ENGINEERING MEASURES FOR REDUCING WRONG-WAY DRIVING

by

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(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

Presented is an evaluation of engineering measures instituted in Virginia to reduce incidences of wrong-way driving. Also discussed are the data collected in a survey of wrong-way driving incidents, the causes of wrong-way entries determined through recent on-site investigations, and corrective measures for preventing them. Measures found highly effective were the installation of reflectorized pavement arrows on ramps and the elimination of corner flares at the junction of exit ramps and crossroads. Measures suggested for further reducing wrong-way entries are (1) continuing the pavement edge line across the exit ramp or placing the stop line very close to the crossroad such that it lies within the zone illuminated by the low beam headlights of a vehicle traveling the crossroads; (2) channelizing the crossover opposite the exit ramp; and (3) placing signs and pavement markings for high visibility and legibility at night under low beam headlights.

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INTRODUCTION

About five years ago the Virginia Department of Highways and Transportation and the Virginia Department of State Police launched a joint venture to combat the worsening problem of wrong-way driving on interstate and primary highways. Under this program the state police investigate and submit detailed reports on each incident of wrong-way driving coming to their attention.

Based on these reports, the Traffic and Safety Division of the Department of Highways and Transportation then inspects the scene of each incident to determine if any engineering measures can be taken that might prevent wrong-way maneuvers. To assist in this program the author has conducted on-site investigations of several interchanges and intersections to develop ideas for improvements.(1)

All the measures initiated have been in the form of signs, pavement markings, and traffic channelization. This approach is supported by Gabriel,(2) who reports that in California during the third year of their accelerated program to reduce wrong-way driving it was found that the majority of the wrong-way movements could be prevented by signs and delineation changes.

PURPOSE AND SCOPE

The investigation reported here was undertaken to assess the efficiency of measures initiated in Virginia to reduce incidences of wrong-way driving on 4-lane divided highways and to identify any needs for additional measures.

The investigation was restricted to (1) a general evaluation of the data collected in the survey of wrong-way driving incidents, (2) an evaluation of the engineering measures adopted to reduce wrong-way driving, and (3) on-site surveys of a limited number of interchanges and intersections.

EVALUATION OF THE DATA

The survey of the wrong-way incidents by the Virginia Department of Highways and Transportation and the Virginia State Police was started in June 1970 and has been continued since then, except for the period from December 1970 to June 1971. In this report data collected up to September 1974 are evaluated.

Wrong-way driving causes exceptionally severe types of accidents as shown in Table 1 for interstate and primary highways. This table gives a comparison of accidents due to wrong-way driving with the total number of accidents in Virginia for the period covered by a 51-month survey. These data show that the fatality rate per wrong-way accident is 31 times greater than the rate due to other types of accidents on interstate roads and 10 times greater on other 4-lane divided highways. The injury rate per wrong-way accident is 2.9 and 2.3 times as great on interstate and primary roads respectively. In the 78 wrong-way accidents on interstate highways, 39 persons were killed and 95 were injured, and in the 116 accidents on other 4-lane divided highways 24 were killed and 113 injured.

Table 2 gives the locations of wrong-way entries on interstate highways at day and night. This table shows that interchanges are the prime locations for wrong-way entries on interstates. Table 3 gives the places of wrong-way entries on primary 4-lane divided highways at day and night. This table shows that intersections and business areas are the main locations for wrong-way entries on 4-lane divided highways. This study therefore considered improvements at intersections, interchanges, and business areas only.

Table 1

Total Accidents Compared with Wrong-Way Driving Accidents on Divided Highways

Accident Data	Interstate			Arterial & Primary		
	All Accidents 1970 - 1974 (60 months)	Wrong-way Accidents		All Accidents 1970 - 1974 (60 months)	Wrong-way Accidents	
		51 Mo. Survey	Ratio to All Accidents		51 Mo. Survey	Ratio to All Accidents
Number of Accidents	39,133	78	0.002	187,727	116	0.0006
Total Fatalities	619	39	—	4,388	24	—
Fatalities per Accident	.016	0.5	31	0.02	0.2	10
Total Injured	16,502	95	0.007	79,731	113	.002
Injured per Accident	0.42	1.2	2.9	0.42	0.97	2.3
Incidents of Wrong-way Driving	—	205	—	—	473	—

Table 2

Number, Places and Lighting Condition of Wrong-Way Entries and Condition of Wrong-Way Drivers on Interstate Highways From July 1970 to September 1974

Driver Condition	Place of Wrong-way Entry and Lighting Condition										Total*
	Interchange		U-Turn		Crossover and Median Crossing		Rest Stop		Unknown		
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	
Drunk	15	31	9	7	2	1	0	1	8	34	118
Non-drunk	27	17	6	6	0	0	0	0	3	4	68
Unknown	6	4	0	0	0	0	0	1	1	7	19
Subtotal	48	52	15	13	2	1	0	2	12	45	
Total*	109*		32*		3*		2*		59*		205*

Total Incidents During Day = 77

Total Incidents During Night = 113

Total Incidents During Dawn and Dusk = 15

*Includes wrong-way entries at dawn and dusk.

Table 3

Number, Places, and Lighting Condition of Wrong-Way Entries and Condition of Wrong-Way Drivers on Non-Interstate, 4-Lane Divided Highways from July 1970 to September 1974

Condition	Place of Wrong-way Entry and Lighting Condition																		Total*
	Intersection		Business Area		Residential Area		Crossover		Median Crossover		U-Turn		Beginning of Divided Sect.		Construction Site & Others		Unknown		
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	
Drunk	9	59	6	19	2	1	3	6	1	2	3	2	1	7	0	2	5	25	162
Non-drunk	59	43	52	34	15	8	16	6	2	1	3	4	0	6	1	1	8	3	280
Unknown	6	5	6	2	0	0	0	0	0	1	0	1	0	0	0	0	1	7	30
Subtotal	74	107	64	55	17	9	19	12	3	4	6	7	1	13	1	3	14	35	
Total*	192		125		28		33		7		13		11		6		54		472*

Total Incidents During Day = 199
Total Incidents During Night = 245
Total Incidents During Dawn and Dusk = 28

*Includes wrong-way entries at dawn and dusk.

EVALUATION OF ENGINEERING MEASURES INSTITUTED

The most significant of the many measures instituted in Virginia during the continuing program to reduce wrong-way driving are discussed in the following subsections.

Reflectorized Pavement Arrows on Ramps

Very large reflectorized arrows have been provided on interstate exit and entry ramps since September 1974.[3] They are in use on all exit and entrance ramps in Virginia. Virginia policy specifies that these arrows be placed 25 ft. (7.5 m) or more from the intersection of the crossroad. Two such arrows are placed on the exit ramp and one on the entrance ramp. The function of these arrows, as is evident from their location, is to inform drivers that they have made a wrong-way entry.

At the request of the traffic and safety engineer, a field survey of these arrows was made by the author and his resultant evaluation is given here. Some arrows were found to be placed for less than 25 ft. (7.5 m) from the stop line. This placement has led to very interesting results, an example of which is shown in Figure 1 (all figures are appended).

Arrows have been placed as close as 5 ft. (1.5 m) from the stop line on exit ramps. Arrows placed close to the intersection of the crossroad and the exit ramp are visible to the wrong-way driver making either a right-hand or left-hand turn into the exit ramp. Arrows placed more than 25 ft. (7.5 m) from the stop line are not visible to the wrong-way driver as is illustrated in Figure 2, where the first arrow is placed 22 ft. (6.6 m) from the stop line on an exit ramp.

The author feels that the first arrow on the exit ramp should be very close, say within 5 ft. (1.5 m), of the stop line, such that it will be visible to a wrong-way driver before he enters the exit ramp from the crossroad and will thus discourage him from making the wrong-way entry. The second arrow should be placed approximately 100 ft. (30 m) from the stop line as recommended[3] so as to provide a second warning to the wrong-way driver.

Similarily the arrow on the entrance ramp can guide the driver from the crossroad into the correct direction only if he can see it from the crossroad. The arrow placed far removed from the junction of the crossroad and entrance ramp will not be visible to the driver from the crossroad and thus will fail to perform its function. It will only reassure the driver after he has gotten onto the entrance ramp, which is not worth the trouble and costs incurred.

Elimination of Flares

In a previous study[1] the author observed that on almost all interchanges on which wrong-way entries had been made either into an exit ramp or from an exit ramp into a crossroad, the left edge of the left lane of the exit ramp flared into the right pavement edge of the crossroad. An example of such a flare is shown in Figure 3. Such flares probably mislead the driver into the wrong lane. The removal or striping of these flares was therefore recommended to the traffic engineers, who agreed that the flares serve no purpose.

The results from the implementation of this recommendation have been very encouraging. At two sites which had experienced incidences of wrong-way driving and which had been included in the previous study by the author,[1] the flares were striped or removed and no further wrong-way incidents have been reported. These sites are discussed below.

Intersection of I-95 South, Exit Ramp to Route 1

Figure 3 is a photograph showing an unmarked left flare at the I-95 — Rte. 1 intersection during the time it was experiencing wrong-way incidents. This interchange had the highest number of wrong-way incidents of any interchange in Virginia. It had been the scene of six incidents, all by non-drunken* drivers during a two-year survey period ending in May 1973. Figure 4 shows that the location of the stop line at this junction is such that the driver coming from the exit ramp is unable to see the crossroad on his left, if he stops at the stop line. Figure 5 shows the same junction with the flare marked with two right angled lines to create an inexpensive precautionary measure. Since the marking of the flare about 18-months ago no wrong-way incidents have been reported. The marking apparently discourages drivers from quickly turning left on the wrong side of the median and increases the visibility distance. Previously, in approaching the crossroad from the exit ramp all drivers would stop on the stop line. With the introduction of the flare marking, a driver who needs an increased visibility distance crosses the stop line and comes to a stop at the corner of the flare marking as shown in Figure 5.

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*Besides sober drivers, the non-drunken drivers category includes those sleepy, fatigued, in poor physical and mental condition, nervous, on medication, sick, senile, and feeble. Intentional wrong-way drivers are also included in this classification.

Drunken drivers include drunken, drinking, and drugged persons.

Interchange 53 — I-81 South, Exit Ramp to Route 11

Interchange 53 was the site of two wrong-way incidents, both by non-drunken drivers, during the two-year survey period ending in May 1973, prior to alteration of the flares. Figure 6 shows the junction of the exit ramp and the crossroad with the "A" designating the location of one of the wrong-way incidents. This interchange, like the immediately preceding one, was discussed by the author in a previous report[1] with a recommendation to remove or stripe the flare. The flare was removed about 18-months ago and the interchange appears as shown in Figure 7. No wrong-way incidences have been reported since the change. Another example of recent striping of the flare is at the I-64 and Route 364 interchange, as shown in Figure 8.

It is the author's belief that flared entrance and exit ramps will continue to contribute to wrong-way incidents on interstate and divided highways. An example of a recent such incident was by a wrong-way entry on a flared ramp during November 1974 on I-64 at Ivy by a drunken driver. This ramp has very wide flares. Figure 9 shows the flares where the driver entered the wrong-way.

Recent investigations by Shepard[4] at this interchange also concluded that the flares should be removed. Scrifes[5] in his report of February 1974 about wrong-way driving in Illinois, has also recommended the removal of flares. There is therefore a great need for making the striping or removal of left flares of exit ramps mandatory. It is desirable that the right flare also be so treated where the traffic volume is low.

Stop Line and Continuation of Pavement Edge Line

The provision of stop lines closer to the crossroad (say within 5 ft. (1.5 m) of the crossroad) and continuation of pavement edge lines were recommended by the author in the previously cited report.[1] This recommendation was based on daylight observations only. Night studies carried out in the present investigation have shown that the absence of these features causes a misleading illusion as shown by the two interchanges discussed next.

Interchange 57 — I-81 North, Exit Ramp to Route 250

Figure 10 is a night photograph of a crossroad opposite an exit ramp from I-81 to Route 250, the site of a wrong-way maneuver at night, due to deceptive pavement edge marking. A driver looking for an entrance ramp from the passing lane entered this exit ramp, probably after seeing an opening in the pavement edge line.

Interchange 55A — Intersection I-81, Exit Ramp to Route 654

Figure 11 shows another exit ramp which was the site of a wrong-way entry. A night photograph of this exit is shown in Figure 12. From the latter figure, it can be speculated that the flare encourages the driver to enter the exit ramp. Continuation of the pavement edge line might discourage wrong-way entries at night. Another alternative is to bring the stop line close enough to the crossroad, within 5 ft. (1.5 m), such that it would be within the zone illuminated by low beam headlights; or, as recommended by the author in the previous report, the stop line could be brought up to the edge of the crossroad. If such a stop line is provided it should be at least 24 inches (600 mm) wide. Shepard has also recommended the same measures.

Figure 13 shows the suggested pavement stripe for removal of flares and the provision of stop lines on exit ramps.

Double Yellow Lines on 2-lane Undivided Crossroads

Undivided crossroads at interchanges are provided with double yellow lines with very wide gaps opposite exit ramps. The author in his previous study[1] had quoted an example where the wrong-way driver entered an exit ramp through this ramp. The author suggested that no gap be provided in double yellow lines and recommended a system of marking as shown in Figure 14. Since then, some undivided crossroads at interchanges have been provided with continuous solid double yellow lines as shown in Figure 15. No wrong-way entry has been reported at these interchanges. Further, it has been observed that the provision of continuous double yellow lines does not cause any inconvenience to the drivers who cross these lines to negotiate an interchange. Since there is no economic loss in removing the gaps and providing continuous double yellow lines, the author is of the opinion that continuation of these double yellow lines may prevent some of the wrong-way entries, without causing an interference to the normal traffic.

ADDITIONAL CAUSES OF WRONG-WAY MANEUVERS AND IMPROVEMENTS SUGGESTED

The data evaluation and field investigations conducted in this study indicated that the following listed features may contribute to wrong-way maneuvers.

1. Wider than recommended crossovers opposite exit lanes.[6]

2. Non visibility of signs and pavement markings at night.

3. Varied placement of regulatory and warning signs at intersections.

4. Unfamiliarity with interchange.

5. Optical illusions at night.

They are discussed under the following subheads.

Crossovers Opposite Exit Lanes

Virginia's traffic engineers realize the need for channelizing crossovers opposite exit lanes and the state is spending a lot of money to provide the needed improvements for reducing wrong-way entries. An example of this is shown in Figure 16, which is a photograph of a parclo (partial clover leaf) interchange on I-81. This interchange, No. 65, was the scene of a wrong-way entry by a sober driver. The photograph shows that though the medians recently have been extended the crossover is still wide enough to encourage a wrong-way entry onto the exit lane by a driver turning left from the crossroad.

Another location at which the nose of the median was recently extended is shown in Figure 17. This interchange was also the scene of a wrong-way entry. The nose of the median is now in line with the edge of the exit ramp, but does not cover the exit ramp. This photograph shows the path traveled by a semitrailer combination. Notice the gap between the wheel path and the newly extended nose of the median on the left. As is evident, the left nose of the median could have been easily extended to cover more than half the width of the exit lane to provide required channelization.

To make full utilization of the money now being spent on channelization by reducing the width of the crossover opposite an exit lane, the traffic technician must have simple techniques for determining the location of the two noses of such crossovers. For this purpose a simple ordinate method was developed in this investigation. Diagrammatic plans of the scissor crossover and a parclo interchange, where this method could be used, are shown in Figures 18 and 19.

The ordinate method is based on the width of two lanes plus the median width, i.e., (2 L + M), where L is the width of the lane and M is the width of the median. It gives the values of the two axes X and Y for different values of (2 L + M). The X axis is taken along the edge of the 4-lane divided crossroad with its origin at the center of the left-turn lane (without flares) of the exit ramp. The Y axis is along the section of the crossroad with its origin at the junction of the crossroad and the centerline of the left lane

of the exit ramp (without flares). Values of (2 L + M) varying from 24 to 70 ft. (7.2 to 21 m) have been used. The noses of the medians on the right and the left of the crossover are termed A and B, respectively, as shown in Figures 18 and 19. The shapes of the median noses that would be achieved for (2 L + M) = 70, 60, 50, 40, and 30 ft. (21, 18, 15, 12, and 9 m) by means of the values of the X and Y axes are given in Table 4 and are shown in Figure 20. This figure could be used for determining ordinates for intermediate values of (2 L + M).

Table 4

Ordinate Method for Channelizing Crossovers Opposite Exit Ramps

(1 ft. = 0.3 m)

Two Lanes and Median Width — Ft.	Radius of Curve — Ft.	Overlap in Outside Lane — Ft.	Maximum Distance Between Wheel Paths — Ft.	Ordinates in Ft.			
				Nose A		Nose B	
(2 L + M)	R.		W	X	Y	X	Y
70	75	0	23 - 24	35	70	120	70
				25	64	80	66
				15	55	60	59
				5	43	40	45
				0	34	30	35
				-5	20	20	22
60	70	0	24 - 28	25	60	120	60
				15	50	80	56
				5	39	60	48
				0	30	40	37
				-5	16	30	30
						20	18
60	50 & 75	0	23 - 24	30	60	110	60
				25	57	100	59
				20	53	80	57
				15	48	60	50
				10	43	40	37
				5	36	30	30
				0	28	20	20
				-5	15		
50	50 & 75	0	22 - 24	21	50	100	50
				15	44	80	48
				10	38	60	43
				5	32	40	34
				0	24	30	28
				-5	10	20	20
50	50 & 60	0	24	30	60	110	60
				20	53	100	58
				10	44	80	55
				5	33	60	48
				0	23	40	36
						20	18
40	50	0	20	17	40	90	40
				10	35	60	37
				5	29	40	31
				0	22	20	18
				-2	18		
30	50	2nd Lane	17	2.5	30	40	30
				0	24	30	25
				-2	18	20	18
30	40	0	17	8	30	60	30
				5	27	40	27
				0	20	20	18
24	40	0 to 5		2	24	30	24
				0	20	20	18

Non Visibility of Signs and Pavement Markings at Night

An on-site survey of the interchanges and intersections was carried out during both daytime and nighttime. The studies showed that many of the signs and pavement markings, because of their locations, are not visible under low beam headlights at night. This fact is evident from the day and night photographs of an interchange shown in Figures 11 and 12. Figure 11, taken during the daytime, shows the one-way sign and the stop line. Figure 12, taken under low beam headlights at night, shows that the one-way sign and the stop line are not visible.

If a driver can successfully negotiate an interchange or an intersection at night with the help of low beam headlights and without seeing some of the signs and pavement markings, then he or she can certainly negotiate the same interchange or intersection in the daytime without the help of those signs and pavement markings which were not visible at night. Such signs and pavement markings which are not visible at night under low beam headlights are therefore unnecessary, hence the placement of signs should be designed for visibility and legibility at night.

Placement of Regulatory and Warning Signs at Intersections

A survey of the intersections on 4-lane divided primary highways, some of which had experienced the wrong-way incidents and some that had not, was made during the day and nighttime in this investigation. In the survey it was noticed that there is no definite pattern in the location of regulatory and warning signs. The pattern varies from location to location and district to district. The driver does not know where to look for a particular sign. An example of this is shown in Figure 21, where the one-way sign is not within the 5^{o} cone of the driver and thus requires a larger cone of vision by the driver at day. At night this sign is not visible. Optimum use of this sign could have been obtained by placing it opposite the vehicle coming out of the shopping center. Uniformity in the location of signs over the state, needs to be achieved for optimum utilization. There is a need for guidance for traffic technicians in the field by providing them with typical regulatory and warning sign placement plans for intersections in The Virginia Manual of Uniform Traffic Control Devices for Streets and Highways.

These plans should include intersections in business areas. Of the 473 wrong-way incidents on the 4-lane divided highways 150 were on intersections and 112 in business areas. The business activities at the sites of wrong-way entries are mostly gas stations, restaurants, motels, and shopping centers.

These signing plans should consider placement of signs based on night visibility. Some of the signs are not visible during dark under low beam headlights as shown in Figures 11 and 12. The sign shown in Figure 21 is not visible at night under low beam headlights when the driver makes an exit into the divided highway. If all drivers are able to find their path under poor visibility by low beam headlights at night without a particular sign, it is obvious that this particular sign has no utility during the daytime. Hence the location of signs should be based on night visibility.

Plans are needed for the placement of regulatory and warning signs at the following locations:

1. Tee-intersection in residential areas consisting of a group of residences which do not justify a crossover, or a small business, e.g., a gas station, a club, a restaurant, or a motel.

2. Tee-intersection in large business areas, small towns in rural areas, or a big residential area which justifies a crossover.

3. Low traffic volume intersection in a rural area.

4. High traffic volume intersection in a rural area.

Diagrams for the above four intersections are shown in Figures 22 through 24. The one-way sign opposite the traffic entering from the crossroad in Figures 22 and 23 should be placed within the central two quarters of the entry lane width, such that it always remains within the 10° cone of vision (i.e. 5° to each side of the centerline). The diagrammatic "Tee", "crossroad", and "left turn over the median" signs should be provided when the undivided crossroad slopes away from the divided crossroad, or the opposite traffic lanes of the divided crossroad are at different elevations and thus prevent visibility of all the lanes of the crossroad. These diagrammatic signs need not be provided when the undivided crossroad slopes towards the divided crossroad such that all the lanes of the divided crossroad are visible to the driver approaching the 4-lane divided intersection.

Unfamiliarity with Interchange

Wrong-way incidents are more common at interchanges during the first year or two after their construction than in the later years. More facilities for the guidance of drivers therefore need to be provided during the first two years after construction. The most economical way to achieve this is by pavement markings (on crossroads)

which have a shorter life as compared to signs and geometrics. Instructions by pavement marking such as "North 95 Rt.", as shown in Figure 14, is likely to help a driver who has low external stimuli or is confused by the introduction of a new interchange with which he is not familiar.

Optical Illusions at Night

Wrong-way entries can be caused by optical illusions that are realized by a wrong-way driver only after he or she has made a wrong-way entry. Two examples, both of which were observed by the author, are given below.

1. Figure 26 is a photograph of a lighted intersection of Routes 301 and 206 at Dahlgren where a wrong-way incident occurred at night. This photograph was taken at the point from which the driver made a wrong turn. During the night investigation of this site, the author saw a wrong-way entry being made. On inquiry the driver (a local resident) said that he did not see the other lane before making a left turn. This is a level intersection and unless a person is very careful he is unable to see the other side of the median. This intersection, as seen from the photograph, is provided with a DIVIDED HIGHWAY sign. This sign is located on the right-hand side of the lane which is for vehicles going straight only. This sign should therefore be moved onto the left nose of the crossover, and should preferably be changed to a suitable diagrammatic sign, to enable drivers turning left to see it and turn around the nose instead of turning before it.

2. Figure 27 is a typical example of drivers heading for a frontage road but turning prematurely into the exit ramp. Figure 28 is a photograph of an optical illusion where, as seen in the photograph the frontage road is hidden from the driver's vision by raised land and trees, the driver made a wrong-way entry into the exit lane at night. Night studies showed that a driver driving towards the exit ramp on the crossroad could see only this tiny "no right turn" diagrammatic sign and the black topped road ahead. He could not see the stop line. The least expensive remedy is either to bring the stop line within 0 to 4 ft. (0 to 1.2 m) of the junction of the exit ramp and the crossroad or to continue the pavement edge line of the undivided crossroad. Another recommendation is to increase the size of the sign.

CONCLUSIONS AND RECOMMENDATIONS

From the findings of the investigation reported here, the conclusions given below appear warranted.

1. The one-way arrow on the exit and entrance ramps should be placed as close as possible to the junction of the ramp with the crossroad such that it is visible to a driver before he starts or completes a wrong-way entry.

2. The removal or striping of the left flare at the intersection of the crossroad with the exit ramp should be made mandatory and that of the right flare made desirable.

3. Continuation of the pavement edge line across the exit ramp or placement of the stop line close enough to the crossroad, say within 5 ft. (1.5 m), such that it lies within the zone illuminated by low beam headlights discourages a driver from making a wrong-way entry onto the exit ramp.

4. To make full utilization of the funds that are now being spent on channelization at crossovers opposite exit lanes, use of the simple ordinate method for locating the two noses of the crossovers given in this report is recommended.

5. All signs and pavement markings and their placement should be designed for visibility and legibility at night.

6. There is a need in Virginia for typical placement diagrams for regulatory and warning signs at intersections.

7. Wrong-way incidents are more common immediately after the opening of an interchange than in later years. Facilities as recommended in this report should be provided to reduce such incidents.

ACKNOWLEDGEMENTS

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6. Commonwealth of Virginia, Department of Highways & Transportation "Operations Manual — Traffic and Safety Division."

Figure 1. Intersection 59 on I-81. Visibility of pavement arrow marking when placed near the stop line.

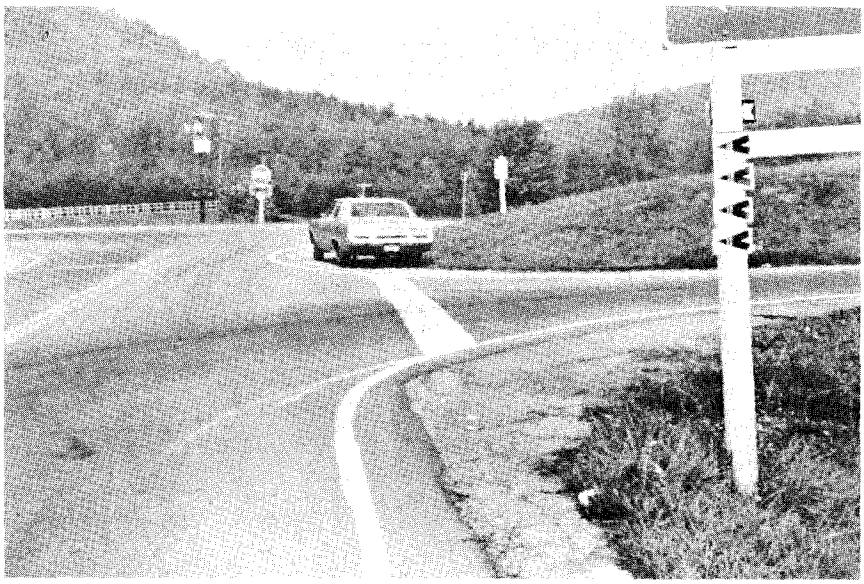

Figure 2. Intersection 43 on I-81 S. Nonvisibility of the pavement arrow marking from the crossroad when placed 22 feet from the stop line.

Figure 3. Junction of I-95 South exit ramp and Route 1 before marking of the left flare.

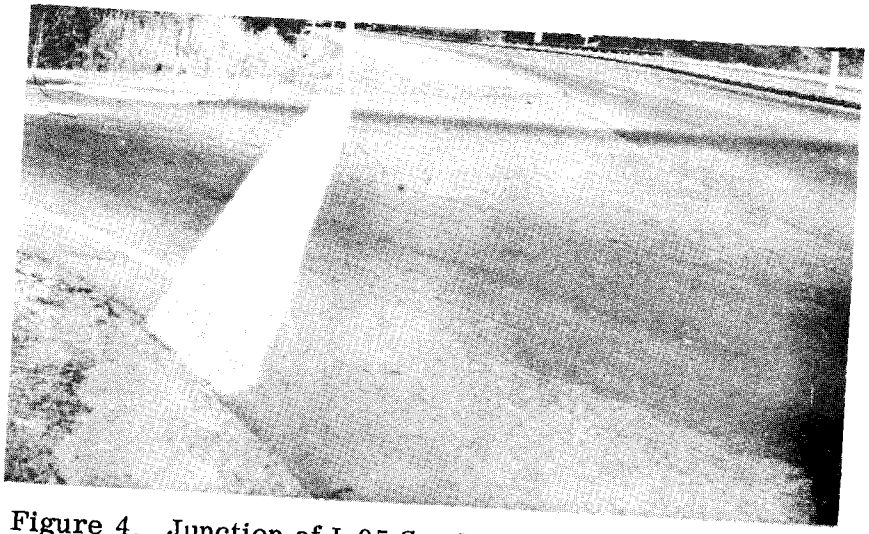

Figure 4. Junction of I-95 South exit ramp and Route 1. The distance of the stop line from the junction of the crossroad and exit ramp is so great that the driver is unable to see the crossroad on his left.

Figure 5. Junction of I-95 South exit ramp and Route 1 after marking of the left flare. Note that the driver ignores the stop line to get a better view of the crossroad.

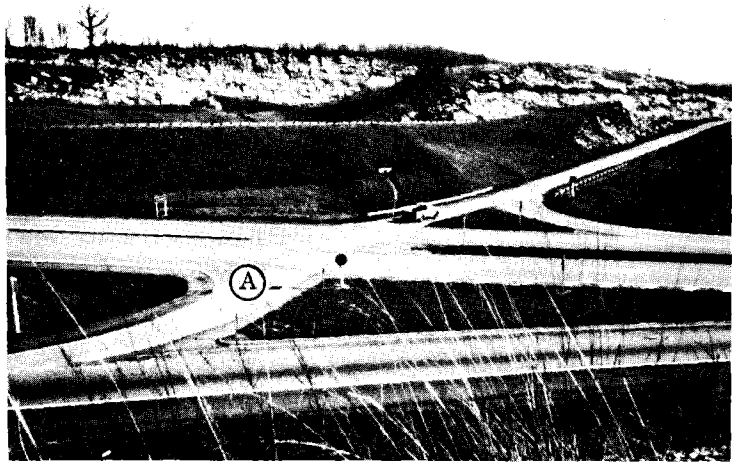

Figure 6. Interchange 53 at intersection of I-81 South exit ramp and Route 11. "A" is left flare before marking.

Figure 7. Interchange 53 showing marking of the left flare.

Figure 8. Junction of I-64 W exit ramp and Route 364 showing recently striped flare.

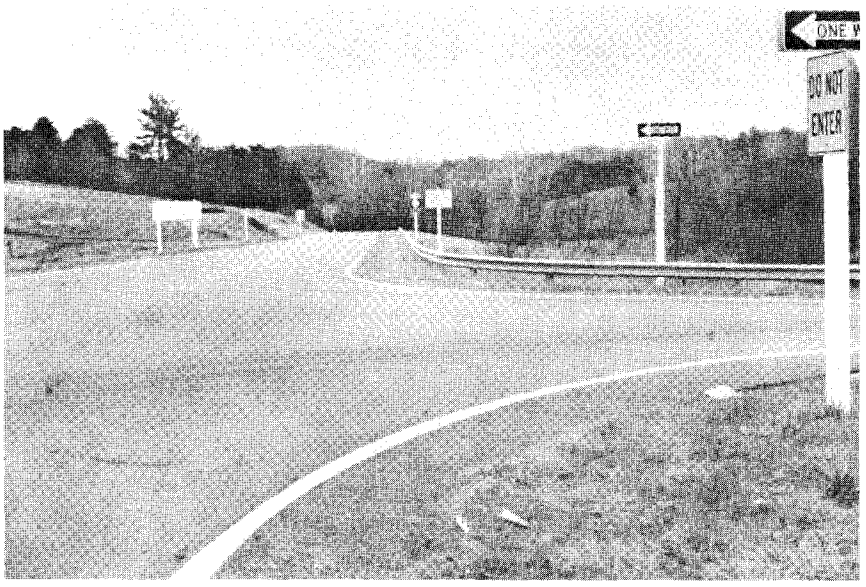

Figure 9. Intersection of I-64 at Ivy showing flared end of exit ramp. Intersection was scene of wrong-way entry that led to accident resulting in three fatalities.

Figure 10. Interchange 57 at I-81 North and Route 250. Opening in the pavement edge line which probably encouraged a wrong-way driver to enter the exit ramp.

Figure 11. Interchange 55-A at I-81 exit ramp and Route 654 in daylight photograph showing one-way arrow and stop line.

Figure 12. Interchange 55-A in night photograph showing that one-way arrow and stop line are not visible under low beam headlights.

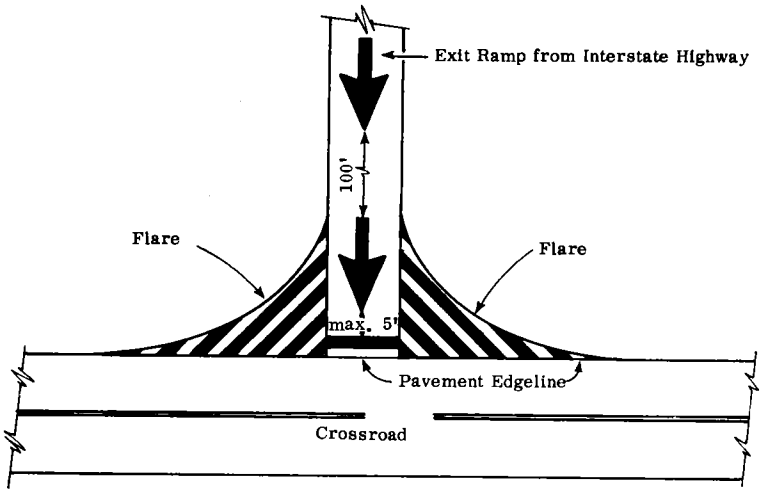

Figure 13. Suggested pavement stripe or removal of flares on exit ramps.

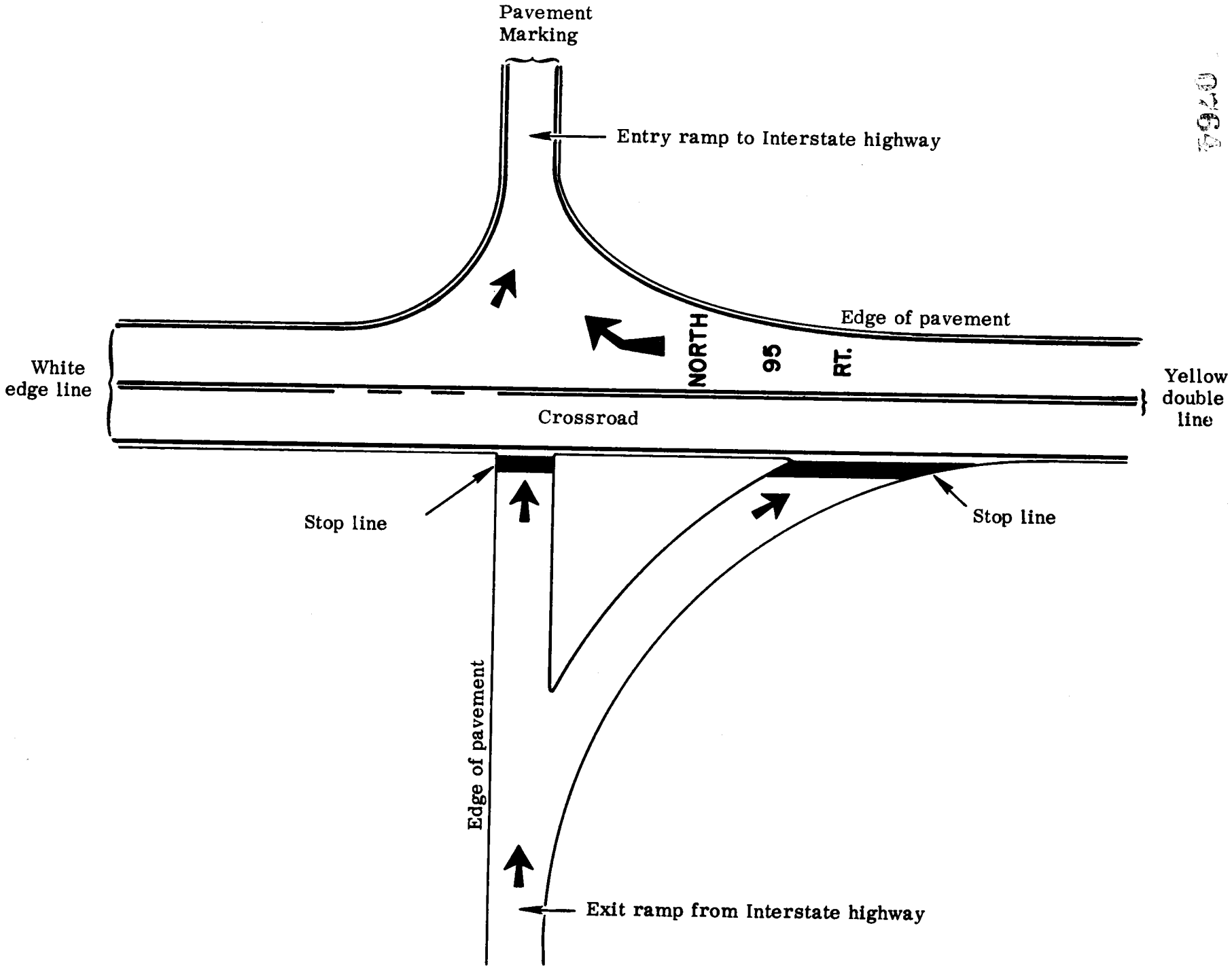

Figure 14. Recommended marking on undivided crossroad.

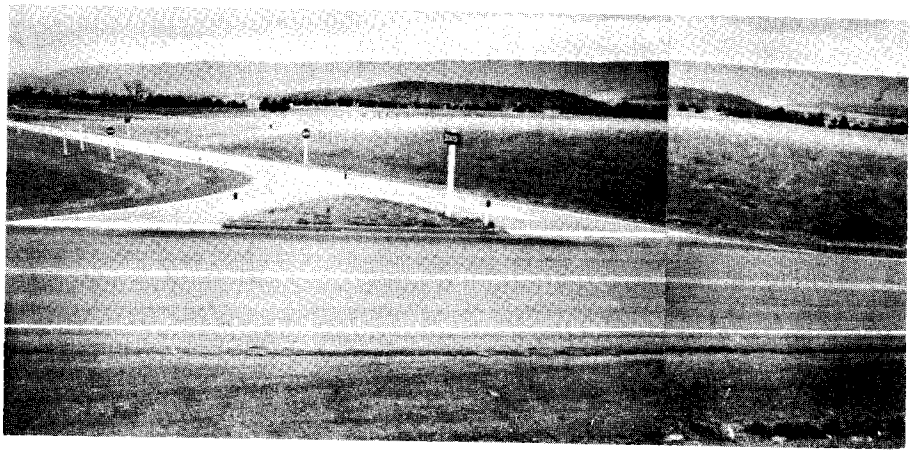

Figure 15. Example of continuous yellow double lines opposite an exit ramp.

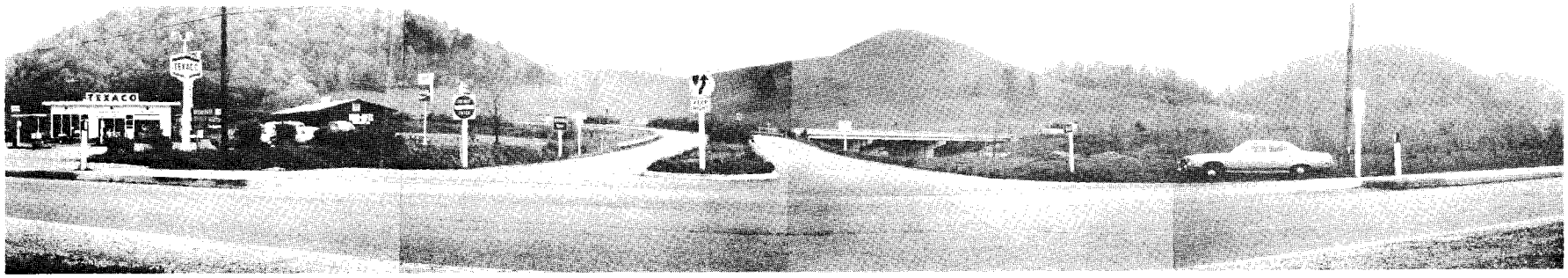

Figure 16. Parclo interchange No. 65 on I-81. Very wide crossover even after extension of the medians.

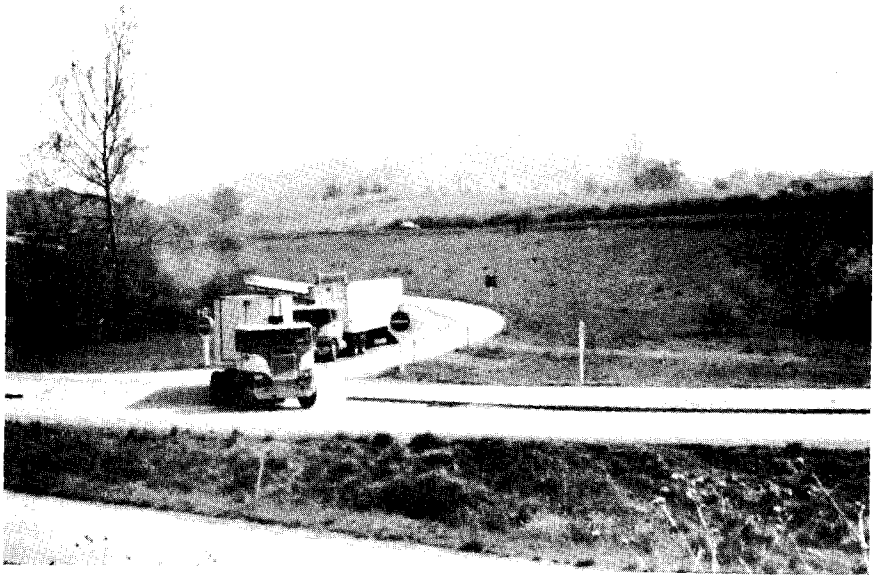

Figure 17. Interchange on I-81. Even after extension of nose of median, there is ample gap between nose and biggest trailer truck.

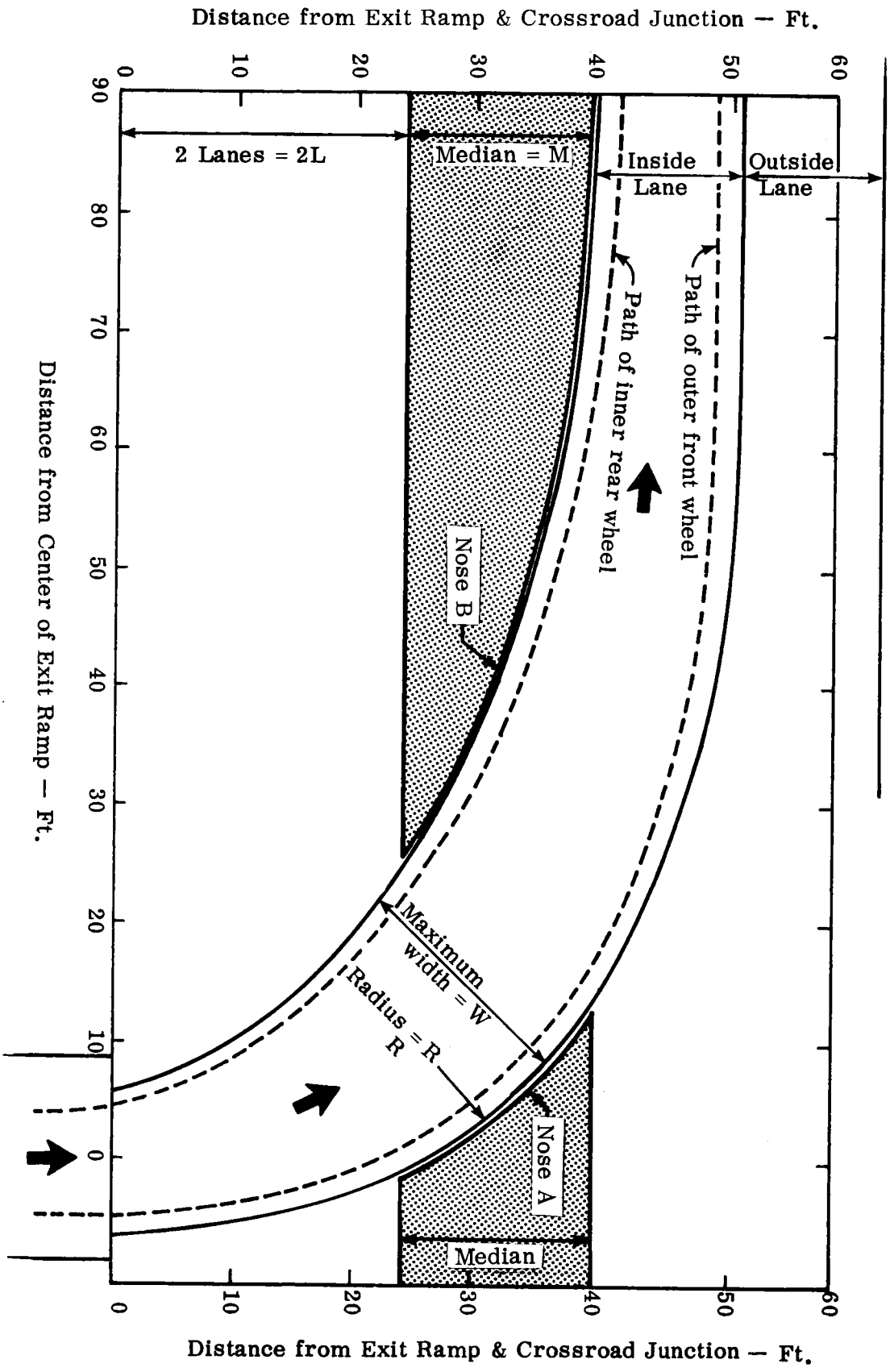

Figure 18. Diagrammatic view of channelization of crossover opposite exit ramp.

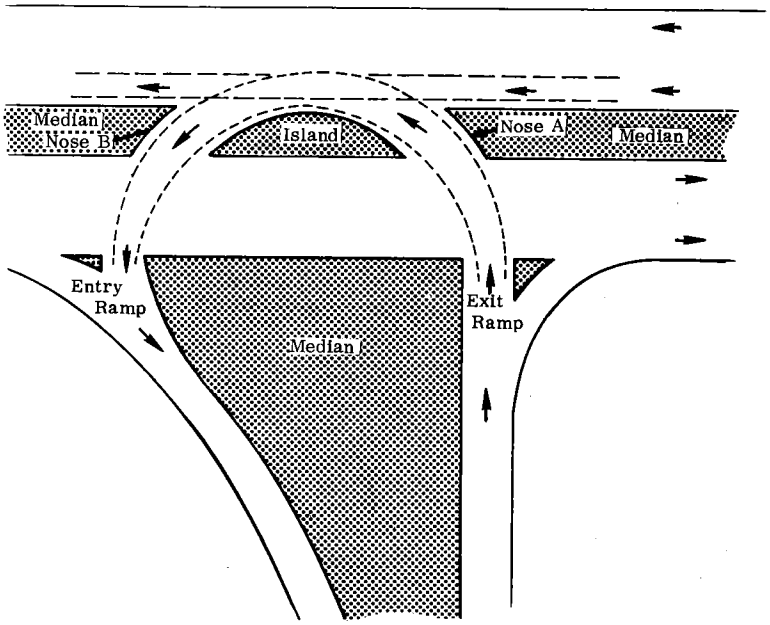

Figure 19. Diagrammatic view of channelization of crossover at parclo interchange.

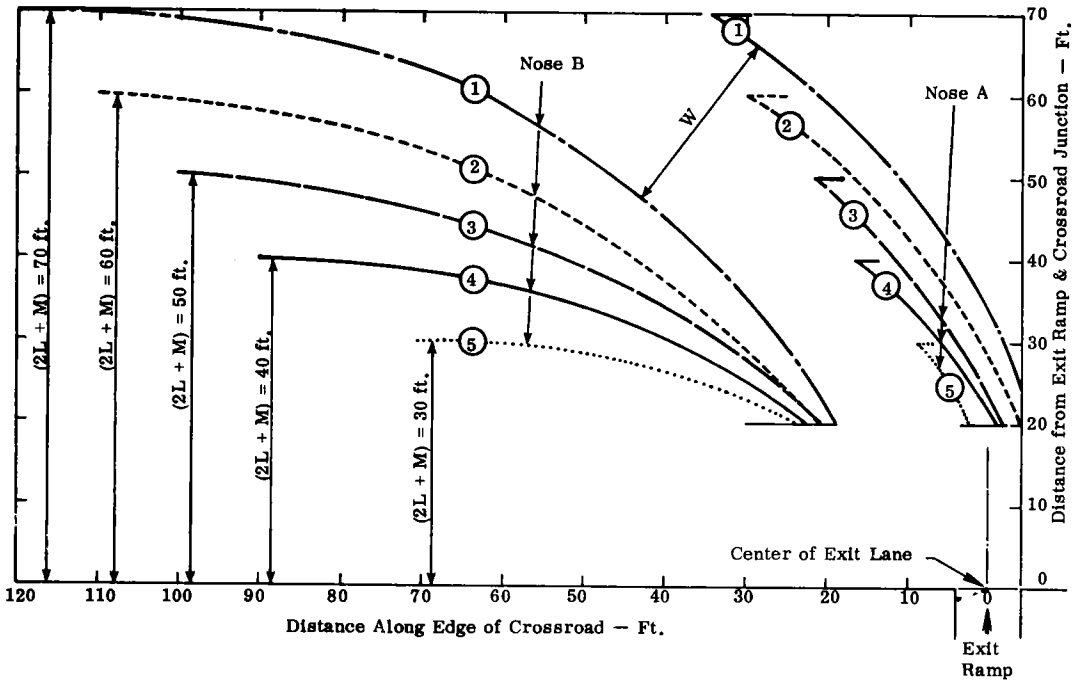

Figure 20. Design of crossover widths for different dimensions of (2L + M).

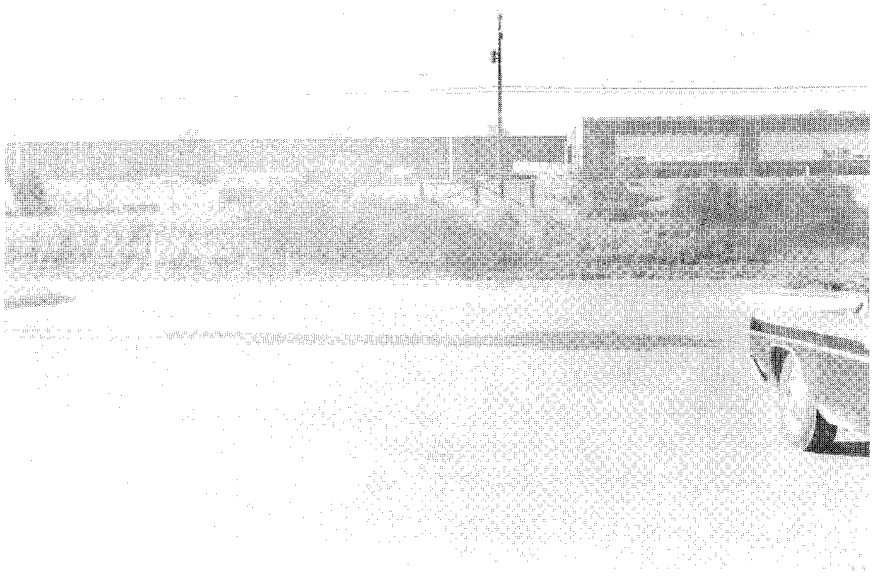

Figure 21. Poor location of one-way sign. For optimum effectiveness, sign should be directly opposite vehicle leaving shopping center.

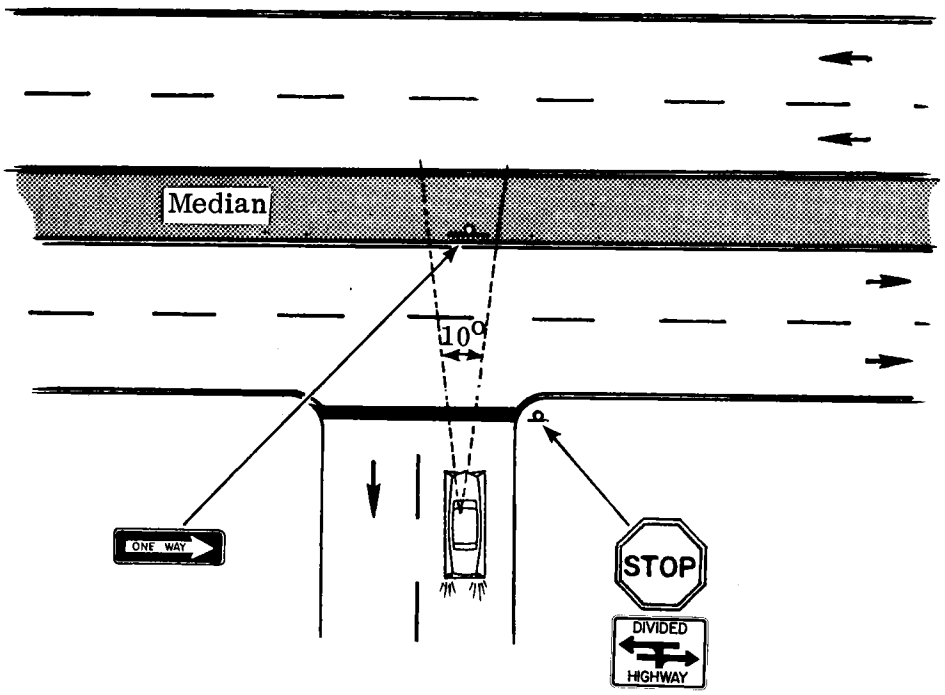

Figure 22. Diagram for sign placement in residential area or small business area, e.g., area with gas station, club, restaurant, or motel.

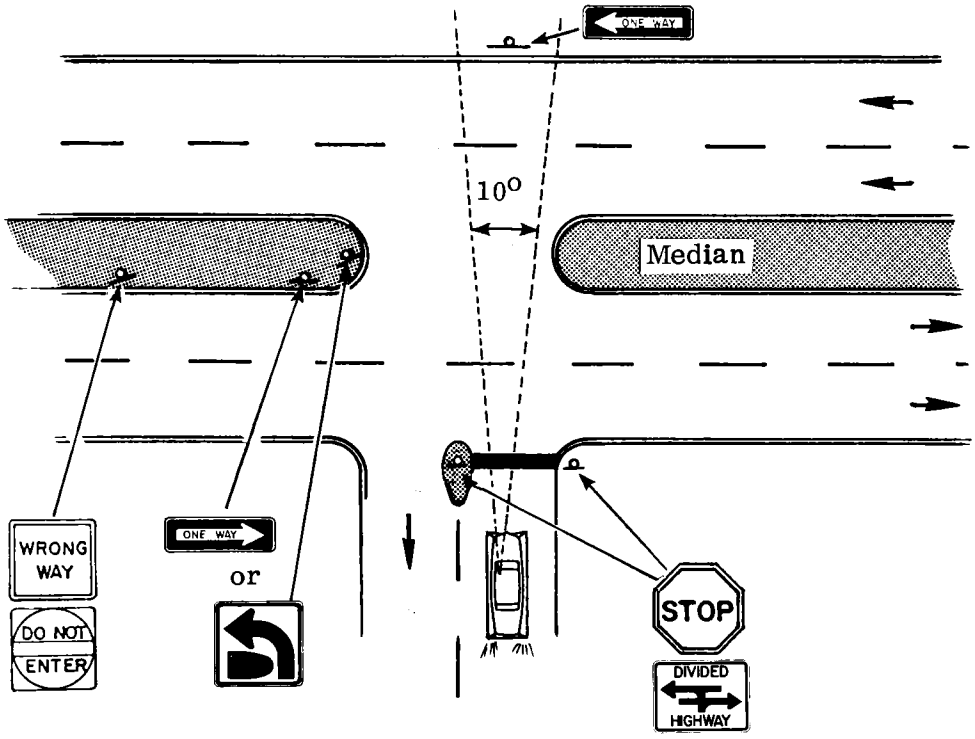

Figure 23. Large business area, small town in rural area, or big residential area that justifies a crossover.
(Note: Median turn sign ( ) is to be provided when opposite lanes of 4-lane divided highway are at different elevations or when median nose is not clearly visible to driver turning left from crossroad.

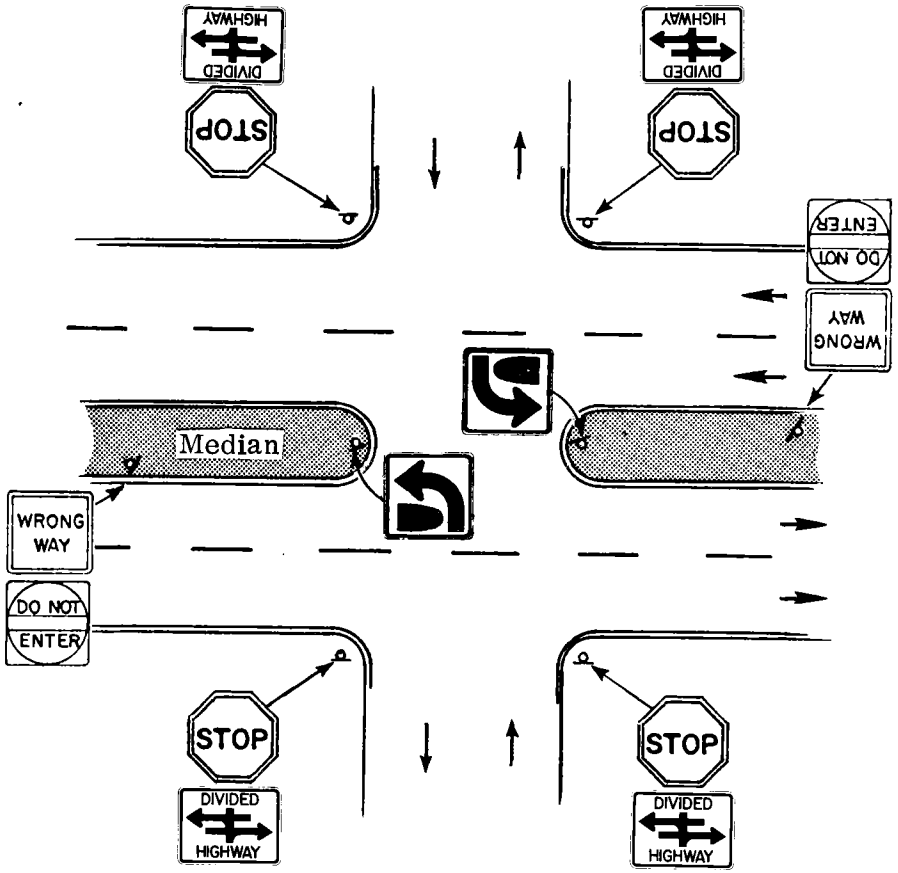

Figure 24. Low traffic intersection in rural area.*

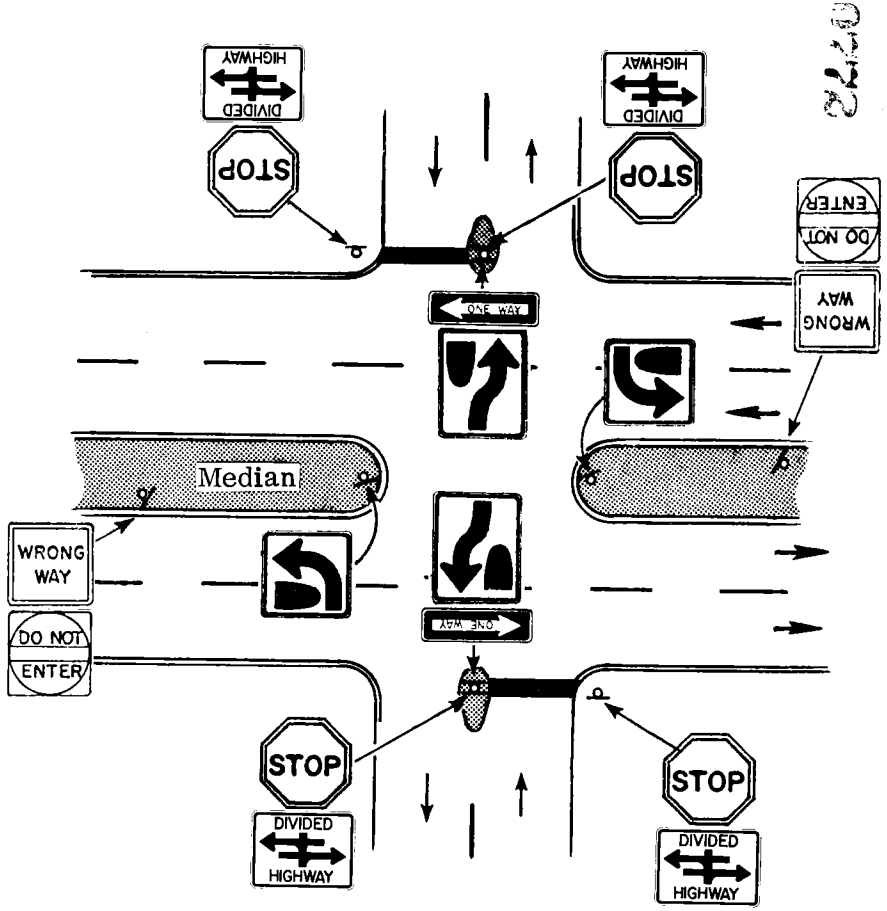

Figure 25. High traffic intersection in rural area.*

* (Note: Median turn sign ( ) to be provided when the opposite lanes of 4-lane divided highway are of different elevations or when nose of median is not clearly visible to driver turning left from crossroad.)

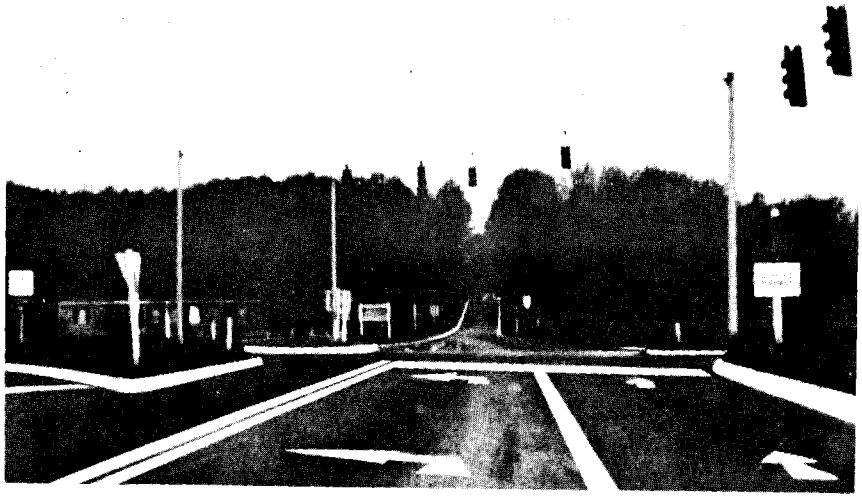

Figure 26. Intersection showing poor visibility of the lanes across the median.

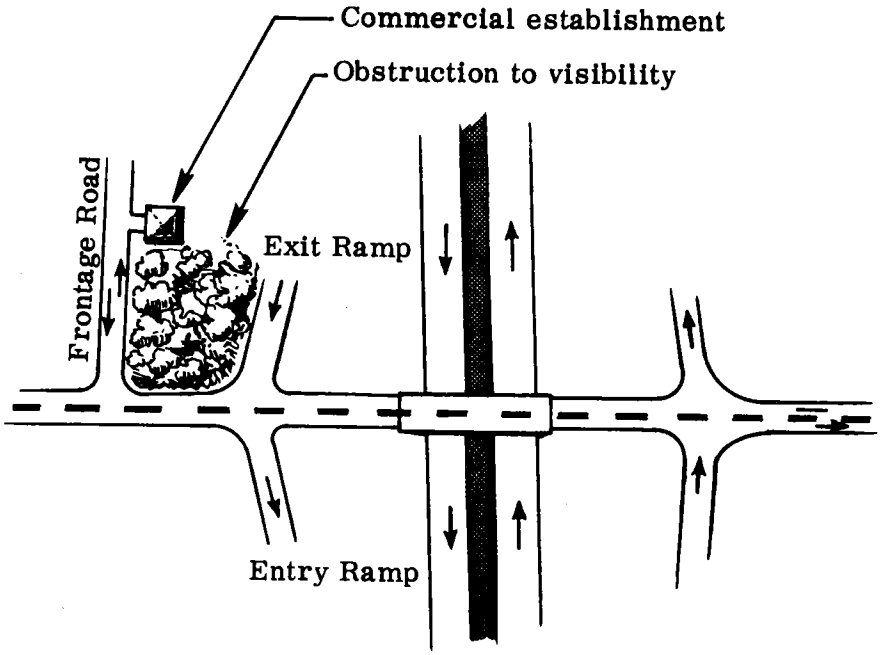

Figure 27. Frontage road with access obstructed from view led to wrong-way entry into the exit ramp from I-95 onto Route 630.

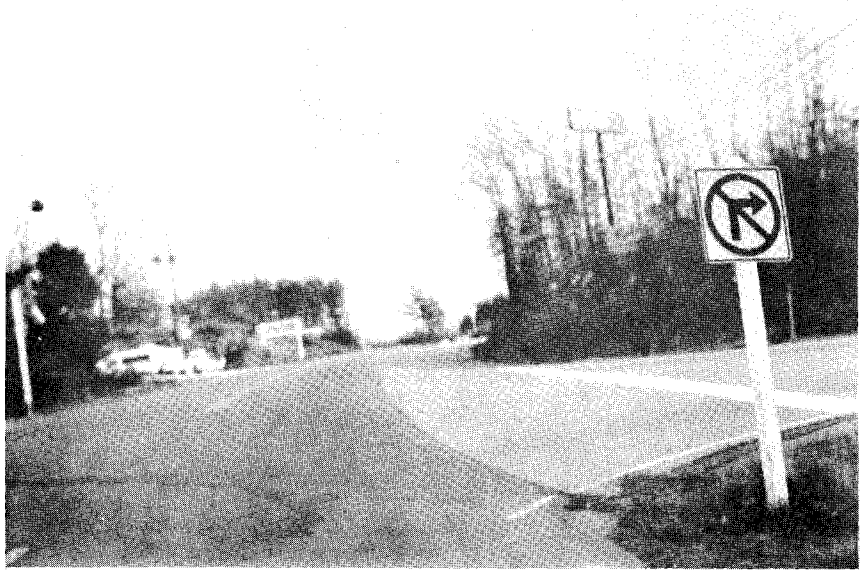

Figure 28. Day photograph of exit ramp in Figure 27. Driver made wrong-way entry at right. Access to frontage road is not visible.