Effect of Guardrail in a Narrow Median Upon Pennsylvania Drivers

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A study has been performed to identify and evaluate changes in traffic behavior resulting from the erection of a barrier on a 4-ft median of a divided highway.

Using the Traffic Analyzer, vehicular speed, lateral placement and clearance were measured both before and after the erection of a median barrier on the Schuylkill Expressway.

Analysis of "before" and "after" data showed that median lane vehicular placements were shifted to the right by as much as 0.5 ft after barrier installation. As a result, clearance between adjacent vehicles was reduced by as much as 0.4 ft.

The presence of the median barrier did not cause any reduction in vehicular speeds or densities; therefore, the median barrier did not cause a reduction in capacity.

A hypothetical model was used to determine the effect of the observed clearance reduction on the safety or allowable tolerances afforded the driver in the passing or lane-changing maneuver. The results of this investigation coupled with other observations led to the conclusion that although the median barrier does have a measurable effect on traffic flow characteristics, it is not of an adverse nature with respect to the movement of vehicles.

To investigate the safety aspect in this work an accident study was conducted to determine further the implications of median barrier installation. The accident study results present a guide to possible outcomes of median barrier construction. Due to the approximations and assumptions inherent in the analysis, all conclusions should be carefully examined before applied to any particular expressway.

•MODERN HIGHWAY design standards emphasize the importance of providing adequate clearance to any fixed objects along the traveled way. One major exception to this practice is the installation of a raised barrier on narrow medians separating opposing flows of traffic. This study identifies and evaluates changes, if any, in traffic behavior resulting from the erection of a median barrier. Although the virtues and warrants for median barrier installation are not treated in this paper, the results herein presented may shed additional light on the subject.

FLOW CHARACTERISTICS

Description of Study

At the inception two basic study approaches were considered. The first examined facilities similar in geometric design and traffic load but different in that one had a median barrier and the other did not. The second approach studied the same facility both before and after median barrier construction. Since erection of a median barrier

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was already scheduled on the Schuylkill Expressway, a heavily traveled divided highway with a predominantly narrow median, connecting the Pennsylvania Turnpike and the western suburbs of Philadelphia with downtown Philadelphia, the latter approach was selected as the study technique.

After a preliminary survey, four sites were selected for study, three on four-lane divided sections, and the fourth on six-lane divided. All lanes were 12 ft wide, composed of portland cement concrete. In each case the median was 4 ft wide and of the mountable concrete type. Figure 1 is a typical median cross-section showing the steel median barrier with broken lines.

For the remainder of this study all reference will be made by location number, each site being composed of two locations, one in each direction of traffic. A description of each location is given in Table 1 and illustrated in Figures 2 through 5.

With the cooperation of the U. S. Bureau of Public Roads "before" data were successfully obtained at five locations during March 1962 using the Traffic Analyzer. In August 1962, several weeks after the median barrier installation was completed, "after" data were collected at the same locations. All measurements were performed during daylight hours and in fair weather. Several thousand vehicles were observed in each traffic lane incorporating either the AM or PM peak movements.

The Traffic Analyzer is an instrumented van capable of automatically recording in digital form on printed paper tapes by means of detectors placed across the roadway. It recorded the arrival time, speed and lateral placement for each vehicle in one to

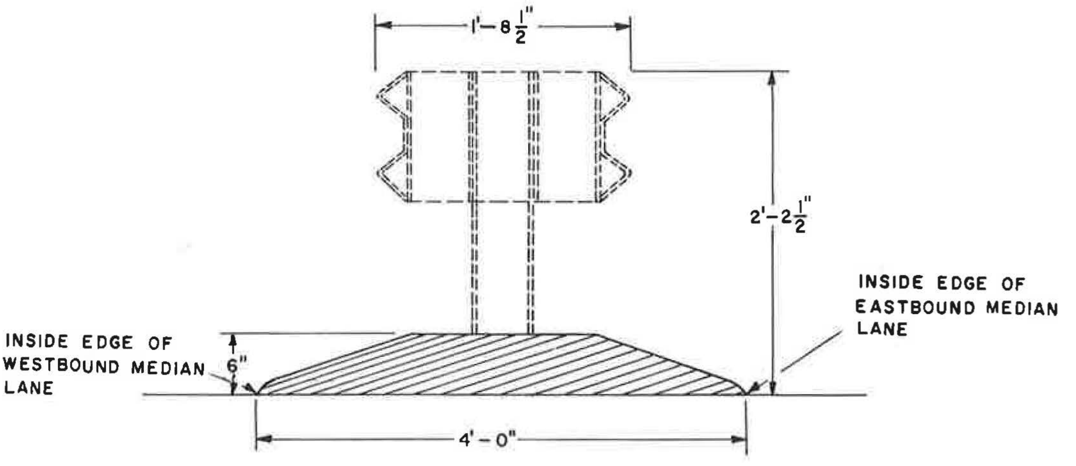

Figure 1. Typical median cross-section.

TABLE 1

Location No.	Station No.	Direction of Traffic	Median Width (ft)	No. of Lanes	Lanes Width (ft)	Alignment	Shoulder Width (ft)	Shoulder Type	Edge of Shoulder	Speed Limit (mph) Car	Speed Limit (mph) Truck
1	219+00	EB	4	2	12	Tangent	12	Gravel	3-cable guard-rail	60	50
2	467+00	WB	4	2	12	Tangent	12	Gravel	Slight embankment	60	50
3	467+00	EB	4	2	12	Tangent	10	Gravel	Steep embankment	60	50
4	110+00	EB	4	3	12	Curve, 2° 20′	8	Gravel	3-cable guard-rail	50	50
5	523+00	WB	4	2	12	Curve, 2° 20′	8	Gravel	3-cable guard-rail	60	50

Figure 2. Location 1, setting up the equipment.

Figure 3. Locations 2 and 3.

Figure 4. Location 4.

Figure 5. Location 5.

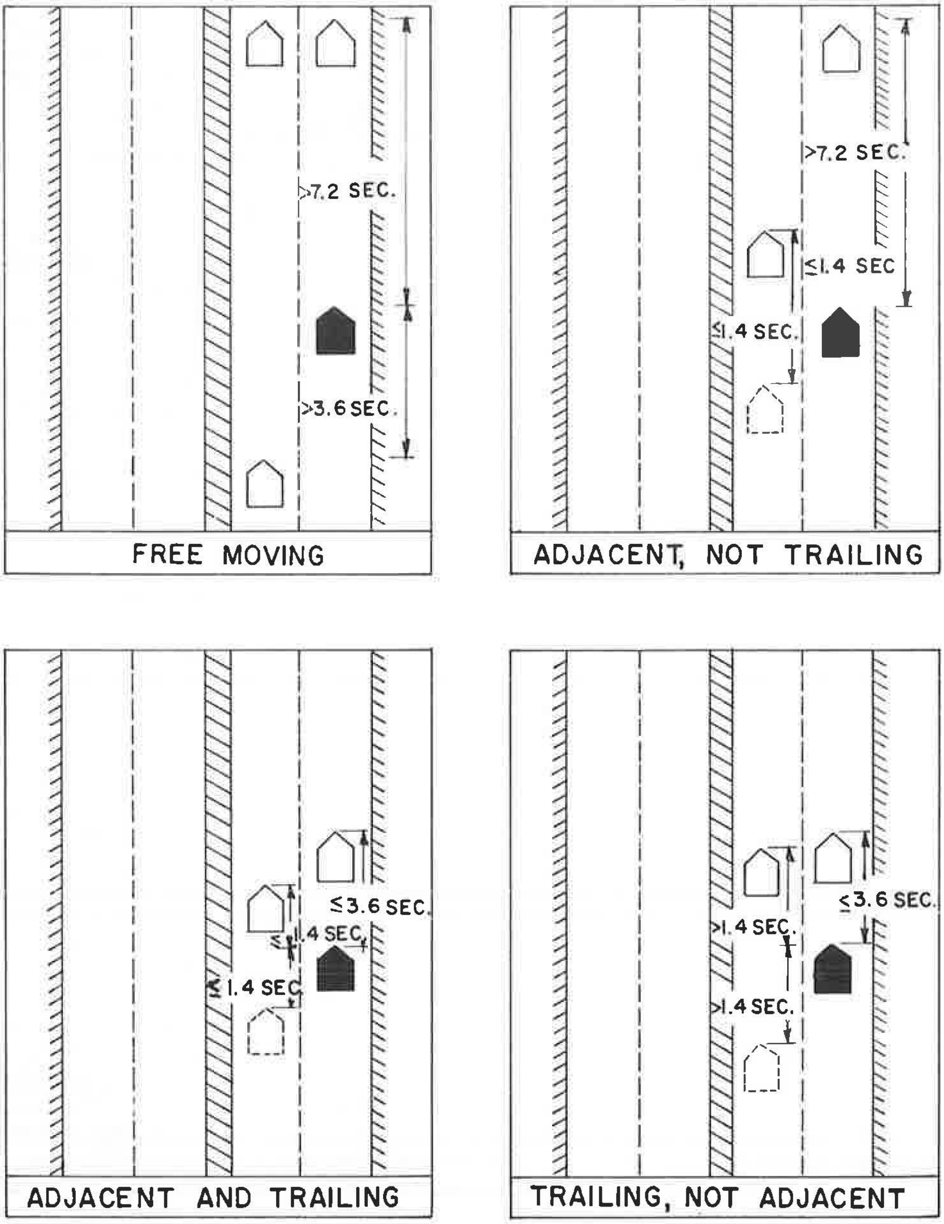

Figure 6. Different traffic maneuvers.

four separate lanes of traffic. In addition, vehicle classification is accomplished by manual recording and coding by means of push buttons. For vehicles other than passenger cars, recording is made on the same printed line as the other data for the vehicle as each vehicle crosses the detectors. The data for each lane of traffic are recorded on a separate tape, one line per vehicle (1).

After the field data were edited in the offices of the U. S. Bureau of Public Roads to confirm accuracy of the data recording, they were forwarded to the Pennsylvania Department of Highways along with two IBM 650 computer programs. Basic data cards were then punched from the data on each roll of tape. The first program used the basic data cards as input and produced as output a deck in which the speed and placement data, originally recorded in coded format, were presented in true form. The intermediate output decks for each lane at each location were merged in ascending arrival time sequence and then used as input for the second program. In this program, traffic in each lane was examined with respect to traffic in the other lane(s) at the location. The final output deck, one card for each vehicle in each lane at each location, contained the speed, placement, clearance between adjacent vehicles and traffic maneuver.

Each vehicle was classified (Fig. 6) in one of five types of traffic maneuvers with respect to nearby vehicles, as follows:

1. Free moving—vehicles more than 20 units of time (7.2 sec) behind a vehicle in any lane and more then 10 units of time (3.6 sec) ahead of a vehicle in the other lane(s).[1]
2. Adjacent, not trailing—vehicles more than 20 units of time (7.2 sec) behind a vehicle in the same lane but within 4 units of time (1.4 sec) either ahead of or behind a vehicle in the other lane(s).
3. Adjacent and trailing—vehicles within 10 units of time (3.6 sec) behind a vehicle in the same lane and also within 4 units of time (1.4 sec) either ahead or behind a vehicle in the other lane(s).
4. Trailing, not adjacent—vehicles 10 units of time (3.6 sec) or less behind a vehicle in the same lane but more than 4 units of time (1.4 sec) either ahead or behind a vehicle in the other lane(s).
5. All others—vehicles not classified in any of the previous categories.

For purpose of analysis, vehicle classification recorded in the field using nine separate categories was simplified, yielding two basic types of vehicles: all automobiles and two-axle, four-wheel, single-body trucks were classified as passenger cars (PC); all three-, four- and five-axle trucks, cars pulling trailers, buses, etc., were classified as commercial vehicles (CV).

Analysis of Data

In a first investigation an IBM 407 accounting machine was used to prepare frequency distributions separately for passenger cars and commercial vehicles in each lane studied for all vehicle placements and the average speed in each placement group. Similarly frequency distributions of vehicle speeds and average placement in each speed group were also constructed. In addition, average speeds and average placements were calculated for vehicles in each type of traffic maneuver. All sites are summarized in Table 2. All placement values tabulated are the distance from the center of the vehicle to the right-hand lane line measured to the nearest 0.01 ft.

As can be seen from Table 2, the presence of the median barrier did not have a uniform effect at all locations. Differences in the values of average speed and average placement, statistically significant at the 0.01 level except for commercial vehicles traveling in the median lane at two-lane locations, ranged from +5.0 to -0.5 mph and from +0.5 to -0.4 ft, respectively (a positive difference in speed indicating an increase in speed after the median barrier was installed and similarly a positive difference in placement representing a shift to the right). Statistical significance was ascertained by comparing the difference between means with the standard error of the difference.

In general, the "after" studies revealed higher average speeds and higher 85 percentile speeds than the "before" studies. A feeling of increased security induced by the presence of the median barrier may explain the speed increase. A lack of consistency between change in speed and change in placement discourages any general relationship to be formed although it would be possible to find the best straight-line fit.

At four locations the change in placement was more pronounced for vehicles traveling in the median lane than for that of vehicles traveling in the shoulder lane. The exception was Location 3 at which the average passenger car placement in the shoulder lane shifted 0.2 ft to the left after median barrier construction and the average passenger car placement in the median lane remained constant. At Location 3, an additional

[1] One unit of time equals one-ten-thousandth of an hour.

TABLE 2

SUMMARY OF SPEED-PLACEMENT DATA

Location	Lane	Vehicle Type	Before Barrier Avg. Speed (mph)	Before Barrier Avg. Placement (ft)	After Barrier Avg. Speed (mph)	After Barrier Avg. Placement (ft)
1	Shoulder	PC	52.8	6.7	57.0	6.7
1	Shoulder	CV	49.4	6.1	51.8	6.1
1	Median	PC	61.8	5.9	63.6	5.7
1	Median	CV	59.2[1]	5.3[1]	58.7[1]	4.9[1]
2	Shoulder	PC	49.2	6.6	54.2	6.7
2	Shoulder	CV	43.1	6.2	47.2	6.1
2	Median	PC	55.3	6.0	59.7	5.6
2	Median	CV	51.0[1]	5.8[1]	54.9	5.4
3	Shoulder	PC	53.2	6.3	53.9	6.5
3	Shoulder	CV	47.5	6.0	48.8	6.3
3	Median	PC	58.0	5.7	57.8	5.7
3	Median	CV	53.2[1]	5.5[1]	54.8	5.7
4	Shoulder	PC	43.5	7.4	45.7	7.4
4	Shoulder	CV	40.4	6.9	43.2	7.0
4	Middle	PC	45.2	7.0	48.4	7.4
4	Middle	CV	44.5	6.6	47.1	6.7
4	Median	PC	46.9	6.8	49.3	6.3
4	Median	CV	46.0	6.4	48.0	5.9
5	Shoulder	PC	51.4	5.8	54.2	5.7
5	Shoulder	CV	47.1	5.5	49.5	5.6
5	Median	PC	56.4	5.2	58.1	4.8
5	Median	CV	53.5	5.2	55.4	5.0

[1] Sample size less than 50.

1½ hr of data for the "after" study were used (4-hr "after" compared to 2½-hr "before"). Lighter volumes during much of this period might account for some of the shift to the left. The increased opportunity for passings to occur might also be a factor. Commercial vehicle placements in each lane also shifted to the left. A possible explanation for this initially unexpected behavior lies in the fact that the location is in cut with an embankment rising at approximately 60 degrees from the edge of the 10-ft shoulder. The security of the median barrier separating opposing traffic may have caused the leftward shift away from the more "constriction-inducing" embankment.

Both Locations 2 and 5 experienced a 0.4-ft average placement shift to the right for passenger cars in the median lane. This represented the maximum placement shift at two-lane locations. At Location 2 passenger car placements in the shoulder lane shifted 0.1 ft to the left and at Location 5, 0.1 ft to the right. Location 2 had 1½ hr more data in the "after" phase than in the "before," and also the time period 4:24 - 4:42 PM appears to show the effect on the shoulder lane of a police car and a truck parked on the shoulder. Removing these data probably would change the result noted.

The most unexpected change in placement occurred in the middle lane of Location 4. After median barrier construction, average placements for passenger cars and commercial vehicles shifted 0.4 and 0.3 ft to the left, respectively. At the same time both passenger car and commercial vehicle average placements in the median lane shifted 0.5 ft to the right. A careful examination of the placement distribution for this lane revealed that one of the placement detector sections was not functioning. If the distribution is smoothed, it is evident that the tabulated placement change represents a systematic error and should be discounted. Therefore, only speed data have been interpreted as valid at this location and lane.

The data for all locations support the conclusion that rightward shifts in the median lane vehicle placements have little effect in inducing similar displacements in the adjacent lane.

Separate frequency distributions of clearance between vehicle bodies and average speed in each clearance group were then prepared for passenger cars and commercial vehicles in each lane that were classified in an adjacent traffic maneuver with respect to vehicles in the contiguous lane. In the case of the middle lane of the three-lane location a vehicle was classified as adjacent to either a vehicle in the median or shoulder lane according to which was closer in time. For each lane the average speeds, placements and clearances were calculated for vehicles adjacent to other vehicles and then separately for each of the two types of adjacent traffic maneuvers. Sample clearance data are summarized for all sites in Table 3. Clearance values are measured to the nearest tenth of a foot. A positive change in placement indicates a shift to the right; a negative change in clearance indicates a decrease. Small sample sizes should be

TABLE 3

SUMMARY OF CLEARANCE DATA FOR ALL VEHICLES ADJACENT TO OTHER VEHICLES

Location	Lane	Description	Before Barrier			After Barrier			Change in	
			Avg. Speed (mph)	Avg. Placement (ft)	Avg. Clearance (ft)	Avg. Speed (mph)	Avg. Placement (ft)	Avg. Clearance (ft)	Placement (ft)	Clearance (ft)
1	Shoulder	PC adjacent to PC in median lane	51.6	6.5	5.5	55.1	6.4	5.6	+0.1	+0.1
1	Shoulder	PC adjacent to CV in median lane	49.7[a]	6.2[a]	4.2[a]	49.3[a]	5.8[a]	4.0[a]	+0.4[a]	-0.2[a]
1	Shoulder	CV adjacent to PC in median lane	49.3	6.1	5.3	51.3	6.0	5.0	+0.1	-0.3
1	Shoulder	CV adjacent to CV in median lane	49.9[a]	6.0[a]	4.5[a]	46.9[a]	5.7[a]	3.7[a]	+0.3[a]	-0.8[a]
1	Median	PC adjacent to PC in shoulder lane	61.6	6.0	5.6	63.6	5.8	5.5	+0.2	-0.1
1	Median	PC adjacent to CV in shoulder lane	61.4	6.2	5.3	63.0	6.0	4.8	+0.2	-0.5
1	Median	CV adjacent to PC in shoulder lane	59.6[a]	5.6[a]	4.3[a]	61.1[a]	4.3[a]	3.4[a]	+1.3[a]	-0.9[a]
1	Median	CV adjacent to CV in shoulder lane	61.8[a]	5.6[a]	3.9[a]	57.3[a]	5.5[a]	3.6[a]	+0.1[a]	-0.3[a]
2	Shoulder	PC adjacent to PC in median lane	47.2	6.3	5.9	52.7	6.5	5.4	-0.2	-0.5
2	Shoulder	PC adjacent to CV in median lane	41.8[a]	6.0[a]	5.3[a]	49.5[a]	6.0[a]	5.2[a]	0.0[a]	-0.1[a]
2	Shoulder	CV adjacent to PC in median lane	42.1	6.1	5.2	47.0	6.0	5.1	+0.1	-0.1
2	Shoulder	CV adjacent to CV in median lane	40.0[a]	6.6[a]	3.7[a]	45.1[a]	6.0[a]	5.2[a]	+0.6[a]	+1.5[a]
2	Median	PC adjacent to PC in shoulder lane	55.1	6.1	5.9	60.1	5.7	5.5	+0.4	-0.4
2	Median	PC adjacent to CV in shoulder lane	54.3	6.2	5.2	58.1	5.9	4.9	+0.3	-0.3
2	Median	CV adjacent to PC in shoulder lane	52.9[a]	5.9[a]	5.3[a]	56.8[a]	6.0[a]	4.8[a]	-0.1[a]	-0.5[a]
2	Median	CV adjacent to CV in shoulder lane	51.0[a]	5.9[a]	3.8[a]	53.1[a]	5.8[a]	3.9[a]	+0.1[a]	+0.1[a]
3	Shoulder	PC adjacent to PC in median lane	50.8	6.1	5.9	51.3	6.3	5.7	-0.2	-0.2
3	Shoulder	PC adjacent to CV in median lane	46.9[a]	5.9[a]	4.5[a]	47.6[a]	5.9[a]	5.1[a]	0.0[a]	-0.6[a]
3	Shoulder	CV adjacent to PC in median lane	47.1	6.1	4.9	47.3	6.2	4.9	-0.1	0.0
3	Shoulder	CV adjacent to CV in median lane	45.0[a]	5.7[a]	4.6[a]	43.4[a]	6.0[a]	4.2[a]	-0.3[a]	-0.4[a]
3	Median	PC adjacent to PC in shoulder lane	56.9	5.9	5.8	57.0	5.8	5.7	+0.1	-0.1
3	Median	PC adjacent to CV in shoulder lane	58.1	6.0	5.0	57.3	6.0	4.9	0.0	-0.1
3	Median	CV adjacent to PC in shoulder lane	53.4[a]	6.2[a]	5.7[a]	55.3[a]	5.9[a]	5.2[a]	+0.3	-0.5
3	Median	CV adjacent to CV in shoulder lane	52.1[a]	5.4[a]	3.7[a]	53.3[a]	5.6[a]	3.8[a]	-0.2[a]	+0.1[a]
4	Shoulder	PC adjacent to PC in middle lane	43.2	7.4	5.8	44.6	7.4	6.4	0.0	+0.6
4	Shoulder	PC adjacent to CV in middle lane	41.2	7.2	4.6	44.5	7.1	5.2	+0.1	+0.6
4	Shoulder	CV adjacent to PC in middle lane	40.1	6.9	5.6	42.6	6.9	6.1	0.0	+0.5
4	Shoulder	CV adjacent to CV in middle lane	38.8[b]	6.8[b]	4.4[b]	40.8[a]	7.1[a]	4.2[a]	-0.3[a]	-0.2[a]
4	Middle	PC adjacent to PC in shoulder lane	44.7	7.3	6.0	47.9	7.9	6.6	-0.6	+0.6
4	Middle	PC adjacent to CV in shoulder lane	45.6	7.7	5.9	47.8	8.2	6.2	-0.5	+0.3
4	Middle	CV adjacent to PC in shoulder lane	46.3[b]	7.0[b]	4.7[b]	47.9[a]	7.0[a]	5.3[a]	0.0[a]	+0.6[a]
4	Middle	CV adjacent to CV in shoulder lane	46.4[a]	7.2[a]	4.5[a]	45.7[a]	7.2[a]	4.5[a]	0.00[a]	-0.00[a]
4	Middle	PC adjacent to PC in median lane	45.0	6.9	6.0	48.0	7.2	5.3	-0.3	-0.7
4	Middle	PC adjacent to CV in median lane	44.5	6.7	4.7	46.9[a]	6.7[a]	4.3[a]	0.00[a]	-0.4[a]
4	Middle	CV adjacent to PC in median lane	44.0	6.5	5.6	46.6	6.8	4.6	-0.3	-1.0
4	Middle	CV adjacent to CV in median lane	42.8[a]	6.9[a]	3.5[a]	45.5[a]	5.5[a]	5.0[a]	+1.4[a]	+1.5[a]
4	Median	PC adjacent to PC in middle lane	46.5	6.8	5.9	49.0	6.3	5.0	+0.5	-0.9
4	Median	PC adjacent to CV in middle lane	47.4	7.0	5.4	50.6	6.3	4.5	+0.7	-0.9
4	Median	CV adjacent to PC in middle lane	45.7	6.4	4.6	48.5[a]	5.9[a]	4.1[a]	+0.5[a]	-0.5[a]
4	Median	CV adjacent to CV in middle lane	48.3[a]	6.6[a]	4.1[a]	47.0[a]	6.1[a]	4.2[a]	+0.5[a]	+0.1[a]
5	Shoulder	PC adjacent to PC in median lane	50.3	5.6	5.7	52.8	5.6	5.3	0.0	-0.4
5	Shoulder	PC adjacent to CV in median lane	48.9	5.6	4.8	51.5	4.9	5.2	+0.7	+0.4
5	Shoulder	CV adjacent to PC in median lane	47.2	5.3	5.2	48.6	5.4	4.7	-0.1	-0.5
5	Shoulder	CV adjacent to CV in median lane	41.9[a]	5.8[a]	3.1[a]	46.3[a]	5.8[a]	3.8[a]	0.0[a]	+0.7[a]
5	Median	PC adjacent to PC in shoulder lane	56.2	5.3	5.8	58.0	4.8	5.4	+0.5	-0.4
5	Median	PC adjacent to CV in shoulder lane	55.7	5.3	5.1	57.1	5.0	4.6	+0.3	-0.5
5	Median	CV adjacent to PC in shoulder lane	54.2[a]	5.2[a]	4.6[a]	56.3[a]	5.0[a]	4.9[a]	+0.2[a]	+0.3[a]
5	Median	CV adjacent to CV in shoulder lane	52.6[a]	5.2[a]	3.9[a]	54.2[a]	5.1[a]	3.4[a]	+0.1[a]	-0.5[a]

[a]Sample size less than 25. [b]Sample size less than 50.

interpreted with caution. They are found in conjunction with clearances involving commercial vehicles in the median lane, an uncommon driving practice.

At first examination the clearance measurements involving passenger cars in the median lane adjacent to passenger cars in the shoulder lane may appear to be a repetition of the measurements associated with passenger cars in the shoulder lane adjacent to passenger cars in the median lane. The two cases are not necessarily drawn from the same set of adjacent vehicles owing to the traffic maneuver classification system employed.

Changes in clearance, more so than placement, are indicative of the effects of the meidan barrier upon the unidirectional traffic stream. Both passenger cars and commercial vehicle placements for vehicles in the shoulder lane and classified in an adjacent traffic maneuver, while slightly less than (to the right of) the averages for all traffic maneuvers, remained fairly constant after the median barrier was installed. Changes ranged from -0.2 to +0.1 ft. In general, changes in clearance resulted from placement changes in the median lane.

Both Locations 2 and 5 exhibited significant clearance reductions of approximately 0.4 ft between passenger cars in the median lane adjacent to vehicles in the shoulder lane. Location 1 demonstrated no appreciable change in adjacent passenger car clearances; however, clearances between passenger cars in the median lane adjacent to commercial vehicles in the shoulder lane were reduced by approximately 0.4 ft. For reasons previously presented, differences in average placements and clearances at Location 3, where statistically significant, were very small. Clearance data for the "after" studies at Location 4 are biased by the placement error in Lane 2.

Interpretation of Data

Reduction in clearance between adjacent lanes of traffic may be studied with respect to safety and also with respect to roadway capacity and level of service. From the safety viewpoint a clearance reduction is manifested in lower tolerance limits for lateral drift as well as for lane-changing maneuvers. Little data, if any, are available on the subject of lateral drift thereby preventing further treatment. It is possible, however, by means of a simplified model, to evaluate a clearance reduction with respect to the passing or lane-changing maneuver.

If Driver B is traveling in the median lane and beginning to change lanes in front of Vehicle A in the shoulder lane, how far behind the front left corner of Vehicle A can the right rear corner of Vehicle B be if a collision is to be avoided?

First assume Vehicle B to be traveling 55 mph and Vehicle A 45 mph or a relative speed difference of 10 mph (14.7 ft/sec). Further assume that in changing lanes Vehicle B moves laterally at 4 ft/sec. Under these conditions if the initial lateral clearance between vehicles is 6.0 ft, the distance in question is 22.05 ft. If the initial clearance is 5.5 ft, the distance is 20.21 ft, or a difference of -1.84 ft. If the relative speed between vehicles is 5 mph (7.35 ft/sec), the difference in distance is -0.92 ft. With a lateral speed of 3 ft/sec, the difference at a relative speed of 10 mph is -2.50 ft; at a relative speed of 5 mph, -1.25 ft.

In these simplified cases the maximum tolerance difference with a 0.5-ft reduction in clearance is -2.5 ft. Although no allowance has been introduced for Vehicle A slowing down, the increased chance for collision remains at this point, a moot question.

In an attempt to discover any changes in roadway capacity or level of service introduced by the presence of the median barrier, summaries of speed-placement data by 6-min time periods were prepared for all vehicles in each lane of each location both before and after median barrier construction. The summaries contained, in addition to average speeds and placements, equivalent hourly volumes for each 6-min period, traffic densities and average absolute differences in speeds and placements between successive vehicles.

Although it is impossible to say whether maximum recorded volumes represent lane capacities, the traffic demand remaining unknown and there being no exhibited flow breakdowns, an appreciation of the level of service may be gained by examining maximum speeds attained throughout the array of recorded volumes both before and after median barrier construction.

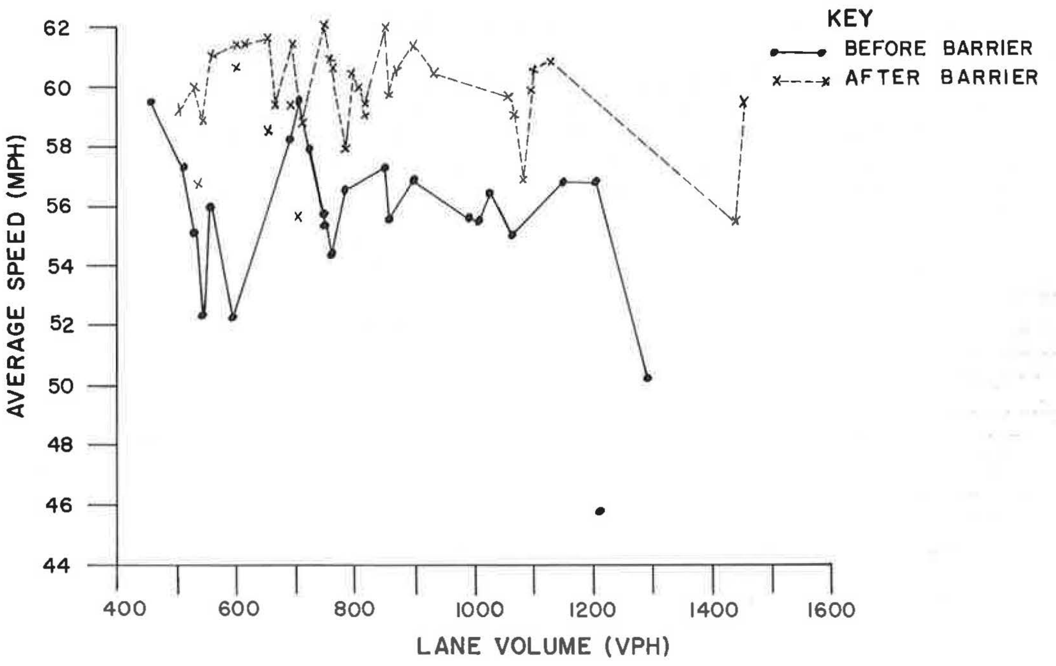

Figure 7. Average speeds and expanded 6-min volumes; maximum speeds at each observed volume, median lane, Location 2.

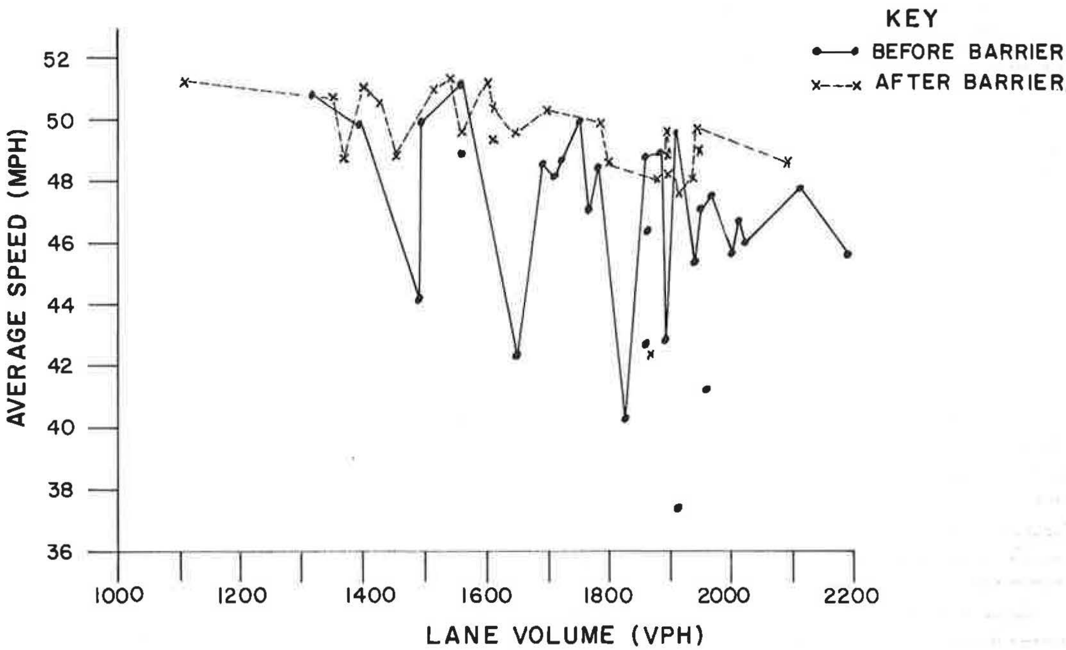

Figure 8. Average speeds and expanded 6-min volumes; maximum speeds at each observed volume, median lane, Location 4.

Figures 7 and 8 show the maximum speeds attained at observed volume levels for the median lanes of Locations 2 and 4, respectively. It was in these lanes that maximum clearance reductions occurred between adjacent vehicles. The graphs indicate that, in general, equal or greater speeds occurred at each volume level after the median barrier was constructed. Therefore, it can be concluded that the median barrier did not, in terms of volume and speed, lower the level of service.

Conclusion

It has been shown that the erection of a barrier on a 4-ft median does have a measurable effect on adjacent lanes of traffic. Whereas vehicle placement in the shoulder lane tends to remain unchanged, average median lane placements can be shifted to the right by as much as 0.5 ft. The clearance between adjacent vehicles at two-lane locations can be reduced by as much as 0.4 ft. Although the increase in average speeds after median barrier construction may be attributed to some variation of conditions, it is safe to say that the median barrier did not have a damping effect on travel speed. The data tend to support the conclusion that the median barrier causes no decrease in roadway capacity. The magnitude of the effects of the median barrier on traffic flow characteristics, smaller than some would expect, may be viewed from the aspect that the median barrier is a continuous rather than intermittent roadside obstacle.

Although changes in vehicle clearance and placement are measured in fractions of a foot, the elimination of the effects of a median barrier upon said may require increasing the median width by several feet.

ACCIDENT OCCURRENCE

Although the safety aspect was briefly treated in the first section, namely from a theoretical viewpoint, no conclusions were reached regarding the effect of median barrier upon accident occurrence. This section presents the findings of a study of traffic accident occurrence as related to the erection of the median barrier on the Schuylkill Expressway.

Description of Study

At present the Expressway has a back-to-back beam-type median barrier erected along its entire length. The median width, although 10 ft in some areas, is predominantly 4 ft. The barrier is erected atop a 6-in. mountable curb.

The barrier, although now continuous, was constructed in two different contracts. As it was decided to look at a 1-yr accident history both before and after median barrier construction, it was necessary to use different time periods for the two contracts. All further reference to the two study sections is made by contract number.

Table 4 gives the sections of roadway comprising each contract as well as the time periods associated with the "before" and "after" studies. Figure 9 is a map of the study area.

A 1-yr accident history for both the "before" and "after" studies was accepted for use for the following reasons.

1. The Schuylkill Expressway experiences daily volumes as high as 130,000 vehicles on certain roadway sections. Thus in one year there are many chances for the rare event, or accident, to occur.
2. The effects of volume growth between the "before" and "after" periods are minimized and any error induced by volume compensation is also reduced.

Generally the volume increase from the "before" study periods to the "after" study periods was 10 percent.

Only accidents occurring completely on the main-line portions of the road were included in the analysis. Those accidents occurring on the interchange crossroads, ramps or at the junction of ramps and the main line were deleted from the analysis. This practice was adopted with the idea that if the median barrier exerted any influence on accident occurrence it would be more pronounced in the proximity of the barrier.

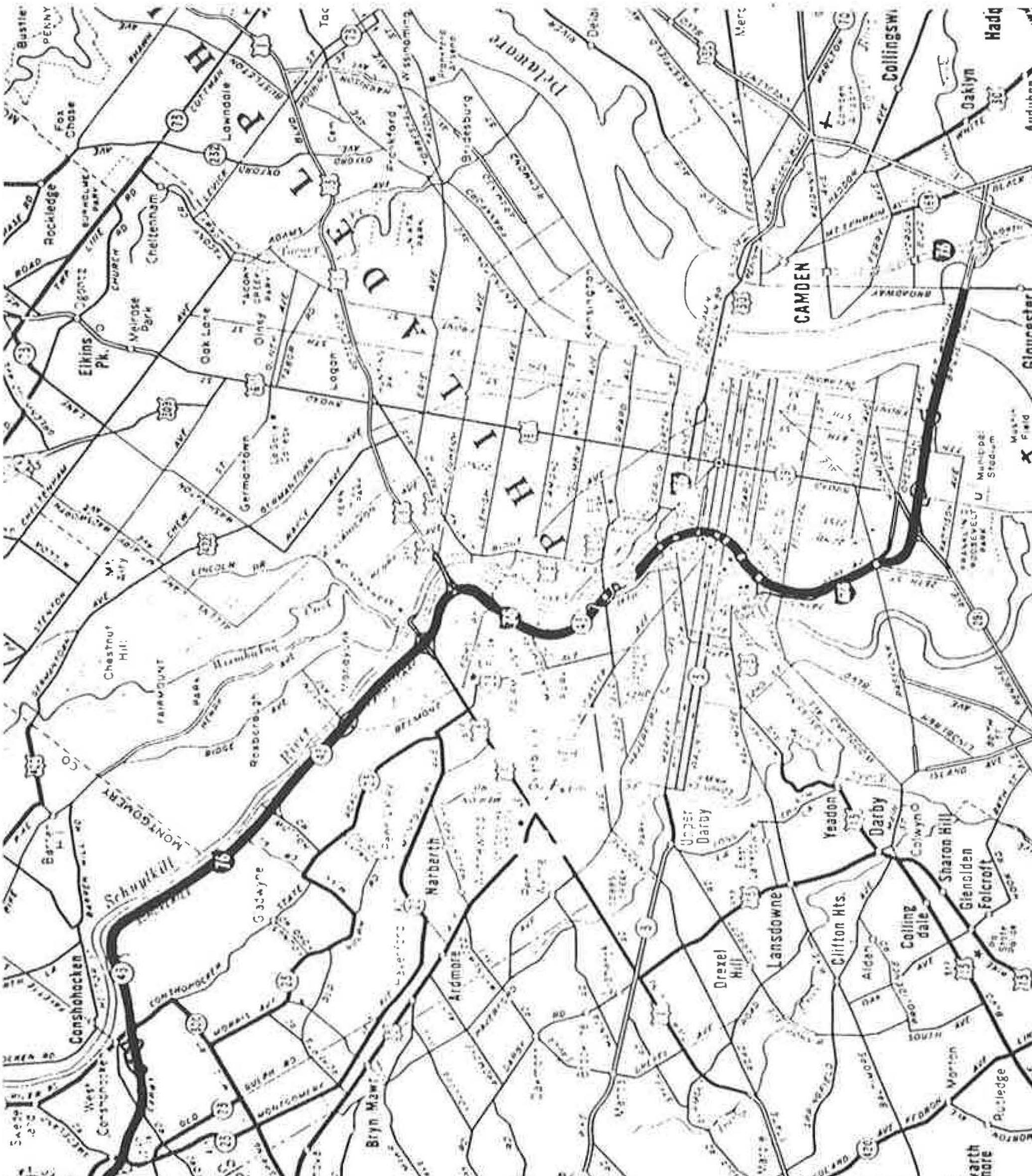

Figure 9. Study area.

TABLE 4

STUDY ROUTES AND TIME PERIODS

Legislative Route	Beginning Station	Ending Station	Length (ft)	Before Period	Construction Period	After Period
			(a) Contract I			
769	0 + 65	153 + 87	15,322	7/60 - 6/61	7/61 - 9/61	10/61 - 9/62
	276 + 50	451 + 50	17,500	7/60 - 6/61	7/61 - 9/61	10/61 - 9/62
			37,822			
			(b) Contract II			
769	153 + 87	276 + 50	12,263	3/61 - 2/62	3/62 - 9/62	10/62 - 9/63
	451 + 50	621 + 70	17,020	3/61 - 2/62	3/62 - 9/62	10/62 - 9/63
67057	48 + 42	160 + 00	11,158	3/61 - 2/62	2/62 - 9/62	10/62 - 9/63
	185 + 27	239 + 00	5,373	3/61 - 2/62	2/62 - 9/62	10/62 - 9/63
	267 + 67	302 + 00	3,433	3/61 - 2/62	2/62 - 9/62	10/62 - 9/63
	307 + 50	363 ± 62	5,612	3/61 - 2/62	2/62 - 9/62	10/62 - 9/63
67278	70 + 47	114 + 62	4,415	3/61 - 2/62	2/62 - 9/62	10/62 - 9/63
			59,274			

NOTES: 1. Median width is predominantly 10 ft in Contract I, whereas a predominant width of 4 ft prevails in Contract II.
2. Median post spacing is 12 ft 6 in. in Contract I; in Contract II the spacing is 6 ft 3 in.
3. Volumes in Contract II approach 130,000 veh/day. Volume in Contract I is considerably less.

Data were obtained from both the State Police and City Police Traffic Accident files. The State Police record is for Legislative Route 769. The remaining Lesiglative Route numbers comprising the study were patrolled by the Philadephia Police Department. All data were code classified and punched on cards for machine analysis.

Findings of Study

Overall accident resumes are presented in Tables 5 and 6. Conventional classification based upon severity suffered by individuals is used to define accident types.

The number of traffic accidents in Contract I increased from 50 before median barrier installation to 87 afterward. Based on the "before" period, this represents an increase of 74 percent. If it is assumed that accident frequency is linearly influenced by amount of travel (vehicle mileage), then, for a constant roadway length, it is also linearly affected by volume. Thus, for a 10 percent volume increase approximately 55 accidents should have occurred. Therefore, 32 accidents represent a certain deviation from the "expected norm," a 64 percent "abnormal" increase.[2]

The accident frequency increase in Contract II was 112, representing a total percentage increase of 38 percent over the "before" period. By similar reasoning to that presented above the "abnormal" increase was 82 accidents or 28 percent.

Time distributions of accident occurrence by month, day and hour (the latter separately for weekdays and weekends) have been prepared (Figs. 10, 11, and 12). The time distributions, while not subjected to rigorous analysis, do not appear to show any significant differences between the "before" and "after" periods. Thus it seems that the increase in traffic accidents experienced after median barrier construction is proportionately distributed throughout the hourly, daily and monthly time periods.

[2] It is acknowledged that accident frequency is probably more than linearly related to vehicle mileage; however, no mathematical relationship is known to allow a more exact calculation of "abnormal" accident frequency increase.

TABLE 5

OVERALL ACCIDENT RESUME

Accident Type	Contract I		Contract II	
	Before	After	Before	After
Fatal	1	0	6	1
Injury	17	29	82	100
Property damage	32	58	199	297
Total	50	87	287	398

TABLE 6

MEDIAN BARRIER ACCIDENT RESUME

Nature of Median Accident	Contract I		Contract II	
	Before	After	Before	After
Crossover	13	2	45	2
Non-crossover	3	18	11	61
Total	16	20	56	63

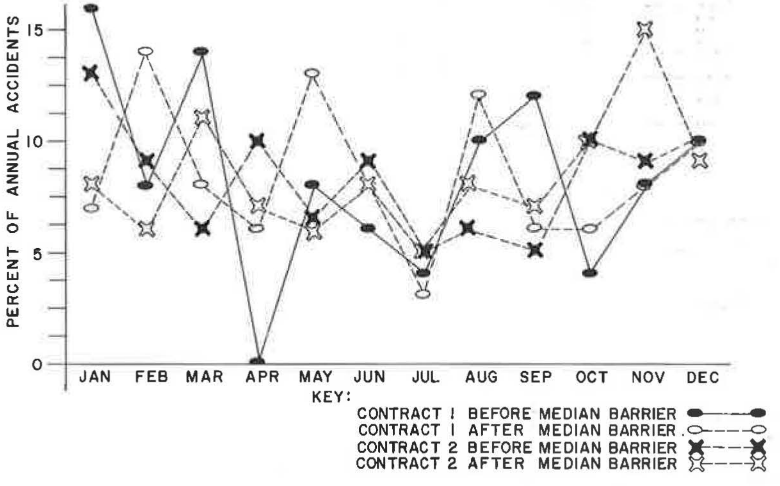

Figure 10. Distribution of monthly accident occurrence.

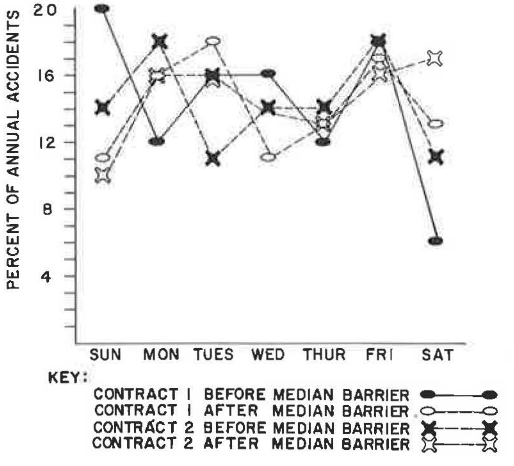

Figure 11. Distribution of daily accident occurrence.

Table 7 gives matrices of "before" accident occurrence with respect to collision type and illumination condition. Collision types are decided by the manner in which initial contact was made and what was first hit.

In both matrices a significant increase in both rear-end and hit-fixed object collision types is readily apparent. The increase in the latter is largely attributed to a new fixed object being present in the highway environment, the median barrier. The large increase in rear-end accidents after median barrier installation has been explained by some analysts as the result of the drivers' attention being diverted from what is in front of them to what is "passing" along side.

Table 8 gives accidents involving the

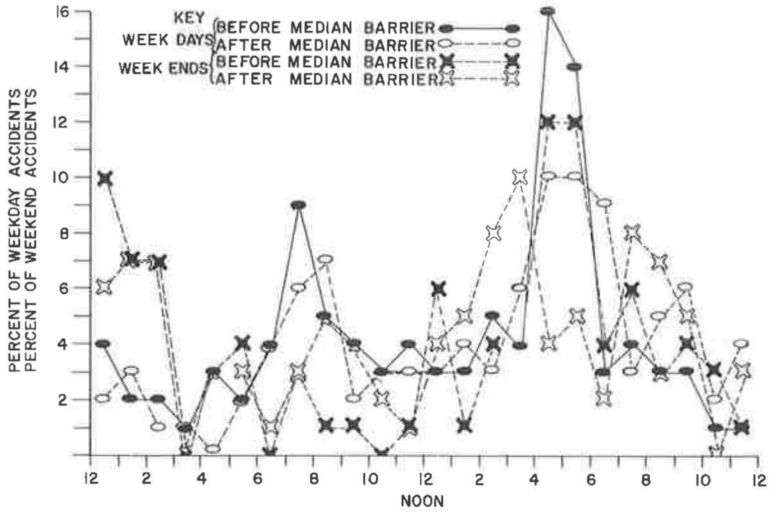

Figure 12. Distribution of hourly accident occurrence, Contract II.

TABLE 7

FREQUENCY OF ACCIDENT OCCURRENCE VS ILLUMINATION AND COLLISION TYPE

Illumination	Head-On		Rear-End		Angle		Side-swipe		Backed In		Hit Ped.		Hit Fixed Object		Run Off		Others		Total	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
(a) Contract I																				
Daylight	3	0	14	28	5	10	3	0	0	0	0	0	0	10	1	4	0	1	26	53
Dawn	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
Night, no lights	0	0	7	9	4	1	4	5	0	0	0	0	3	8	3	4	0	1	21	28
Night, lights	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Dusk	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
Total	3	0	24	40	9	11	7	5	0	0	0	0	3	20	4	9	0	2	50	87
(b) Contract II																				
Daylight	8	0	97	135	17	10	21	26	0	0	2	0	6	35	6	9	1	0	158	215
Dawn	0	0	1	4	1	1	0	0	0	0	0	0	1	1	0	0	0	0	3	6
Night, no lights	3	2	10	18	6	5	1	2	0	1	0	0	6	21	7	3	0	0	33	52
Night, lights	2	0	31	61	3	1	7	10	0	0	1	2	15	33	8	0	0	0	67	107
Dusk	0	0	22	13	1	2	0	1	0	0	0	0	2	2	1	0	0	0	26	18
Total	13	2	161	231	28	19	29	39	0	1	3	2	30	92	22	12	1	0	287	398

NOTES: B = before median barrier construction.
A = after median barrier construction.

TABLE 8

FREQUENCY OF MEDIAN SUCCESSES AND FAILURES VS COLLISION TYPE

Median Accidents	Head-On		Rear-End		Angle		Side-swipe		Backed In		Hit Ped.		Hit Fixed Object		Run Off		Others		Total	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
(a) Contract I																				
Success	0	0	3	3	0	1	0	3	0	0	0	0	0	11	0	0	0	0	3	18
Failure	3	0	1	1	8	0	1	0	0	0	0	0	0	1	0	0	0	0	13	2
Total	3	0	4	4	8	1	1	3	0	0	0	0	0	12	0	0	0	0	16	20
(b) Contract II																				
Success	0	0	3	4	0	9	3	5	0	0	0	0	0	43	5	0	0	0	11	61
Failure	13	0	4	0	14	0	4	0	0	0	0	0	6	2	4	0	0	0	45	2
Total	13	0	7	4	14	9	7	5	0	0	0	0	6	45	9	0	0	0	56	63

NOTES: B = before median barrier construction.
A = after median barrier construction.

median by collision type. Median accidents have been classified in two types; a median success meaning that no part of the vehicle reached the pavement of the opposing lane of traffic, a failure meaning the opposite.

While head-on accidents were eliminated, fixed-object accidents involving the median increased greatly from 0 to 12 in Contract I and from 6 to 45 in Contract II. The median barrier was also hit in the other accident collision types recorded as median accidents in the "after" studies.

During the before period in Contract I, there was one cross-median accident in which three persons were killed. In Contract II there were four cross-median accidents in which five persons were killed. Neither contract suffered a cross-median fatality after

TABLE 9

DISTRIBUTION OF INJURY TYPES

Major Injury Inflicted	Accident Type							
	Non-Median Accidents		Median Failure Accidents		Median Success Accidents		All Accident Types	
	B	A	B	A	B	A	B	A
(a) Contract I								
Internal injuries	0	1	2	0	0	0	2	1
Contusions	0	0	1	0	0	1	1	1
Bruises	4	6	1	1	1	6	6	13
Fracture, head or back injury	7	6	3	0	0	2	10	8
Loss of eye	1	0	0	0	0	0	1	0
Lacerations	2	12	4	0	1	1	7	13
Abrasions	0	3	2	0	0	1	2	4
Total injuries	14	28	13	1	2	11	29	40
Total injury accidents							17	29
(b) Contract II[1]								
Internal injuries	2	0	0	0	0	0	2	0
Contusions	4	3	2	0	0	1	6	4
Bruises	14	12	2	2	1	4	17	18
Fracture, head or back injury	12	10	5	1	0	2	17	13
Loss of eye	0	0	0	0	0	0	0	0
Lacerations	11	10	9	1	1	6	21	17
Abrasions	2	6	2	0	0	5	4	11
Total injuries	45	41	20	4	2	18	67	63
Total injury accidents							37	45

NOTES: B = before median barrier.
A = after median barrier.

[1] Montgomery County portion only (i.e., investigated by the Pennsylvania State Police).

the erection of the barrier. While the accident severity associated with the loss of lives was eliminated, the effect of the median barrier upon the number and nature of injury accidents was much different. In Contract I the number of injury accidents inceased from 17 to 29. In Contract II the increase was from 82 to 100 injury accidents.

To understand better the effect of the median barrier upon the nature or severity of injuries incurred, a special study was undertaken of those injury accidents occurring in Contract I and those occurring on the Montgomery County, Legislative Route 769 portion of Contract II. This segment of the study roadway is patrolled by the State Police and the accident and injury data are more easily attainable. The findings of this study are given in Table 9. As a word of caution, State Police injury descriptions are not always most accurate. An examination of the distribution of injury types leads one to believe that no significant claim can be presented that the median barrier reduced either the number or nature of injuries. It is planned to expand the injury analysis to one that will incorporate data reflecting personal disability.

In another phase of this section an approximation was formed as to the probable nature of accident occurrence in the "after" periods had not the median barrier been installed. Probabilities were extrapolated from the "before" periods as to what would occur subsequent to the incidence of a vehicle upon the median. These probabilities were then applied to the "after" data.

Representative total property damage costs and number of injuries associated with different median barrier accident circumstances were computed and applied to the approximated accident occurrence in the "after" periods.

A cost difference was then computed between the actual and approximated "after" period accident occurrence. Incorporated in the economic analysis was the annual cost of the barrier and increased traffic delay costs owing to that portion of the "abnormal" accident frequency increase occurring during peak periods. Savings in time due to the increased operating speeds of vehicles after median barrier construction, approximately 2-3 mph, were deleted as insignificant. It is claimed that although total time savings to all road users may amount to thousands of hours, the incremental time saving to each vehicle occupant, approximately 30 sec/hr of trip, is too small to be recovered economically.

The accident analysis was somewhat conservative in that vehicles hitting the median barrier and continuing on were ignored. Additional study is now in progress to measure this deletion.

Nowhere in the analysis were monetary values labeled as "loss." Instead, the analysis was in terms of cost.

This study attempted to show the cost of saving a life through the use of median barriers. It did not attempt either to justify or condemn the use of median barriers for several reasons. First, is consumer sovereignty the governing factor; is something worth what the consumer will <u>knowingly</u> pay? Second, if consumer sovereignty is the proper economic approach, the amount the public is <u>willingly</u> and <u>knowingly</u> ready to pay for a life is undetermined.

The results of the economic analysis are being withheld at this time for several reasons:

1. The statistical base used in each segment of the economic analysis is not yet believed to be significant at any usable level.
2. Premature conclusions are too easily formed and cost figures tend often to be quoted out of context.

It is hoped that data gleaned from the next few years of experience will allow a definitive economic statement.

<u>Conclusion</u>

After median barrier construction, increases in accident frequencies in Contract I and Contract II of 74 percent and 38 percent, respectively, were observed with but an approximate 10 percent increase in travel.

Although the median barrier does eliminate, for all intensive purposes, the accident severity associated with the cross-median fatality, the frequency of injury accidents was found to increase.

"Abnormal" accident frequency increase attributed to the median barrier is found normally distributed throughout all time periods.

Total property damage costs suffered, as well as costs of congestion arising from accidents occurring during peak periods, increased after median barrier construction.

ACKNOWLEDGMENTS

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