highway safety, an investigation was conducted to evaluate the effects of the system on vehicle spacings, speeds, and accidents. Traffic and accident data were collected for a period 1 year before and 1 year after the monitors were installed. The results of the study reveal that use of the FTC system resulted in a significant reduction in accidents. A decrease in injury, property damage, and all crash types, including rear end collisions, was found. Monitors located in a suburban area, within a 0.5-mile section downstream from traffic signals, were found to be more effective in reducing incidences of following too closely and accidents than were monitors in rural areas. After 9 months of operation, the monitors appeared to begin to lose their effectiveness in decreasing the number of short vehicle gaps and reducing accidents. A minimal police effort was used to issue citations to motorists who were following at unsafe intervals. The enforcement campaign was effective in decreasing the number of short vehicle gaps and reducing accidents. The monitors were found to be cost effective. Further research is recommended to determine the amount of police enforcement necessary to sustain long-term benefits of the system.

ACKNOWLEDGEMENTS

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INTRODUCTION

Following too closely occurs when a motorist fails to leave a safe interval between his vehicle and the one preceding him. The rule of thumb is for a driver to allow one car length between his car and the preceding one for each ten miles per hour (mph) of vehicle speed when the road surface is dry and the visibility is good.(1) In Virginia following too closely is a violation of the law. Section 46.1-213(a) of the Code of Virginia requires the driver of a motor vehicle to follow another vehicle at a reasonable and prudent distance, having due regard for traffic speed and highway conditions.(2) Most states have a similar law.

Although following too closely is a violation of the law, the maneuver continues to be a contributing factor in a substantial number of highway accidents. For example, in 1973 in Virginia 14% of the citations issued to drivers involved in accidents were for following too closely.(3) The only violation to exceed following too closely was failure to yield the right-of-way, which accounted for 17.2% of the violations.

As shown in Table 1, following too closely is also reported to be a contributing factor in accidents throughout the United States. This table gives the Virginia and national percentages for 1973. As noted in Table 1, approximately twice as many following too closely citations were given in urban areas than were given on rural highways. This fact appears reasonable as urban facilities generally carry denser traffic streams, and they have a large number of intersecting streets and commercial driveways that generate turning volumes under stop and go conditions.

Table 1

Percentage of Following Too Closely Citations
Issued To Motorists Involved in Accidents in 1973

Location	Percentage of All Citations		
	Urban	Rural	Total
United States (a)	14.0	7.5	11.8
Virginia (b)	17.5	10.0	14.0

(a) Accident Facts, 1974 Edition, National Safety Council, Chicago, Illinois, 1974.

(b) Virginia Crash Facts 1973, Department of State Police, Richmond, Virginia, May 1974.

The New York Department of Motor Vehicles conducted a study in 1964 and found that following too closely accounted for 25% of the motor vehicle accidents in that state during the period January through October 1963.(4) Following too closely was cited as a major factor in 0.6% of the fatal, 30.1% of the injury, and 19.7% of the property damage accidents on New York's highways. The study did not examine the type(s) of accidents associated with unsafe following distances.

Although the New York study and the data given in Table 1 indicate that following too closely is a contributing factor in a substantial number of accidents, no studies were found that examined the effectiveness of increased spacing intervals in reducing accidents. Based on the results of a correlation analysis between short headways and accident rates on rural, two-lane highways, Crowther and Shumate concluded that "any programs which successfully decrease the flow of these short headways would also have some effect on the accident rate."(5) Thus, if motorists allowed safe intervals between their vehicles, it appears reasonable to assume there would be fewer collisions caused by following too closely.

Using the rule of thumb for determining a safe spacing, i.e., one car length for each 10 mph of speed, and assuming a standard car length of 20 feet, the safe spacing time interval is 1.36 seconds for any speed. An analysis of vehicle gap (vehicular gap, expressed in units of time or distance, is the interval between vehicles measured from the rear of one vehicle to the front of the following vehicle) data collected at several points on highways in Virginia revealed that from 3% to 12% of the motorists observed unsafe intervals, i.e., they left gaps of less than 1.25 seconds.[6] In fact from 0.5% to 2.4% of the observed vehicles had gaps less than 0.70 second. These data indicate that the magnitude of the following too closely problem is much greater than police citations suggest.

The reason some motorists follow at dangerously close intervals is not clear; however, the results of several research studies using drivers in typical car-following situations indicate that driver judgment of vehicle spacing is extremely poor.[7,8] Although motorists were found to be poor judges of vehicle spacing, the present motor vehicle instrument panel does not contain a device to measure spacing and inform the driver that he is following too closely.

To meet the motorist's need for such a device, Arthur N. Marshall, president of Traffic Safety Systems, Inc., designed and patented the FOLLOWING TOO CLOSELY (FTC) MONITOR System. Marshall theorized that if motorists were informed that they were following too closely, they would increase their vehicle spacing and reduce the accident potential.[9]

The FTC systems are installed on the highway just ahead of areas of known accident concentrations. A typical installation on a four-lane undivided highway is shown in Figure 1. The system consists of sensors embedded in the pavement and an infrared light source connected to an electronic timer and sign. If the gap time between two vehicles passing through the system is between 0.70 and 1.25 seconds, the motorist following too closely is given a flashing "DANGER" on the sign in the panel below the permanent FOLLOWING TOO CLOSELY message. The motorist with a time interval of less than 0.70 second receives a flashing "VIOLATION" message and a buzzer sounds a warning. The system was designed so that the DANGER and VIOLATION gaps can be varied. For the experiments in Virginia, the inventor chose a DANGER of 1.25 seconds to educate motorists to the feeling of following too closely and a 0.70 second VIOLATION time because this time is less than the 0.75 second average reaction time given in the Code of Virginia.[2,9] As a gap of 0.70 second is an unreasonable interval, the monitor also could be used to furnish police officials with prima facie evidence against motorists violating the following too closely law. Each monitor is equipped with counters which record the traffic volume and the number of vehicles with DANGER and VIOLATION intervals. The distance between the embedded sensors and the sign is determined by the speed limit and is set to minimize the possibility of the lead car receiving the message intended for the following vehicle. Further details of the FTC equipment and operational aspects are given in a paper by Marshall.[9]

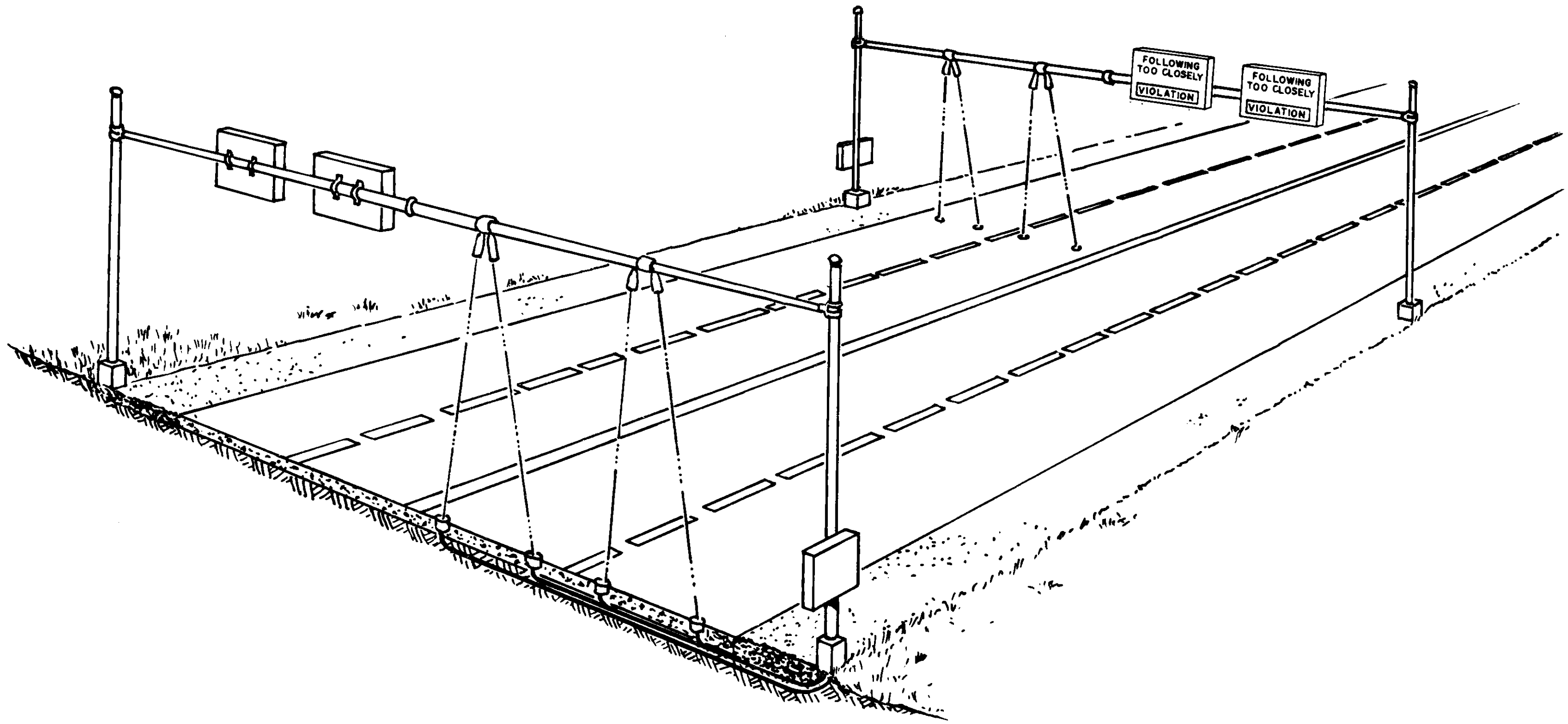

Figure 1. Typical FTC MONITOR system installation on a four-lane undivided highway.

As the FTC MONITOR is the first device to be used on the highway to inform all motorists when they are following too closely, the system represents a new concept in highway safety. This research was designed to evaluate the effectiveness of the system in increasing vehicle spacings and reducing accidents on a 4-lane undivided highway.

PURPOSE AND SCOPE

On October 31, 1974, the Virginia Department of Highways and Transportation completed installation of ten FTC monitors at four sites within a 6-mile area of U. S. Route 1 in the Northern Virginia community of Woodbridge. The purpose of this research was to evaluate the FTC monitors to determine the —

1. effects of the monitors on accidents, including the number, severity, type or types of accidents affected, and duration of the effectiveness;
2. effects of the monitors on traffic flow, i.e., headways, speeds, and on driver reactions;
3. aspects of police enforcement;
4. correlations between changes in traffic flow parameters and accidents; and
5. general conditions of effectiveness, including a benefit/cost analysis and limitations of the monitors.

Due to personnel and budget constraints, data collection for the study was held to a minimum. The research included —

1. a before and after accident analysis of the 6-mile study area;
2. an analysis of accidents in the area downstream from each monitor site;
3. an analysis of random samples of volume, headway, and speed data collected with an electronic data acquisition system at various distances from the FTC monitors;
4. an analysis of traffic volumes and gap times taken weekly from counters on the FTC monitors; and
5. a determination of driver reaction to the FTC device.

The scope of the study was limited to an evaluation of the FTC monitor system designed by Marshall and described in his paper.(9) Due to budget limitations, no attempt was made to experiment with other sign messages or gap intervals other than 0.7 to 1.25 seconds for danger and less than 0.70 second for violation. The scope includes an evaluation of the effectiveness of the FTC system used with and without the benefits of police enforcement.

The emphasis in this interim report is on the analysis of accident and vehicle gap data obtained from the FTC counter readings. The analysis of the headway and speed data requires the preparation of several computer programs, and this work was deferred due to the priority of several other projects. A complete analysis of the traffic flow data will be included in a final report on the study.

METHODOLOGY

Study Approach

The methodology selected for the study was the empirical before and after technique. Volumes, headways, speeds, driver reactions, and accident reports were collected for similar periods before and after installation of the FTC monitors. The data were summarized and tested for statistical significance.

Study Area

The 6-mile study area of U. S. Route 1 is located in the Northern Virginia community of Woodbridge in Prince William County. Route 1 throughout this area is a 4-lane undivided highway carrying an average of 23,530 vehicles per day (1975 count). Of the total traffic volume, 15% consists of out-of-state vehicles and 5% of commercial vehicles. Approximately 3 miles of the study route are located in a highly developed commercial area and the remaining 3 miles are generally rural in nature. There are eight signalized intersections within the study site. The speed limits are 35 and 55 mph in the suburban and rural areas, respectively.

Route 1 through the Woodbridge area historically has a poor accident record. In a 3-year period (November 1, 1971, through October 31, 1974) prior to installation of the FTC monitors, Virginia State Police records indicated that a total of 761 accidents, (5 fatal, 233 injury, and 523 property damage), within the 6-mile study area. In these accidents 8 persons were killed, 346 were injured, and property damage was estimated to be $602,000. Approximately 43% of the crashes were rear end accidents which figure is considerably above the 25.9% statewide average.(3) Following too closely was reported to be a contributing factor in only 10% of the accidents. Assuming the annual 9% increase in accidents and injury crashes would continue, the method of least squares was used to develop regression equations to project that 296 accidents and 100 injury crashes could be expected during the 12-month period from November 1, 1974, through October 31, 1975. These trends are shown in Figures 2 and 3.

Numerous highway improvements, including the construction of turning lanes at intersections, the erection of traffic signals, and the lowering of the speed limit, have been made over the last 10 years but have had very little effect in reducing the accident frequency. Due to limited highway right-of-way and the high cost of construction in an area of this nature it will not be possible to finance major highway improvements in the foreseeable future. These economic factors, coupled with the rapidly increasing accident rate and high incidence of rear end collisions, prompted highway officials to consider installing ten FTC monitors at four sites on an experimental basis.

Installation of the system, which was financed under a §402 highway safety project grant from the Highway Safety Division of Virginia, began in August 1974 and was completed on October 31, 1974 at a cost of $63,927.78. The sites for the monitors were selected at points prior to accident concentrations. No other changes in traffic controls, i.e. speed limits, signals, markings, etc., were made during the study period. However during the last 3 months of the study (August, September, and October 1975) Prince William County police periodically issued citations to motorists who were following too closely (following at less than 0.7 second).

After the system was completed on October 31, 1974, statements were issued to the news media for the purpose of informing motorists of the nature and operational aspects of the signs. During August 1975, motorists were advised through the media that citations would be issued for violations of the following too closely law. Public reaction did not appear to be adverse. Only a few letters were received and they were inquiries concerning the purpose of the system.

A schematic of the study area including the location of traffic signals and the FTC monitors is shown in Figure 4.

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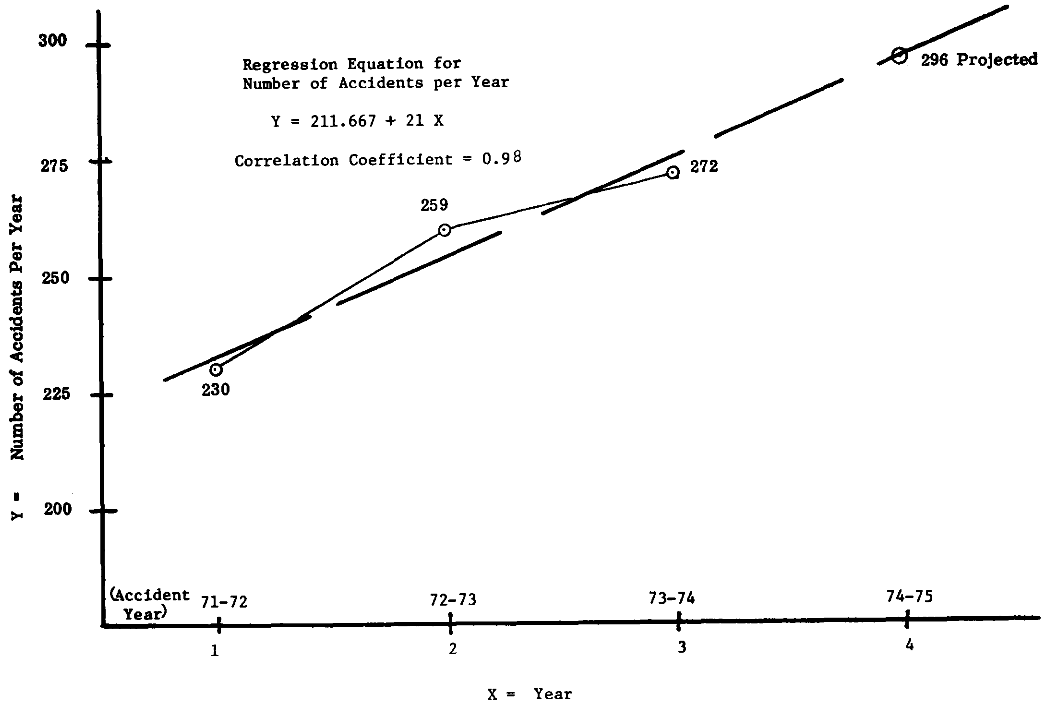

Figure 2. Accident trend at Woodbridge.

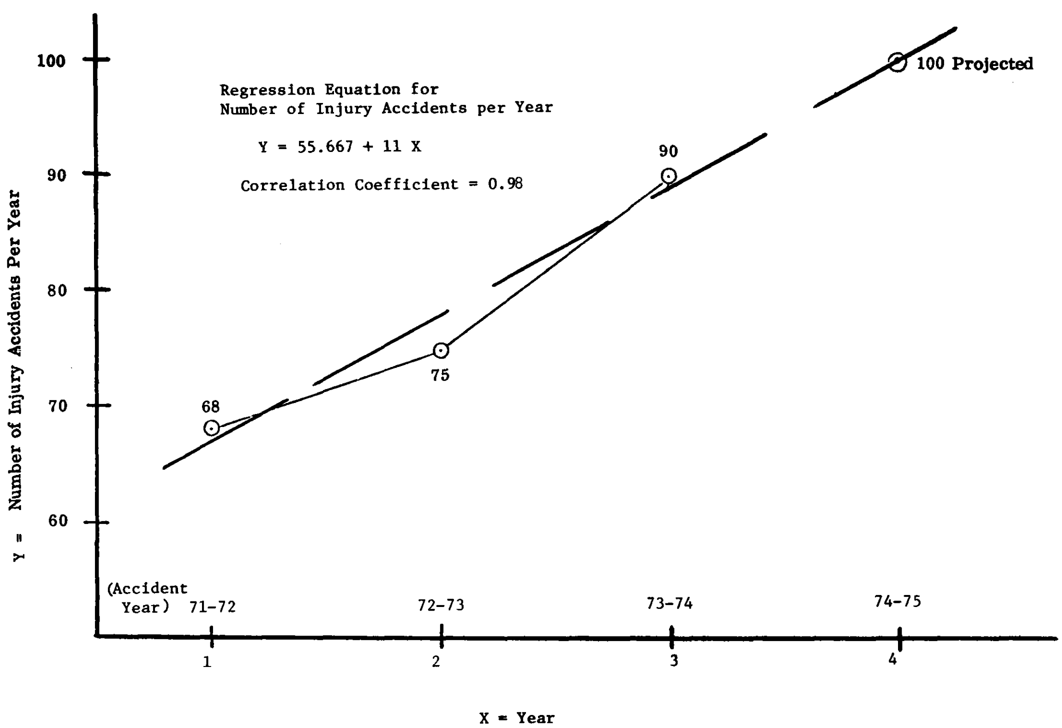

Figure 3. Injury accident trend at Woodbridge.

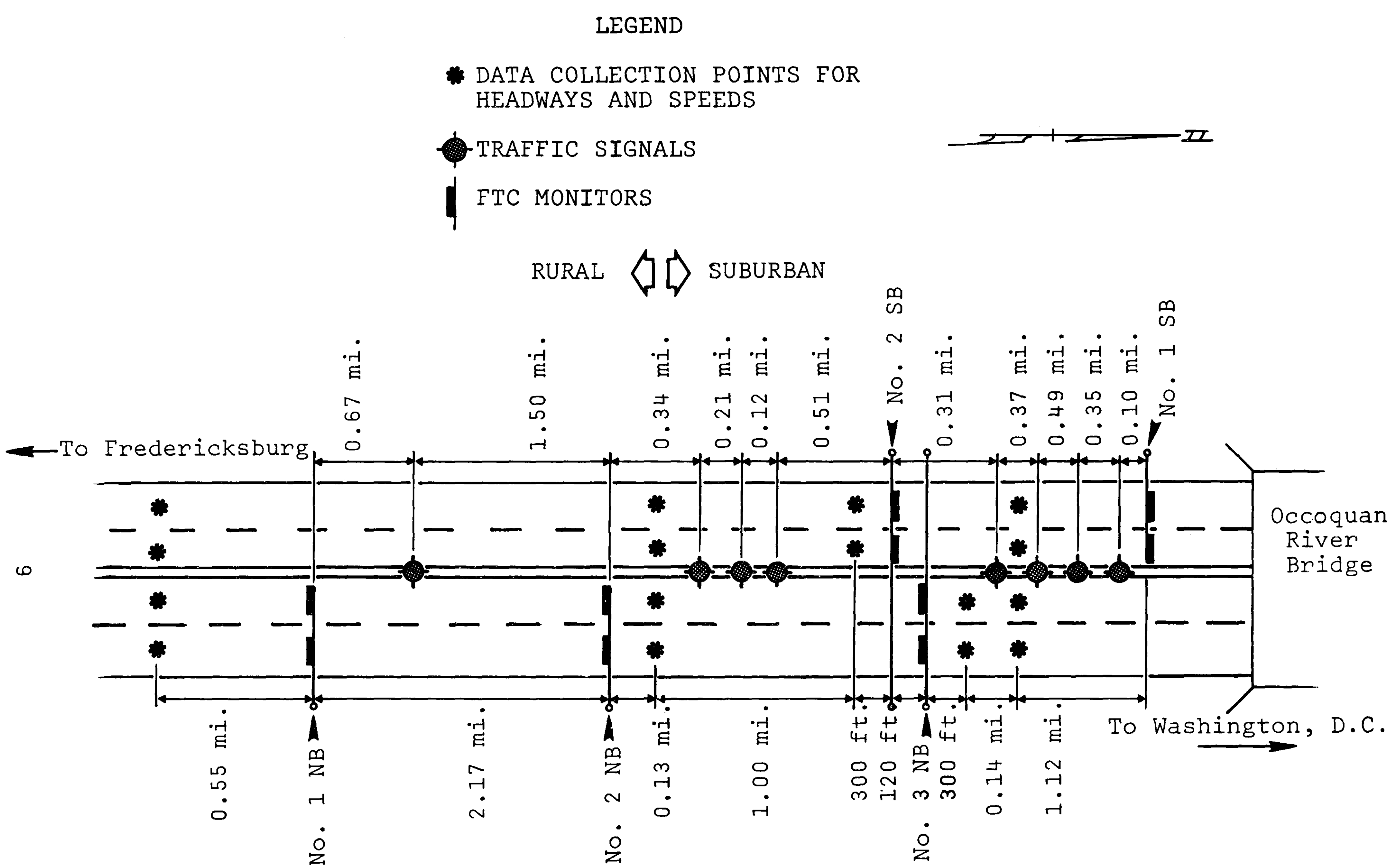

Figure 4. Schematic of Woodbridge study area.

As illustrated in Figure 4, three of the monitor sites are located on the northbound lane and two on the southbound lane. Two of the northbound sites (NB 1 and 2) are rural in nature, while the other monitors are in a suburban area. Sites SB 2 and NB 3 are at the low point of a sag vertical curve on a tangent section of Route 1 and monitor traffic on all four lanes at the same point. Traffic at the other sites is monitored in only one direction and the monitors are located on a tangent section with nearly level vertical alignment. The signs and monitoring equipment for sites SB 2 and NB 3 are on overhead spans 72' long. Equipment for the other sites is on canilever arms 35' in length.

Data Collection

Data collected for the study included (1) accident records, (2) headway and speed data, (3) traffic volume, and DANGER and VIOLATION readings at each monitor, and (4) observations of driver reactions to the monitor.

Accident Data

To examine the effects of the FTC monitors on highway safety, accident data were collected for the 6-mile Woodbridge area for a 3-year before and 1-year after period. As the installation of the FTC monitors was completed on October 31, 1974, for the purposes of discussion in this report an accident year is defined as the 12-month period from November 1 of one year through October 31 of the following year. For example, accident year 1971-72 covers the period from November 1, 1971, through October 31, 1972. The designation of these dates for an accident year was made so as to obtain similar before and after periods for the study comparisons.

Effective January 1, 1975, the Code of Virginia was amended to raise from $100 to $250 the limit on which a property damage accident must be reported to the Division of Motor Vehicles. To eliminate the effect of this change on the accident analysis at Woodbridge, all property damage crashes with damage less than $250 were disregarded in the before and after periods.

Volumes, Headways, and Speeds

Vehicle volumes, headways, and speeds were taken with an electronic data acquisition system at the four locations denoted by asterisks in Figure 4. The headway and speed data were taken at each location for both directions of travel. The data collection sites were carefully located at varying distances from the monitors and traffic signals in the area. The data were collected with a 4-channel general purpose recorder connected to tapeswitches placed in each of the four lanes at any given site.

The before data were collected in July 1974 and on October 30, 1974; the after data were taken on October 31, 1974, and in July 1975. Data were collected for approximately a 10-hour period at each site, which included morning and evening peak periods.

Upon completion of the data collection process, the headway and speed data, which had been recorded on paper tapes, were measured and the readings were transferred to work sheets. The data were then keypunched for computer analysis. Fortran programs are now being prepared to summarize the data for further analysis. Completion of this analysis is expected by July 1976.

Vehicle Spacings

Following installation of the FTC monitors on October 31, 1974, traffic volumes and DANGER and VIOLATION readings were taken from each unit by field personnel and mailed to the research unit for analysis. From October 31 through December 23, 1974, the readings were taken on a daily basis. Thereafter, the readings were taken on a weekly basis,viz., every Monday between 1:00 and 1:30 p.m. The data were tabulated on weekly and monthly bases. The readings not only provide a record of traffic volumes and the number of motorists following too closely but are used to determine if the monitors have functioned properly, i.e., unusual readings can usually be traced to an equipment or electrical power failure. All readings taken during equipment malfunctions were deleted from the analysis. During the study period, gap times for over 18 million vehicles were recorded at the four monitoring sites.

Vehicle Spacing and Accident Correlations

Vehicle spacing and accident data were subjected to a correlation analysis to test the hypothesis that a decrease in the number of short vehicle gaps would result in a reduction in accidents. These data were summarized on a monthly basis.

Effects of Police Enforcement

During the last 3 months of the study period (August, September, and October 1975) the Prince William County police periodically issued citations to motorists violating the code by following too closely (less than 0.7 second). The officers were alerted to violators as they drove through the FTC system, but all arrests were based on personal observation of the officer; i.e. the motorist was following at an unsafe distance. The effects of the enforcement campaign were evaluated by analysis of the vehicle spacing and accident data.

Driver Reactions

Observations and movies of drivers reacting to the FTC monitors were made on the day the devices were installed and again during July 1975. Although these data are subjective, they do provide an account of individual driver reaction to the FTC system.

FTC Equipment

The accuracy and reliability of the FTC equipment were periodically checked by electronic technicians. As volume and vehicle gap readings were taken weekly from each monitor, a record of all equipment malfunctions was maintained. When the readings indicated a malfunction, maintenance personnel were advised. All maintenance expenses and equipment problems were noted.

Benefit-Cost Factors

One of the most important factors in an evaluation of a highway safety improvement is determining if the benefits from the project outweigh the costs. As the FTC system is a new device and only one year of data were available for evaluation, a 1-year comparison of benefits derived from accident savings to the costs of the monitors (includes equipment, installation and maintenance costs) was made.

ANALYSIS

Accident Data

As the major purpose of installing the FTC monitors in the Woodbridge area was to reduce accidents, an extensive analysis of the accident data was conducted. This analysis was divided into two phases: (1) analysis of all data within the 6-mile study area, and (2) analysis of the reported accidents at each monitor site. It should be reiterated that unless specifically noted,the accident statistics used in these analyses are based on accident years beginning on November 1 and extending through October 31, and that the data include all fatal and injury reports and only those property damage accidents where the amount of damage was $250 or more.

Study Area

Based on an analysis of the 3-year before accidents reported within the 6-mile Woodbridge study area, it was shown in Figure 2 that if the accident trend had continued, 296 accidents would have been expected during the 12-month period November 1, 1974, through October 31, 1975. On October 31, 1974, the ten FTC monitors were installed within the study area, and accident data for the ensuing year were compiled to provide a comparison between the projected and actual number of accidents. The before and after data are summarized in Table 2.

Table 2

Woodbridge Accident Summary

Category	Before FTC			After FTC 74-75		% Change	
	71-72	72-73	73-74	Actual With FTC	Expected Without FTC	Actual	Expected
Total Accidents	230	259	272	220	296	-19.1	-25.7
Fatal Accidents	4	1	0	1	---	+100.0	--
Persons Killed	7	1	0	1	---	+100.0	--
Injury Accidents	68	75	90	66	100	-26.7	-34.0
Persons Injured	106	109	131	100	---	-23.7	--
Property Damage Accidents	158	183	182	153	196	-15.9	-21.9
Prop. Dam. x $1,000	$187	$195	$220	$197	---	-10.5	--
Average Daily Traffic	21,480	23,470	21,990	23,530		+7.0	--
Accident Rate per 100,000,000 vehicle miles of travel	489	504	565	427	595	-24.4	-28.2
Statewide Rate	475	455	430	not available			

Although there was approximately a 7% increase in traffic volume in the after period, total accidents were reduced* by 19.1%, injury accidents by 26.7%, property damage accidents by 15.9% and the accident rate by 24.4%. A comparison between the projected figures and the actual number of accidents reported in the after period revealed that total accidents were reduced by 25.7%, injury accidents by 34.0%, property damage accidents by 22.7% and the accident rate by 28.2%. The total accident and injury accident statistics are given in graphic form in Figures 5 and 6.

It should be noted that projections were not made for fatal accidents as these occurrances were too infrequent to compare statistically. The one fatality that occurred in the after period was the result of a drinking driver traveling east on Route 123, failing to stop at the intersection of Route 1, and crashing into the railroad tracks and embankment on the east side of Route 1.

Statistical Significance

Before further analysis of the accident data was conducted, the statistical significance of the 19.1% reduction in accidents had to be determined. This determination is an important part of the evaluation and was made using several procedures.

The regression equation shown in Figure 2 was used to estimate that 296 accidents would be expected during the period beginning November 1, 1974, and ending October 31, 1975. The 99% confidence limits for this estimate are shown in Figure 5. The lower 99% limit was 279 accidents, which was greater than the 220 accidents actually reported in the after period. As the actual number of accidents was considerably lower than the number expected, the indication is that the presence of the FTC monitors created a significant reduction in accidents in the Woodbridge area.

As another test of significance, the paired t test was used to determine if there was a significant difference between the number of accidents reported per month in the before period to that in the after period. The t value was 3.18, which is significant at the 99% confidence level. ($t_{0.99}$ for 11 degrees of freedom = 2.72). This finding is further evidence that there was a significant difference between the numbers of accidents occurring in the before and after study periods.

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*This reduction is based on a comparison between accidents reported 1 year before (73-74) and 1 year after (74-75).

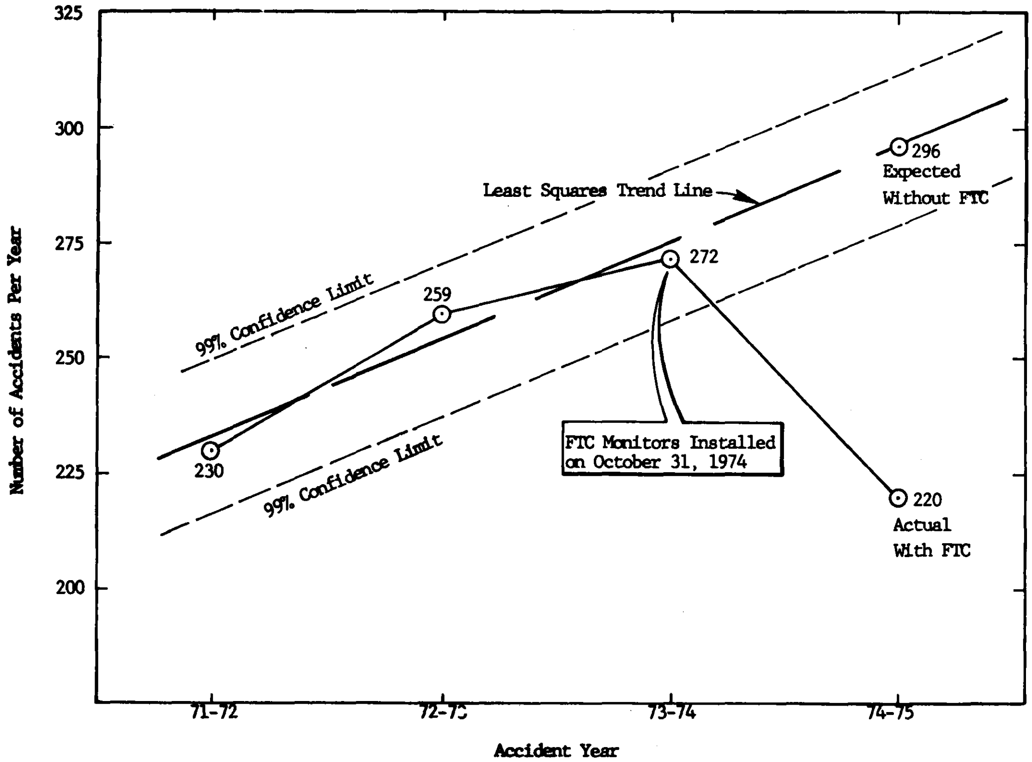

Figure 5. Comparison of projected and actual accidents at Woodbridge.

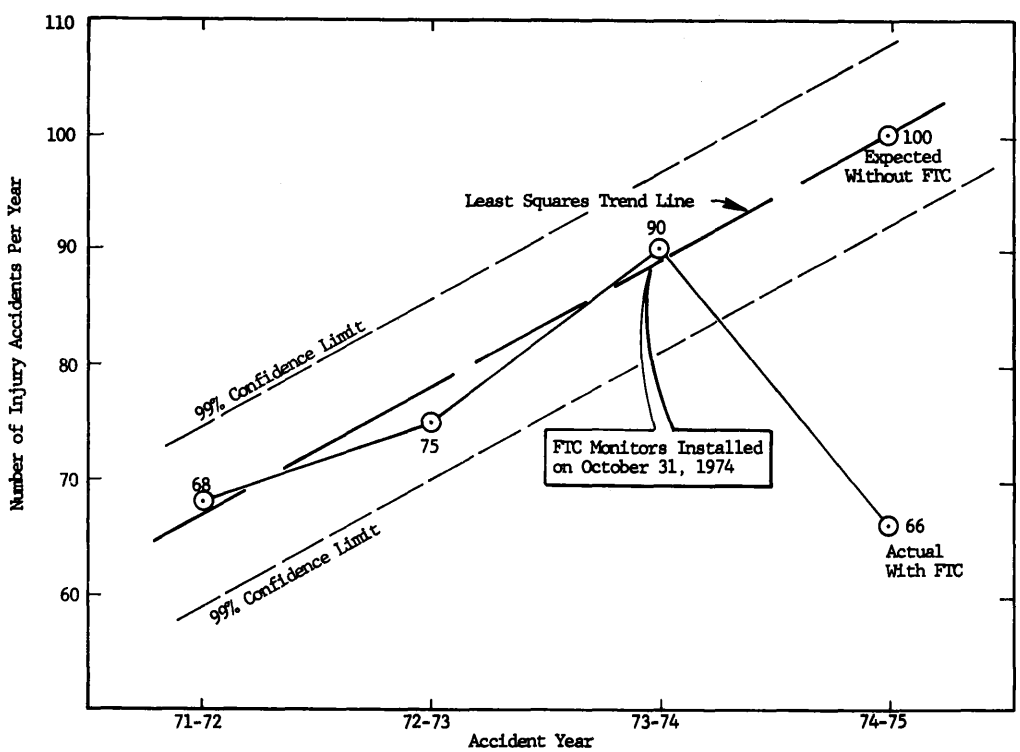

Figure 6. Comparison of projected and actual injury accidents at Woodbridge.

The accident reduction at Woodbridge was further tested for statistical significance with the use of the chi-square test. The Woodbridge data were compared to the statewide data and to the total data for Prince William County. To make this comparison, it was necessary to adjust the Woodbridge data to the same base as the state and county data. For example, the statewide accident data for 1974 obtained from the state police include all accidents with $100 property damage or more and all injury and fatal accidents.(10) However, the 1975 figures include only those property damage accidents amounting to $250 or more with all injury and fatal accidents.(11) Thus, for 1975 there appears to be a reduction in accidents in Virginia as compared to 1974, but the reduction is created by the change in the limitation on property damage. Therefore, before the Woodbridge data could be compared to the state police data, all property damage accidents occurring in 1974 with damage estimates of $100 or more had to be added to the figures given in Table 3. In a similar manner, the Woodbridge data were adjusted to be comparable with the Prince William County data.

As can be seen in Table 3, there was a statistically significant reduction in accidents at the Woodbridge study area as compared to both the number of accidents reported for the state and the number reported for Prince William County.

Table 3

Statistical Significance of Accident Data

Category	Number of Reported Accidents			
	Woodbridge Study Area(a)	Prince William County(b)	Woodbridge Study Area(c)	State of Virginia(d)
1974 — Before FTC	271	2,017	354	144,537
1975 — After FTC	190	1,889	236	127,187
% change	-29.89	-6.35	-33.33	-12.00
X^2	8.44		10.96	
Significant at α = 0.01 level	Yes		Yes	

(a) Only accidents reported by the Prince William County Police

(b) Obtained from the Prince William County Police.

(c) All accidents reported to the Virginia State Police

(d) From Virginia Crash Facts 1974 and 75, Department of State Police (1975 report in publication).

As another comparison technique, accidents occurring in a 0.75-mile section of the northbound lane of Route 1 upstream from monitor NB 1 shown in Figure 4 were analyzed. The results of this analysis are summarized in Table 4.

Table 4

Summary of Accidents in 0.75-Mile
Section Upstream of FTC Monitor NB 1

Category	Number of Accidents			
	Before FTC			After FTC
	71-72	72-73	73-74	74-75
Total Accidents	6	1	5	10
Fatal Accidents	0	0	0	0
No. Killed	0	0	0	0
Injury Accidents	2	0	4	4
No. Injured	5	0	11	6
Property Damage Accidents	4	1	1	6
Type				
Rear End	2	0	3	6
Angle	1	0	0	0
Sideswipe	1	0	1	1
Fixed Object	1	1	1	2
Other	1	0	0	1

While the accident numbers in the 0.75-mile section are small and the roadway length is too short to consider the section a proper control, several trends are noteworthy. First, in this section the total number of accidents and the number of rear end type accidents increased. Second, these results indicate that there may have been an increase in accidents in areas not influenced by the monitors. Furthermore, these data indicate that the monitors may not be effective in reducing accidents upstream.

Accident Characteristics

After it was determined that there was a significant reduction in accidents following installation of the system, there remained questions concerning what effects the monitors had on accident characteristics. For example, did the monitors significantly reduce accidents for only a short period of time, or was the reduction uniformly distributed in every month of the year? What was the effect of the monitors on accident severity or type of accident? To examine these and other factors, the accident data were analyzed to determine if there were significant changes in the monthly trends, severity, type of accident and numerous other variables including day of week, time of day, and day vs. night.

The analysis reflected in Table 5 was done to determine if there were statistically significant changes in the percentages of accidents occurring for any month during the 1-year before and 1-year after periods of study, or if the reduction in accidents occurred in every month of the after period.

Table 5

Summary of Monthly Accident Data

Month	Before FTC		After FTC		Z Statistic	Significance
	No.	%	No.	%		α = 0.05
November	21	7.72	20	9.09	-0.55	No
December	24	8.82	24	10.91	-0.78	No
January	19	6.99	12	5.45	0.70	No
February	17	6.25	12	5.45	0.37	No
March	25	9.19	21	9.55	-0.14	No
April	18	6.62	10	4.55	0.99	No
May	21	7.72	19	8.64	-0.37	No
June	29	10.66	21	9.55	0.41	No
July	20	7.35	23	10.45	-1.21	No
August	34	12.50	19	8.64	1.37	No
September	18	6.62	16	7.27	-0.28	No
October	26	9.56	23	10.45	-0.33	No
TOTAL	272	100.00	220	100.00		

As shown in Table 5, there was not a statistically significant change in accidents for any month. The importance of this result is that the reduction in total accidents was uniformly distributed in the 12-month after period. It is interesting to note, however, that accidents reported during the month of July approached a significant increase while August data approached a significant decrease. For an explanation of this phenomenon, see the section on Effects of Police Enforcement.

The next step in the analysis procedure was to determine if the severity of accidents changed during the study period. For example, although there was a significant reduction in total accidents there could have been a disproportionate increase or decrease in injury accidents. As shown in Table 6 there was not a significant difference between the before and after accident severity. Again, this result indicates that the reduction in total accidents was uniformly proportioned among fatal, injury, and property damage accidents.

Table 6

Summary of Accident Severity

Category	Before FTC		After FTC		Z Statistic	Significance
	No.	%	No.	%		α = 0.05
Fatal Accidents	0	0.00	1	0.45	-1.10	No
Injury Accidents	90	33.09	66	30.00	0.73	No
Property Damage Accidents	182	66.91	153	69.55	-0.62	No
Total Crashes	272	100.00	220	100.00		

The accident data shown in Table 6 were compared to statewide totals for the same period of study. There were no significant differences in the proportions of fatal, injury, and property damage accidents reported in Woodbridge as compared to reported statewide accidents.

Perhaps the most important part of the analysis was to determine if there were significant changes in the distribution of types of accidents. Although there is little research available to support this hypothesis, one observation noted in the Marshall report was that the FTC monitors were expected to induce a decrease in the incidences of following too closely and a corresponding decrease in rear end type accidents.(9) As shown in Table 7, 43% of the accidents in the before period were rear end crashes. The percentage of rear end accidents was also 43% in the after period, which indicates a nonsignificant change. In fact, of the five accident categories tested, only the sideswipe crash was reduced significantly.* This result indicates that the reduction of accidents in the Woodbridge area was uniformly distributed over the five accident types shown in Table 7, except that sideswipe accidents were disproportionately affected. Perhaps the reason for the percentage of rear end crashes remaining unchanged was not attributable to the effectiveness of the monitors but to the change in accident reporting procedures.

Table 7

Distribution of Accidents by Type

Category	Before FTC		After FTC		Z Stat.	Significance	% Change Before and After
	No.	%	No.	%		$\alpha = 0.05$	
Rear end	118	43.38	96	43.64	-0.58	No	-18.6
Angle	98	36.03	89	40.45	-0.99	No	- 9.2
Sideswipe	28	10.29	12	5.45	1.95	Yes	-57.1
Fixed Object	12	4.41	10	4.54	-0.69	No	-16.7
Other	16	5.89	13	5.92	-0.14	No	-18.8
Total	272	100.00	220	100.00			

*A further analysis of this change will be made before the final report is completed; however, when an accident analysis of each monitor site was conducted, a significant change in sideswipe accidents was not found. Therefore, it does not appear reasonable to assume that the reduction in sideswipe accidents can be attributed to the FTC monitors.

The property damage accidents in Table 7 are for accidents involving damage of $250 or more. In the accident year before FTC (November 1, 1973, to October 31, 1974), 82 property damage accidents involving less than $250 property damage were reported. Of these, 38 (46.3%) were rear end type crashes. In the after period, (November 1, 1974 to October 31, 1975), which encompassed the change in Virginia law that dropped the requirement for reporting minor damage accidents, 16 accidents with less than $250 damage were reported and only 5, or 31.3%, of these were rear end crashes. There is reason to believe that the FTC monitors may have reduced the minor property damage type of rear end crash, but unfortunately, due to the change in accident reporting procedures, it is impossible to verify this conjecture.

A before and after comparison of the variables listed in Table 8 was made to determine if they exhibited significant changes during the study period. Only the results are shown in Table 8, but the analysis for each parameter is available upon request.

Table 8

Summary of Other Accident Variables Tested

Variable Tested	Significant Change
Day of Week	No
Time of Day	No
Day Accident	No
Night Accident	No
Residence of Driver	No
Northbound Accidents	Yes, decrease
Southbound Accidents	No
Type of Vehicle	No
Weather Condition	No
Road Surface Condition	No
Estimated Speed of Vehicle before Crash	No

For the 11 variables tested, the only significant change was a reduction in the percentage of drivers involved in northbound accidents. While there was an overall reduction in accidents in the study area after installation of the FTC monitors, the reduction was uniformly distributed throughout the variables shown in Table 8, with the exception of the significant reduction just noted. It is also interesting to note that there was a nonsignificant decrease in the percentage of motorists involved in an accident who were charged with following too closely.

FTC Monitor Sites

After the statistical significance of the reduction in accidents in the 6-mile Woodbridge area was determined, attention was turned to the effect of each monitor on accidents. For this analysis, a collision diagram was made of the area and the location of each monitor was plotted on the diagram. The area downstream (north- or southbound lane only) from each monitor was divided into approximately 1/4-mile increments, and an analysis was made of the accidents in each increment. If an increment had a higher number of accidents in the before period than in the after period, the monitor was taken as being effective in reducing accidents in that increment. Conversely, when the number of accidents was higher in the after period, the monitor was taken as not being effective in reducing accidents. This criterion was applied to the five monitor sites to develop the summary data given in Table 9.

Table 9

Summary of Accidents Reported at Each FTC Site

Monitor Site	Area Type	Lane Monitored	Distance Downstream in miles	No. Accidents		% Change
				Before FTC	After FTC	
1 NB	Rural	NB	0.56	6	5	- 16.7
2 NB	Rural	NB	0.20	1	0	-100.0
3 NB	Suburban	NB	1.91	55	40	- 27.3
1 SB	Suburban	SB	0.29	7	18	+157.1
2 SB	Suburban	SB	1.48	40	30	- 25.0

As was mentioned earlier, monitors NB 1 and 2 were located in relatively rural areas where the speed limit is 55 mph. As shown in Table 9, they were effective in reducing accidents for only a short distance downstream. Furthermore, the numbers of accidents at these sites were too small to permit a statistical comparison.

According to the number of reported accidents, there was a 157% increase in accidents at site SB 1. This monitor is located only 0.28 mile south of the Occoquon River bridge, on which the repair of extensive flood damage extended into the after study period. During the reconstruction traffic was confined to two lanes, but when the bridge was completed all four lanes were put into service. Consequently, during February and March 1975, there was a 15% increase in the traffic volume.

Because of the proximity of monitors at this location to an animal hospital, the buzzers on the signs warning of an FTC violation were disconnected as the sound disturbed the animals. The increase in volume and the disconnection of the buzzers may have led to an increase in accidents at this site.

As shown in Table 9, accidents were significantly reduced for considerable distances downstream from monitors SB 2 and NB 3. In the case of NB 3, accidents may have been reduced beyond the 1.91-mile area of effectiveness, but this distance was the limit of the 6-mile study area. To determine the effective length for NB 3, an analysis will be made further downstream for the final report.

Because of the 27.3% reduction in accidents at NB 3, a further analysis of crashes at this site was conducted. The accident history of this area is shown in Table 10, and the distribution of accidents by crash type is given in Table 11. As noted in Table 10, 15 fewer accidents were reported in this area following installation of the monitors. Of these 15 accidents, 12 (80.0%) were property damage crashes and 3 (20%) were injury accidents.

A statistical analysis of the distribution of accidents by type in the 1.91-mile section of the northbound lane north of NB 3 indicated that there was not a significant reduction in the percentage of accidents in any specific crash category, including rear end accidents. This finding indicates that the overall reduction in accidents in this section was uniformly distributed among the types of crashes. Of the 55 accidents reported for this section prior to the installation of the FTC monitor, 34, or 61.82%, were rear end accidents. This value is considerably larger than the 43% reported for the entire 6-mile study area. However, following the installation of the monitor the percentage of rear end accidents was 60.0%, with the difference indicating a nonsignificant reduction. Again, this finding may be attributable to the change in reporting property damage accidents as discussed earlier.

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Table 10

Accident Summary for 1.91-Mile Section of Northbound Lane North of NB 3

Category	Before FTC			After FTC	%
	71-72	72-73	73-74	74-75	Change
Fatal Accidents	1	0	0	0	—
No. Killed	1	0	0	0	—
Injury Accidents	7	11	16	13	-18.8
No. Injured	9	15	19	18	- 5.3
Property Damage Accidents	32	49	39	27	-30.8
Total Accidents	40	60	55	40	-27.3

Table 11

Distribution of Accidents by Crash Type for 1.91-mile Section of Northbound Lane North of NB 3

Category	Before FTC		After FTC		Z Statistic	Significance $\alpha = 0.05$
	No.	%	No.	%		
Rear End	34	61.82	24	60.00	0.18	No
Angle	14	25.45	13	32.50	-0.75	No
Sideswipe	2	3.64	1	2.50	0.31	No
Fixed Object	3	5.45	1	2.50	0.71	No
Other	2	3.64	1	2.50	0.31	No
Total	55	100.00	40	100.00		

A further analysis of these data as well as the accident data at the other FTC sites will be included in the final report.

Summary

Given below is a summary of the findings of the accident data analysis.

1. Following installation of the FTC monitors, there was a statistically significant reduction in accidents. Total accidents were reduced by 25.7%, injury accidents by 34.0%, and property damage crashes by 21.9%. The accident rate was reduced by 28.2%.

2. There was a proportionate decrease in injury and property damage accidents.

3. The reduction in accidents was uniformly distributed among all crash types, including rear end crashes.

4. Only 10% of the motorists involved in accidents in either the before or after study periods were charged with following too closely.

5. There was a significant reduction in the number of drivers involved in northbound accidents.

6. The number of accidents reported downstream from each monitor decreased except for site SB 1, where significant changes in traffic volumes may have resulted in an increase in accidents.

7. At sites NB 1 and NB 2 accidents were decreased only for short distances downstream; however, sites SB 2 and NB 3 indicated reductions in accidents for 1.48 and 1.91 miles downstream, respectively.

Volumes, Headways and Speeds

As discussed in the Methodology section, computer programs are being prepared for analyzing the traffic flow data taken with the recorder. Thus, an analysis of these data is not possible at this time. However the results of before and after speed studies made by the Traffic and Safety Division at three sites within the study area indicated that there was not a statistically significant change in speed as a result of the FTC monitors.(12)

An analysis of the traffic flow data will be made for a final report on the study. Analyses of these data will include an investigation of the effects of the monitors on capacity, speeds, and headways and the relationship between volume and unsafe following distances. Characteristics of peak and off peak hour volumes will be reviewed. As the FTC system measures only two unique spacing intervals (DANGER and VIOLATION gap times) at a point before motorists have had an opportunity to react to the message, the data supplied by the system are not sufficient to describe traffic characteristics such as speeds and headway distribution. However, the traffic flow data were taken downstream and will provide additional information concerning the effects of the monitors on traffic flow.

Vehicle Spacings

Each FTC monitor has a counter which records the volume, number of vehicles with a DANGER spacing interval (0.7 to 1.25 seconds), and number of vehicles with a VIOLATION spacing interval (less than 0.7 seconds). For the analysis, the weekly monitor readings were summarized on a monthly basis. The results for all the monitors are similar to those for the monitor on the right lane at site NB 3, which are displayed graphically in Figure 7.

As inidcated in Figure 7, in the first two months following installation of the monitors the percentages of vehicles having DANGER and VIOLATION gaps decreased; i.e., motorists increased vehicle spacing. During January 1975, they reached maximum effectiveness. After January, incidences of following too closely increased, and during May, June, and July 1975 the DANGER and VIOLATION readings were not significantly different from the readings taken during November 1974. The monitors may have been more effective downstream as the FTC counter readings are recorded at a point on the highway before the driver has had an opportunity to react to the FTC message. This assumption can be verified when computer analysis of the headway and speed data is completed for the downstream data collection points.

In July 1975 the first monthly increase in accidents (compared to July 1974) occurred since the FTC system was installed in November 1974. The increase in incidences of following too closely, coupled with the increase in accidents, indicated that the FTC monitors were beginning to lose their effectiveness. Therefore it was decided that police enforcement would be necessary to continued benefits from the monitors. During August, September, and the early part of October 1975, the Prince William County Police Department issued citations to motorists who were following too closely. As a result, there were significant decreases in following too closely and accidents. The effects of police enforcement will be discussed in a later section of this report.

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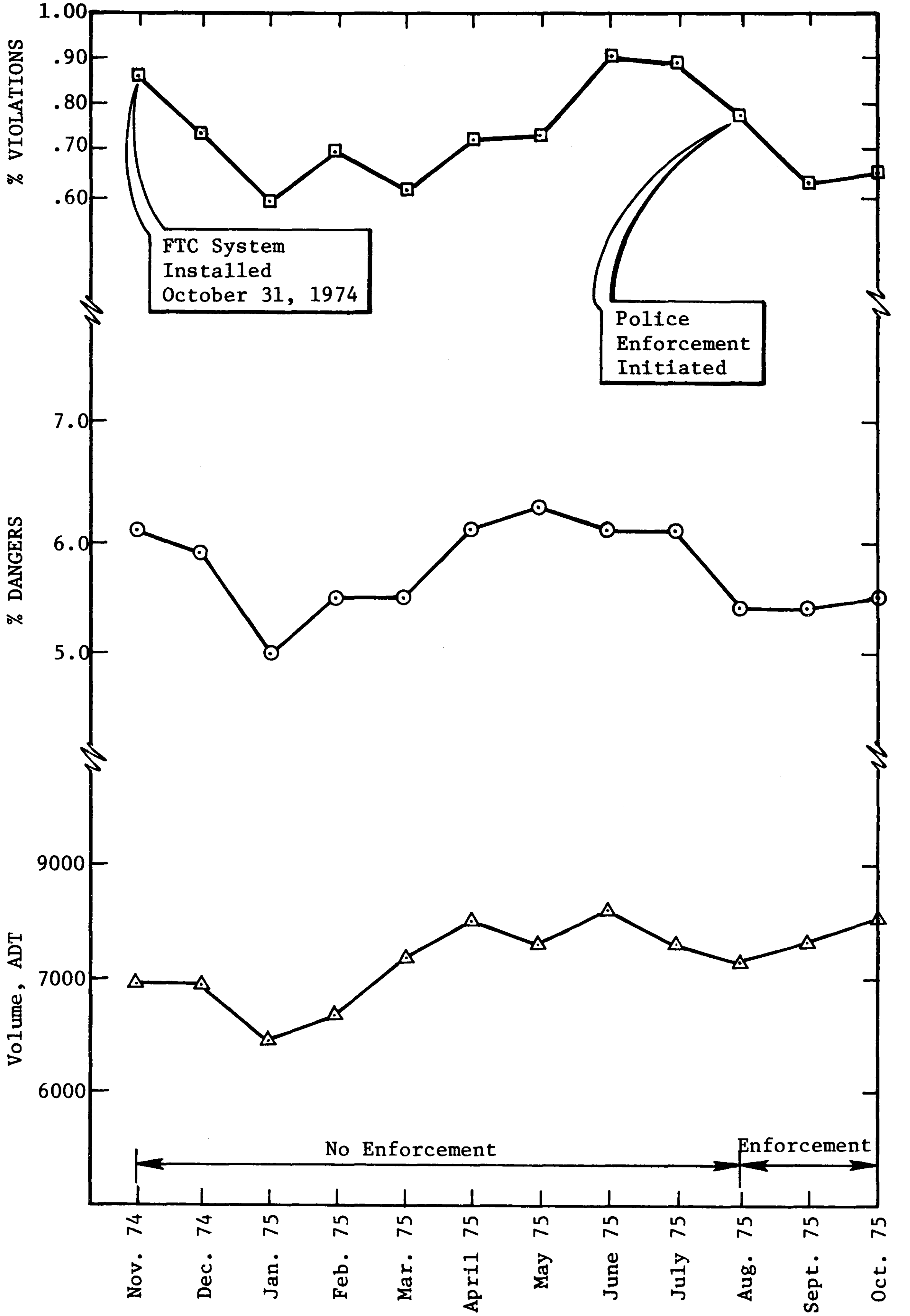

Figure 7. Monthly volume, DANGER, and VIOLATION relationships for FTC site NB 3, **right** lane.

Vehicle Spacing and Accident Correlations

The FTC system was designed on the hypothesis that if vehicle spacings were increased to a safe interval, there would be a reduction in accidents. Consequently, a linear correlation analysis was performed to determine if a correlation existed between the average percentage of DANGERS or VIOLATIONS per month (as determined by using the mean readings taken from all ten counters) and the number of accidents reported each month for the study area. A similar analysis was made with spacing intervals vs. rear end accidents; and as the number of accidents are often dependent on volume, the accident rate was compared to the percentages of DANGER intervals and VIOLATIONS. The results of these analyses are given in Table 12.

Table 12

Correlation Indices for Vehicle Spacings and Accidents

Category	% Dangers	% Violations
No. Accidents	0.06	0.04
Rear End Accidents	0.04	0.01
Accident Rate	0.07	0.08

The low correlation indices (values of R^2) indicate that there is no reason to believe the percentage of motorists following too closely (in either the DANGER or VIOLATION interval) for any given month can be associated with the number of accidents or accident rate per month. The coefficients were tested using the t statistic and they were not significant at the 95% level ($\alpha = 0.05$). It should be noted that the results of this analysis suggest that there is no linear correlation between unsafe vehicle spacings and accidents, but it is possible that a nonlinear relationship exists.

Hasty conclusions should not be drawn from this analysis. There are several possible sources of error that should be considered. Perhaps the most notable weakness is that the spacing intervals were measured at only 10 points on 6 miles of highway. There was considerable variation in vehicle spacings at each monitor site and the average reading may not be a proper indicator for the entire study area. Furthermore, the relationships between following too closely and accidents are probably more complex than the simple correlation suggested here. To reduce these possibilities for error, a similar correlation analysis was conducted for the NB 3 monitor site and the results are given in Table 13.

Table 13

Correlation Indices for Vehicle Spacings and Accidents for NB 3

Category	% DANGERS	% VIOLATIONS
0.5 mile downstream		
No. Accidents	0.22	0.17
Accident Rate	0.22	0.16
1.0 mile downstream		
No. Accidents	0.16	0.13
Accident Rate	0.16	0.13
1.91 mile downstream		
No. Accidents	0.10	0.03
Accident Rate	0.09	0.03

Several comments are generated by Table 13. Although all of the coefficients were not significant, which indicates little or no linear correlation between unsafe vehicle spacing and accidents, the best correlation occurs within a 0.5-mile distance downstream from the monitor. Also, the correlations 0.5-mile downstream are much greater than those found on an area-wide basis. This observation gives some credence to the hypothesis that there may be an association between following too closely and accidents. This subject will be explored in more detail before the final report is completed.

Effects of Police Enforcement

During the first 9 months after the FTC monitors were installed (November 1974 through July 1975), the Prince William County police did not use them to enforce the following too closely law. As shown previously in Figure 7, without enforcement the readings at the monitor site decreased for the first few months (vehicle spacing increased), then slowly increased until May, when they were similar to the readings taken in November 1974. Throughout

May, June, and July 1975, the percentages of DANGER and VIOLATION readings sometimes exceeded the November readings. Throughout August 1975, the Prince William County police spent 11 man-hours specifically issuing 18 warning citations for following too closely.[13] In September and early October, 28 arrests were made. As noted in Figure 7 the percentages of VIOLATION and DANGER readings declined and were equal to or below the November 1974 readings. Similar results were noted for the other nine monitors.

A comparison of the maximum effectivenesses of the FTC monitors with and without enforcement, based on the FTC counter readings taken from November 1974 through October 1975, is given in Table 14 for the right lane monitors and Table 15 for the left lane monitors.

Several important relationships are illustrated in Tables 14 and 15. First, before FTC operations the section of Route 1 0.31 mile south of the signalized intersection of Route 1279 (the site for monitor SB 2), had the highest incidences of following too closely on both of the southbound lanes. A section 0.51 mile north of a signalized intersection (the site for monitor NB 3), had the second highest danger and violation rates. These sections also had the best improvement records both with and without police enforcement. Thus, it appears that signalized intersections tend to create queues that encourage motorists to follow too closely and the FTC monitors are more effective in increasing vehicle spacings in these areas. Note, however, that the incidences of following too closely were fewer at locations further downstream from traffic signals (NB 1 and NB 2), probably because of the dispersion effect of the queues. Due to repairs on the Occoquon River Bridge and subsequent changes in traffic, the data in SB 1 should not be accepted without a detailed analysis, which is beyond the scope of this report. SB 1 data do suggest that similar to the queuing effect created by signals, highway constrictions (4 lanes reduced to 2) also can be related to high incidences of following too closely. It is also interesting to note that at every site the percentage of VIOLATIONS in the left traffic lane (inside lane) was approximately twice the percentage of VIOLATIONS in the right lane (outside lane). Whether this finding holds for most 4-lane undivided highways is unknown at this time, but will be investigated further.

Based on an analysis of the FTC counter readings there were only minor differences in the reductions of motorists in the danger interval (0.7 to 1.20 seconds) induced by the monitor alone and the monitor coupled with police enforcement. There was, however, a greater reduction in the VIOLATION rate with enforcement.

Table 14

Maximum Effectiveness of FTC Monitors With and Without Police Enforcement
Right Lane

Site	Area	Annual ADT	% Dangers					% Violations				
			Nov. 1974	No. Enfor.	% Red	With Enfor.	% Red	Nov. 1974	No. Enfor.	% Red	With Enfor.	% Red
1 NB	Rural	5,090	3.19	2.49	21.9	2.42	24.1	0.54	0.34	37.0	0.28	48.1
2 NB	Rural	5,163	3.15	2.72	13.7	2.53	19.7	0.47	0.27	42.6	0.23	51.1
3 NB	Suburban	7,172	6.12	5.00	18.3	5.40	11.8	0.86	0.59	31.4	0.64	25.6
1 SB	Suburban	7,689	6.26	5.20	16.9	4.86	22.4	0.70	0.56	20.0	0.48	31.4
2 SB	Suburban	7,249	7.72	5.56	28.0	6.09	21.1	1.39	0.88	36.7	0.78	43.9

Data based on FTC counter readings taken from November 1, 1974 to October 31, 1975.

Table 15

Maximum Effectiveness of FTC Monitors With and Without Police Enforcement
Left Lane

Site	Area	Annual ADT	% Dangers					% Violations				
			Nov. 1974	No. Enfor.	% Red	With Enfor.	% Red	Nov. 1974	No. Enfor.	% Red	With Enfor.	% Red
1 NB	Rural	2,148	3.16	2.51	20.6	2.92	7.6	1.13	0.74	34.5	0.71	37.2
2 NB	Rural	2,303	3.34	2.91	12.9	3.12	6.6	0.73	0.57	21.9	0.51	30.1
3 NB	Suburban	4,396	4.94	4.13	16.4	4.48	9.3	1.38	0.96	30.4	0.81	41.3
1 SB	Suburban	3,567	5.30	3.14	40.8	5.24	1.1	0.91	0.75	17.6	0.77	15.4
2 SB	Suburban	4,675	9.23	8.12	12.0	7.16	22.4	2.39	1.56	34.7	1.29	46.0

Data based on FTC counter readings taken from November 1, 1974 to October 31, 1975.

The effects of the FTC monitor with and without police enforcement also influenced the incidences of accidents. This influence is shown in Figure 8 and Table 16. In Figure 8 the general decline in monthly accidents following installation of the monitors is vividly displayed. The figure also shows that the numbers of accidents reported during January and February 1975 were well below those for all other months, with the exception of April 1975. Also, it was in this time period that the lowest levels of danger and violation readings for the FTC sites were recorded. Note also that similar to the increases in the following too closely, accidents increased during May, June, and July 1975, which indicated that the monitors may have been losing their effectiveness in reducing incidences of following too closely and accidents. During July 1975, when accidents increased 15%, as noted in Table 16, it was decided to use police enforcement. During August, FTC warning tickets were issued, and in September and early October, 1975, citations were given. As discussed earlier, following police enforcement, the counter readings indicated significant reductions in the incidences of following too closely. This minimal police enforcement also had a pronounced effect on reducing accidents, as is illustrated in Figure 8 and Table 16. For August 1975, accidents were 44% below the August 1974 level.

Although the vehicle spacing and accident data can be used to show the changes induced by the FTC monitors with and without police enforcement, the data do not explain why the changes occurred. The following hypothesis is offered as one possible explanation of this phenomenon.

As 85% of the motorists in the Woodbridge area are Virginia residents, it is reasonable to assume the majority of motorists on Route 1 use this highway nearly every day for work and shopping trips. As these motorists were continuously exposed to the FTC monitors, they began ignoring the message and the effectiveness of the system declined. As a result of the police enforcement, beginning in August 1975, motorists realized that there was a penalty associated with an FTC violation and improved their driving behavior. As enforcement decreased in late October 1975, FTC violations again began to slowly increase.

The effects of enforcement on driver behavior were recently investigated by Cooper.[14] Perhaps the most significant finding was that a modest enforcement campaign influenced significant driver behavior improvement but increased enforcement only slightly reduced driver violations.[14] Thus, it would appear that a minimal amount of police enforcement would provide more efficient use of enforcement officers and have significant effects in improving driver behavior. Further research is desirable to determine how much police enforcement is needed to sustain the beneficial effects of the monitors.

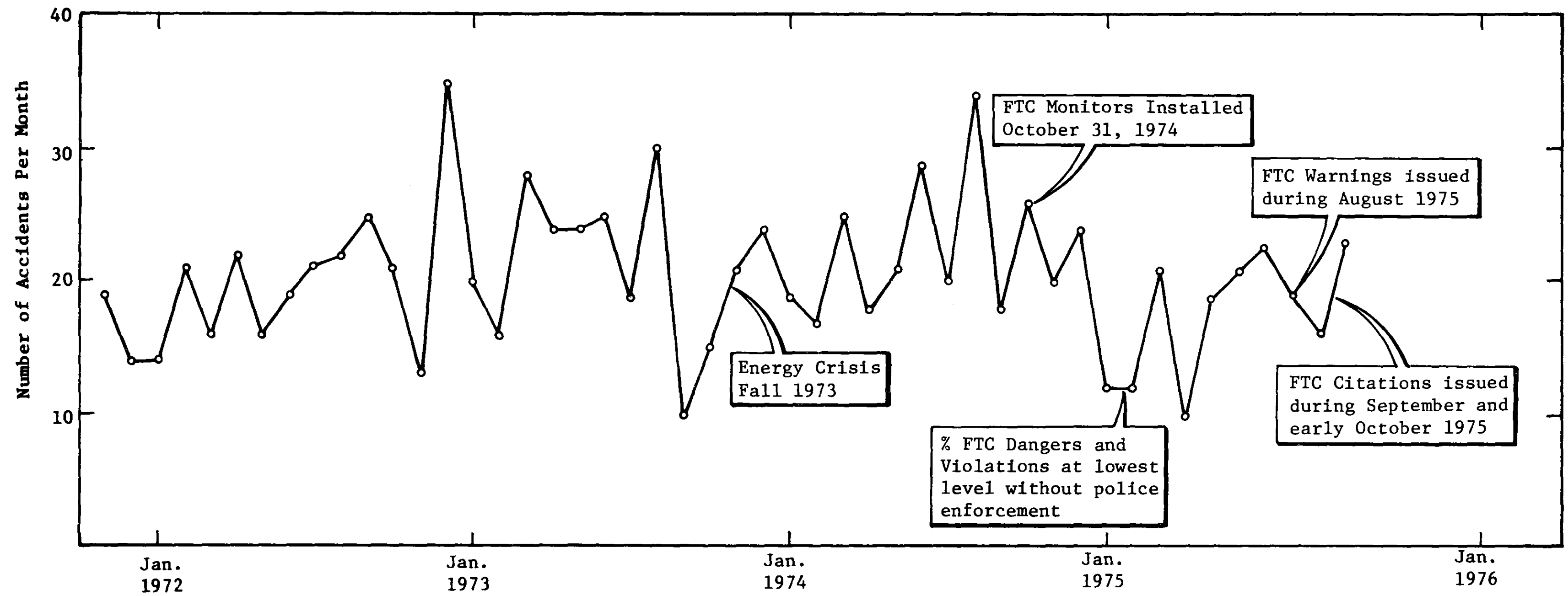

Figure 8. Effects of the FTC monitors and police enforcement on monthly accident trends.

Table 16

Woodbridge Monthly Accident Summary

Month	Before FTC			After FTC 1974-1975	% Change	Status of Police Enforcement
	71-72	72-73	73-74			
November	19	13	21	20	- 4.8	No Enforcement
December	14	35	24	24	0	
January	14	20	19	12	-36.8	
February	21	16	17	12	-29.4	
March	16	28	25	21	-16.0	
April	22	24	18	10	-44.4	
May	16	24	21	19	- 9.5	
June	19	25	29	21	-27.6	
July	21	19	20	23	+15.0	
August	22	30	34	19	-44.1	Enforcement
September	25	10	18	16	-11.1	
October	21	15	26	23	-11.5	
TOTAL	230	259	272	220	-19.1	

After the last summonses were issued in early October 1975, the Prince William County police did not specifically assign officers to enforce VIOLATION of the FTC monitors. Enforcement is continuing but only to the extent that if a regularly assigned patrolling officer is a witness to an FTC violation, either as a result of the monitor indication or through personal judgment, he will issue a ticket. This type of enforcement is minimal and has been in effect for only a few months. Thus, at this time, it is not possible to evaluate the effectiveness of this enforcement procedure.

It should be noted that the Prince William County judge did not accept following too closely violations as denoted by the monitors as prima facie evidence. Although police officials may have been alerted to a motorist following too closely by the monitor, before the judge would consider the case, the arresting officer must have witnessed the event and judged that the motorist was not following at a reasonable and prudent distance.

Driver Reactions

As mentioned in the Methodology section of this report, observations and movies to determine initial driver reactions to the monitor system were made on October 31, 1974 (first day of operation). Additional observations were made during July 1975 (9 months after the monitors were installed) to determine changes in behavior.

A general conclusion from the observations made during the first day of operation was that most drivers who were following too closely (less than 0.70 second gap time) reacted to the system by applying their brakes (as evidenced by taillights) to increase their spacing intervals. Other behavior or erratic maneuvers were not observed. Only a few of the motorists who activated the danger warning (gap time between 0.70 and 1.25 seconds) displayed any observable reaction to the system. This perhaps suggests that the audible warning during an FTC violation may be a more effective message to the motorist than the flashing sign.

Based on the observations made in July 1975, only a very few drivers showed any reaction to the FTC DANGER or VIOLATION warnings. This finding further supports the previously cited evidence that the counters were losing their effectiveness and police enforcement was desirable to provide continuing benefits from the system.

Of the 220 accidents analyzed for the year of FTC operation only a few occurred in the vicinity of the four monitor sites. The accident reports indicate no evidence of a single case in which a driver may have been involved in an accident at a result of reacting to the FTC system.

FTC Equipment

The ability of the FTC system to accurately measure gap time was periodically checked by electronic technicians. On most occasions the equipment was found to operate well within predetermined gap tolerance levels. The major problems experienced were with electrical shorts caused by moisture in an underground detector cable, burned out photocells, and transformer power failures. As the device was experimental, problems of this nature were anticipated. By replacing the initial underground cable with a heavy duty one, the moisture problem was eliminated. An annual bulb replacement schedule should reduce the chances of a monitor becoming inoperative due to bulb failure. Transformer failure was not related to the FTC system, but to the power company. A record was kept on the failure of each monitor and the data are summarized in Table 17. The data were determined from weekly counter readings; thus, the days lost are only approximations.

Table 17

FTC Equipment Failures
(October 31, 1974 through March 1, 1976 = 486 days)

Site	Right Lane			Left Lane		
	No. Failures	Days Lost*	% Time Lost	No. Failures	Days Lost*	% Time Lost
1 NB	2	50	10	3	74	15
2 NB	None	None	None	None	None	None
3 NB	3	44	9	3	32	7
1 SB	2	54	11	3	26	5
2 SB	5	66	14	1	6	1

*Approximate only; estimated from weekly readings.

Generally, installation and maintènance of the FTC system did not create any difficult problems for Department employees. During the 14-month period from November 1974 through January 1976, a total of $1,686.95 was expended as labor and vehicle expenses for maintenance of the system. In addition, $50.90 was spent for materials, most of which resulted from problems with the underground cable. Now that this problem apparently has been solved, future maintenance costs should be lower than those for the experimental period.

Benefit-Cost Factors

Based on the results of the Woodbridge study, the most immediate, and perhaps most important, benefit from the use of the FTC monitors was a reduction in accidents. Other benefits derived were reductions in court costs, hospital expenses, and insurance premiums (from a reduction in accidents). However, in this evaluation the only benefits considered were direct savings in accident reduction. The only costs included were those for materials, labor and maintenance.

Benefit-cost analyses for highway safety improvement projects are generally based on comparisons of annual benefits to annual costs. The annual benefits and costs are usually empirically derived by measuring the savings and costs over the effective life of the improvement (period of time until the improvement is no longer effective in reducing accidents). However, for the FTC project the period of effectiveness is unknown as only 1 year of after data are available. Thus, there are several ways the benefit-cost can be viewed.

One is to compare the direct benefits and costs after one year of study as follows:

$$\frac{\text{Benefit}}{\text{Cost}} = \frac{\text{1st year savings due to reduction in accidents}}{\text{material, labor and maintenance costs}}$$

$$\frac{\text{Benefit}}{\text{Cost}} = \frac{\$4{,}000\ (I_B - I_A) + (PD_B - PD_A)}{I_c + M_c}$$

where

I_B = No. persons injured before FTC = 131

I_A = No. persons injured after FTC = 100

PD_B = Property damage before FTC = \$220,000

PD_A = Property damage after FTC = \$197,000

I_c = Initial project cost = \$63,928

M_c = 12-month maintenance cost = \$1,490

NOTE: \$4,000 = cost of nonfatal disabling injury. (Data from the National Safety Council.[15])

Therefore,

$$\frac{\text{Benefit}}{\text{Cost}} = 2.25/1$$

In other words, after the first year of operation, benefits due to savings in accidents were more than double the costs of the project. If consideration is given to the projected accident trend shown in Figures 2 and 3, the benefit-cost ratio would be 2.95/1 based on the procedure outlined above. Assuming an effective life of 3 years, and considering a 7% increase in traffic with a 5% rate of interest, the benefit-cost ratio is 10/1 (see reference 16 for details of analysis).

While other assumptions will generate different ratios, the benefits in accident savings have far exceeded the costs of the FTC monitors.

SUMMARY OF FINDINGS

The results of the 1-year before and after study of the following too closely monitors are summarized below.

1. Although the traffic volume increased by 7% after installation of the monitors, total accidents were reduced by 25.7%, injury accidents by 34.0%, and property damage accidents by 21.9%. The reduction in accidents was statistically significant.

2. The reduction in accidents was uniformly distributed among all types of crashes, including rear end crashes.

3. The monitors located in the suburban areas within 0.5 mile downstream of traffic signals were more effective in reducing accidents and incidences of following too closely than were the monitors in rural areas.

4. Based on the results of radar speed studies at three sites, the FTC monitors did not significantly affect traffic speeds.

5. The monitors significantly increased the spacings of motorists following too closely at the monitor sites for a 3- to 5-month period without the aid of police enforcement.

6. After 9 months of operation, the FTC monitors appeared to begin to lose effectiveness in increasing vehicle spacings and reducing accidents.

7. During the 10th month of operation, 11 police man-hours were spent issuing warning citations for following too closely, and as a result, accidents decreased 44% and the spacings increased significantly.

8. Significant correlations found were not between monthly accident and vehicle spacing data on an areawide basis.

9. The preliminary analysis indicates that there may be correlations between accidents and vehicle spacing for areas immediately downstream from the FTC monitors.

10. There was no evidence that motorists reacted in an erratic manner to the FTC DANGER or VIOLATION signals.

11. Based on 1 year of FTC operation, direct savings in accident reduction compared to project costs, including maintenance expenditures, resulted in a benefit-cost ratio of 2.2/1.

CONCLUSIONS AND RECOMMENDATIONS

It is unfortunate that the relationship between following too closely and accidents has not been thoroughly investigated. The analyses of data collected during this study indicate the effects of following too closely on accidents have been underestimated.

As demonstrated with the use of the FTC system, a program that effectively reduces the number of short vehicle gaps can significantly reduce accidents. The assumption that following too closely is primarily a major causal factor only in rear end accidents does not appear to be accurate. It is possible, however, that once a driver is informed that he is following too closely, he will not only increase his following distance but will improve his overall driving performance.

Until an analysis of all traffic flow data is completed, final conclusions for this experimental study cannot be made. Based on the analysis of accident and vehicle spacing data conducted for this interim report, it is apparent that the long-term effectiveness of the FTC monitors in reducing accidents and incidences of following too closely is limited without some form of minimal police enforcement. However, the type and amount of enforcement needed is unknown. In August 1975, 11 police man-hours were used to enforce FTC violations. This effort significantly affected vehicle spacings and accidents. It is possible that fewer hours would have similar effects.

To allow determination of the relationship between enforcement of following too closely and accident reductions, it is recommended that the project be continued to include a program of specific police man-hours or monthly citations for following too closely. This additional study would involve minimal expenditure for police officials and the Department. Data collection would include continuing the weekly FTC counter readings (approximately 4 man-hours per month), collection of accident data, and a few hours of police enforcement per week.

The reduction in accidents on Route 1 achieved by the use of the FTC system is encouraging. Unfortunately, the analyses of the data presented in this report, perhaps, generated as many questions as were answered. For example, would the system be cost effective if police enforcement were used? Is enforcement manpower available? Will minimal enforcement sustain long-term accident reductions? Would changes in the sign shapes, size, or message or number of signs enhance the effectiveness of the system? Determination of these factors as well as many others can best be made by a continued research effort.

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