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Virginia's Crash Program to Reduce Wrong-Way Driving

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Over a 4-year period beginning in 1970, wrong-way incidents and accidents were reduced on Virginia's interstate highways by 50 percent and on noninterstate four-lane divided highways by 70 percent. However, since 1975 an upward trend has been observed on interstate roads, while the downward trend has continued on noninterstate roads. This paper discusses the following engineering measures taken to reduce wrong-way driving: using reflectorized pavement arrows on ramps, eliminating pavement flares, providing stop lines across exit ramps near junctions with crossroads, continuing the pavement edge line across exit ramps, continuing double yellow lines on two-lane divided crossroads opposite exit ramps, reducing crossover width across exit ramps, adding guidance to local drivers on new interchanges, informing the driver of the geometry of the intersection before he or she enters it, and providing guidance for drivers at T-intersections without a crossover.

A survey of wrong-way incidents by the Virginia Department of Highways and Transportation and the Virginia State Police was initiated in June 1970 and has continued since, except for December 1970 to June 1971. The data collected show that until June 30, 1976, a total of 114 wrong-way accidents involving 54 deaths and 120 injuries had occurred on interstate highways. In the 167 accidents reported on other four-lane divided highways during the same period, 33 were killed and 173 injured.

Fatalities and injuries caused by wrong-way driving on interstate highways and four-lane divided highways in Virginia were compared with total accident fatalities and injuries on major highways in the state during 1970 to 1976. This comparison showed that although wrong-way accidents were relatively few compared to the total number of accidents they were exceptionally severe. The data showed that the fatality rate per wrong-way accident was 31 times greater than that for other types of accidents on interstate highways and 10 times that for other types on four-lane divided highways. The data also showed that the injury rate was 2.9 times that for other types of accidents on interstate highways and 2.3 times the rate for these on four-lane divided highways.

However, as shown below, the wrong-way incidents and accidents could not be related to the total accidents on a statewide basis for interstate and other four-lane divided highways. Table 1 gives the vehicle kilometers, total accidents, wrong-way incidents, and wrong-way accidents for each calendar year since 1970 for interstate, arterial, and primary highways.

These data show that on interstates the total number of accidents during 1972 was 1947 billion vehicle kilometers (1515/billion vehicle/miles) of travel. In 1973 the total dropped to 868 (1389), a decrease of 8.3 percent from 1972, which was possibly accomplished by the legislation effective in June 1972 that reduced the blood alcohol content (BAC) level from 0.15 percent to 0.10 percent for a presumption of drunk driving and stipulated a mandatory revocation of the driver's license for a period of 6 months for persons convicted of driving while intoxicated (DWI). Later, in December 1972, breath tests were introduced to make conviction for drunk driving easier.

On interstate roads in 1973 enforcement of these regulations sharply cut the total anticipated accident rate. In 1974 on the interstate highways the total number of accidents decreased to 639 billion vehicle kilometers (1022/billion vehicle/miles), a reduction of 26.4 percent from 1973. This shift might have been caused largely by the energy crisis of 1973 to 1974 and its accompanying reduction in the speed limit to 88.5 km/h (55 mph).

As shown in Figure 1, there was a considerable dip in wrong-way incidents and accidents at the beginning of 1973, possibly because of fear of DWI conviction. Later in 1973 the trend reversed and did not seem to be affected by the new legislation and reduced speed limit. The 26.4 percent reduction in total accidents during 1974 was apparently not reflected in the figures for wrong-way incidents and accidents (Figure 1 and Table 1).

From 1970 to 1973, when the total travel and accidents were increasing, incidents and accidents either remained constant or decreased. Since 1974, when total travel and accidents again increased, wrong-way incidents and accidents also tended to increase, a reversal of the relationship between total accidents and wrong-way incidents and accidents. Therefore there is no apparent relationship between vehicle kilometers of travel or total accidents and wrong-way incidents or accidents on interstate highways.

On arterial and primary highways total travel increased until 1973. In 1974 it decreased, probably be-

Table 1. Traffic and wrong-way driving and accident summary.

Year	Interstate				Arterial and Primary Highways			
	Annual Vehicle Kilometers of Travel (millions)	Total Accidents	Wrong-Way Incidents	Wrong-Way Accidents	Annual Vehicle Kilometers of Travel (millions)	Total Accidents	Wrong-Way Incidents	Wrong-Way Accidents
1970	7 532	6729	38[c]	12[c]	16 198	35 617	83[c]	18[c]
1971	8 393	8133	38[c]	13[c]	16 807	37 195	113[c]	26[c]
1972	9 568	9005	64	25	17 794	40 366	135	39
1973	10 515	9076	41	19	18 081	39 929	100	24
1974	10 197[a]	6474[a]	37	19	18 286[a]	35 125[a]	60	18
1975	10 916	6617[b]	42	17	18 902	30 747[b]	56	31
1976	—	—	28[d]	12	—	—	22	9

Note: 1 km = 0.62 mile.

[a]The energy crisis during 1973 and 1974 reduced the total travel. A reduction in the speed limit to 88 km/h (55 mph) also accounted for fewer total accidents.
[b]Effective January 1, 1975, the accident reporting threshold changed from $100 to $250.
[c]June through December.
[d]January through June.

cause of the energy crunch, and began a continuing increase in 1975. The total accident rate on the arterial and primary highways increased from 1970 through 1972 (as shown in Table 1), and since then has decreased (see Figure 2). This reduction might be attributed to the 1972 change in DWI legislation. For four-lane divided noninterstate highways, no statistical relationship seems to exist between total travel or total accidents and wrong-way incidents or accidents.

From Figure 1 we see that wrong-way incidents decreased, during 1970 through 1974, from 38 during the first 7 months to 18 during the second 6-month period of 1974. For the same periods, wrong-way accidents on the interstate system fell from 12 to 6, about a 50 percent reduction.

Figure 2 shows that wrong-way incidents from 1970 to 1976 decreased from 83 during the first 7 months to 22 during the last 6-month period. Wrong-way accidents on the four-lane divided noninterstate highways simultaneously fell from 18 to 9, reductions of more than 70 percent in wrong-way incidents and approximately 50 percent in the accident rate during the 4-year period.

Figures 1 and 2 also show the proportional decrease in day and night accidents from wrong-way entries. These data for 1974 to 1976 show very low rates both of increase in wrong-way incidents and the accident rate on interstate highways and of reduction on four-lane divided noninterstate highways.

The data collected from 1970 to 1976 show that about 50 percent of the wrong-way entries originate from interchanges; about 15 percent originate at crossovers and rest stops or are associated with U-turns and median crossings. The origins of the remaining 35 percent are unknown.

On noninterstate four-lane divided highways, about 40 percent of the drivers making wrong-way entries emerge from intersections with crossroads or exit ramps connecting with interstate roads; about 25 percent originate from business establishments such as gas stations and motels; and about 20 percent originate from residential areas, crossovers, beginnings of divided sections, and construction sites or are associated with U-turns and median crossings. The origins of the remaining 15 percent are unknown.

In order, therefore, to reduce wrong-way driving, improvements have been focused on interchanges, intersections, and exits from business areas. In addition, some crossovers on interstates have been closed. U-turns, which are more common on interstates than on other four-lane divided highways, do cause wrong-way driving, but no preventive measures for them have been devised.

The drunk driver compounds the problem of wrong-way driving. A survey showed that, out of the 287 wrong-way drivers spotted on interstate highways, 152 were drunk, 85 were not drunk, and the condition of the others was not stated. On the noninterstate four-lane divided highways, 188 out of 569 wrong-way drivers were drunk, 302 were not drunk, and the condition of the remainder was not stated. Among the 302 sober drivers on noninterstate highways, many could have made intentional wrong-way maneuvers to cut driving distance (Figure 3). Also among the sober wrong-way drivers were quite a few whose responses to stimuli were impaired because of age, sickness, medication, or other factors.

The 1972 Virginia legislation on drunk driving does not seem to have reduced wrong-way driving by drunk drivers. Figure 4 shows that although the total number of wrong-way incidents on interstates decreased after June 1972 it was the elimination of faulty maneuvering by sober drivers rather than improved drunk driving that caused the reduction. Figure 5, however, shows that on noninterstate highways the decrease in the number of wrong-way incidents was attributable to improvements by both drunk and sober drivers. The data do not, therefore, confirm that the change in the law has contributed to the reduction of wrong-way incidents. The reduction probably resulted from other factors such as the engineering measures and increased public awareness of wrong-way driving.

ENGINEERING MEASURES TO REDUCE WRONG-WAY DRIVING

The most significant of the many engineering measures instituted in Virginia during the program to reduce wrong-way driving will be discussed in what follows.

Reflectorized Pavement Arrows on a Ramp

All interstate exit and entry ramps in Virginia have been provided with 5.6-m (18.8-ft) reflectorized direction arrow indicators. Two arrows are placed on the exit ramp and one on the entrance ramp, and the distance from the tip of the arrow to the stop line on the exit ramp varies from 1.5 to more than 7.5 m (5 to 25 ft).

Observations have shown that arrows placed close to the intersection of the crossroad and the exit ramp are visible to the potential wrong-way driver making either a right or a left turn onto the exit ramp as shown in Figure 6; those placed beyond 4 to 5 m (13 to 16.5 ft) from the intersection are not visible. Therefore, the first arrow on the exit ramp should be very close, say within 1.5 m, to the junction of the exit ramp with the crossroad. This arrow can then be seen by the potential wrong-way driver during the day and at night under low-beam headlights. The second arrow on the exit ramp should be placed approximately 30 m (100 ft) from the stop line (1) as a second warning to the wrong-way driver.

Similarly, the arrow on the entrance ramp can guide the driver from the crossroad into the correct direction only if the driver can see it from the crossroad. An arrow far from the junction of the crossroad and entrance ramp will not be visible to the driver from the crossroad and will fail to perform its function, except to reassure the the driver after he or she is already on the entrance ramp.

Elimination of Flares

On almost all interchanges on which wrong-way entries have been made, either into an exit ramp or from an exit ramp onto a crossroad, the left edge of the left lane of the exit ramp has been flared into the right pavement edge of the crossroad. An example of such a flare, which probably misleads the driver, is shown in Figure 7.

Figure 1. Incident and accident data for Virginia interstate system.

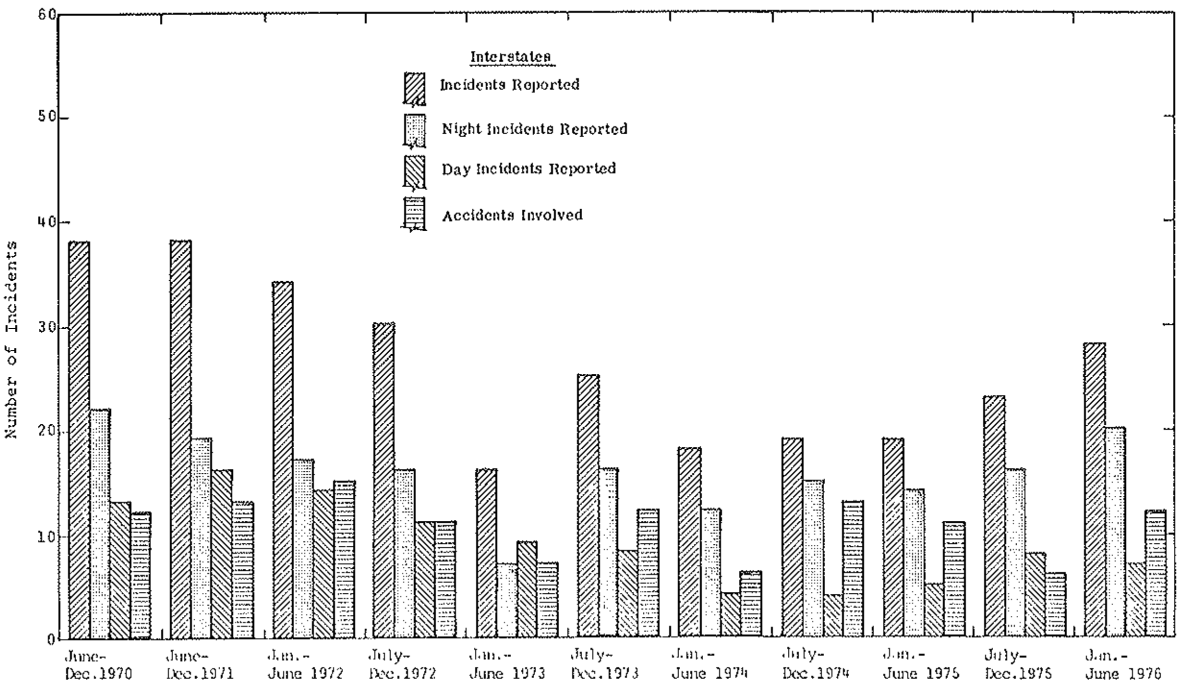


Figure 2. Incident and accident data for noninterstate Virginia highways.

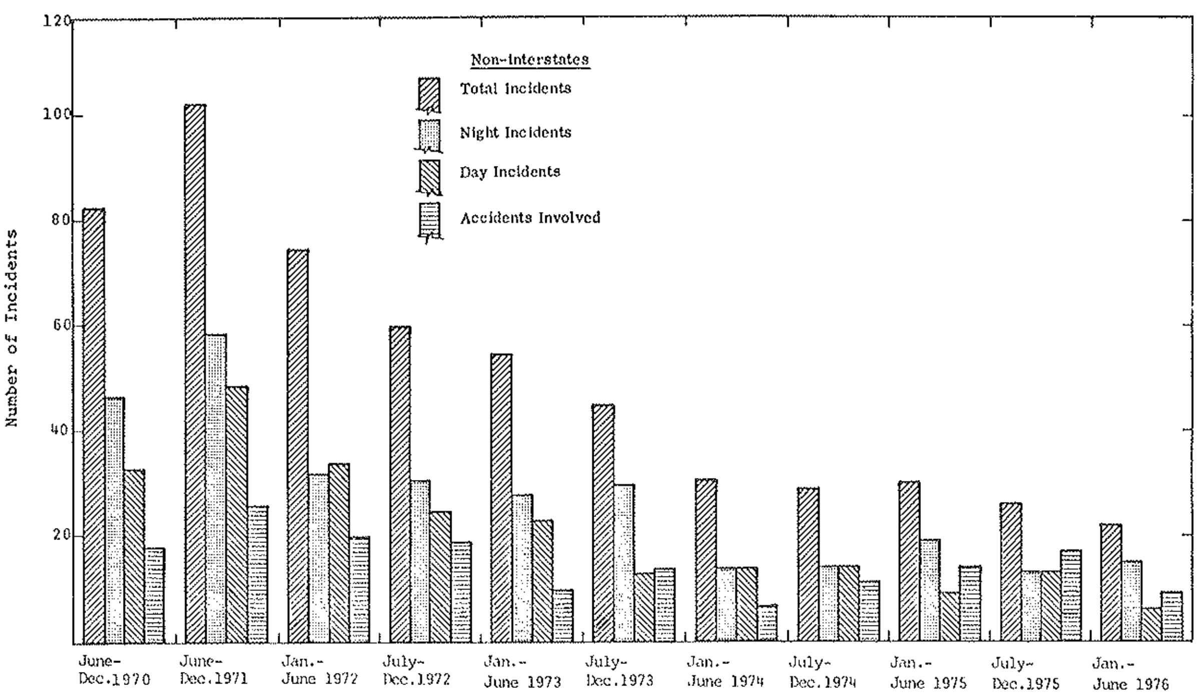
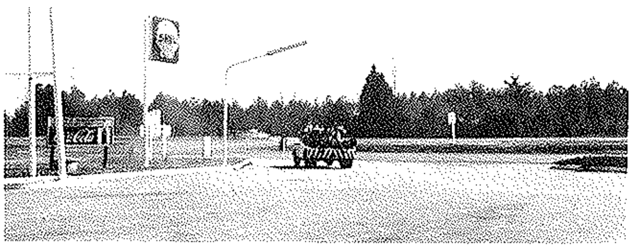


Figure 3. An intentional wrong-way exit from a gas station.



The results of removing these flares have been very encouraging, and the following example shows how wrong-way entries can be completely eliminated.

This flare at the intersection of an interstate exit ramp and a primary highway experienced six wrong-way entries (the highest in Virginia), all by sober drivers during the first 2 years of the survey period. All approaching drivers would stop on the stop line. In 1974 I suggested that the flare be eliminated by installing two right-angled white lines (2), and over the next 30 months no wrong-way incidents were reported. The marking

Figure 4. Wrong-way incidents and drunk and nondrunk drivers on the Virginia interstate system.

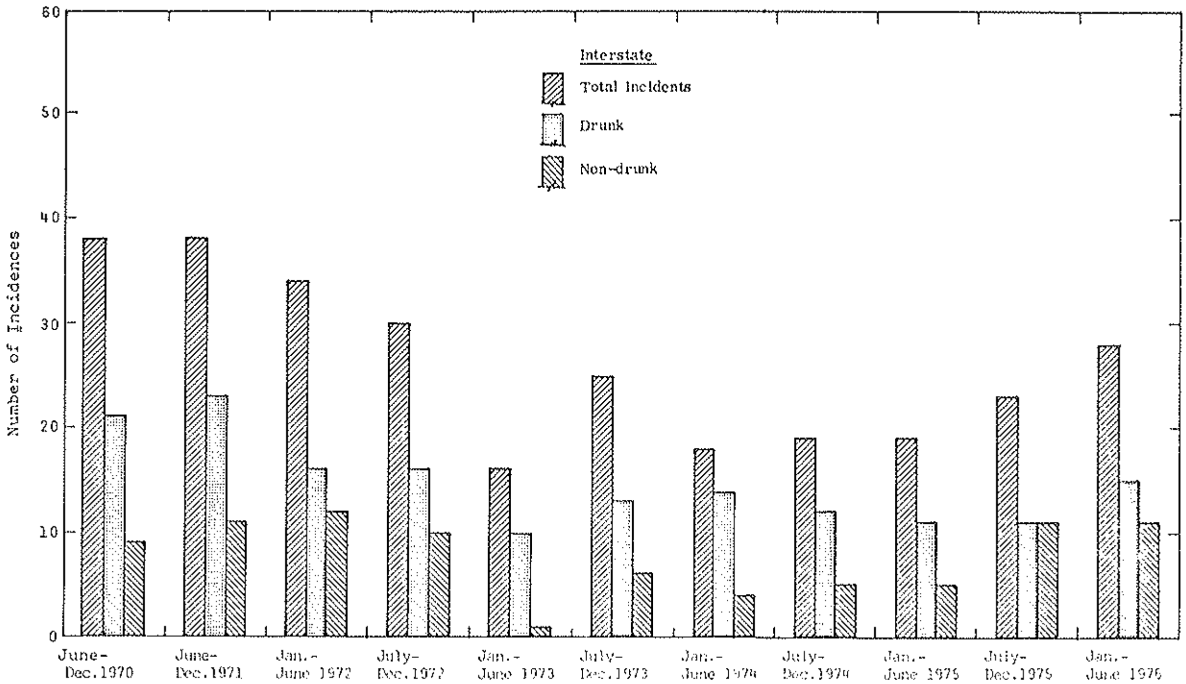
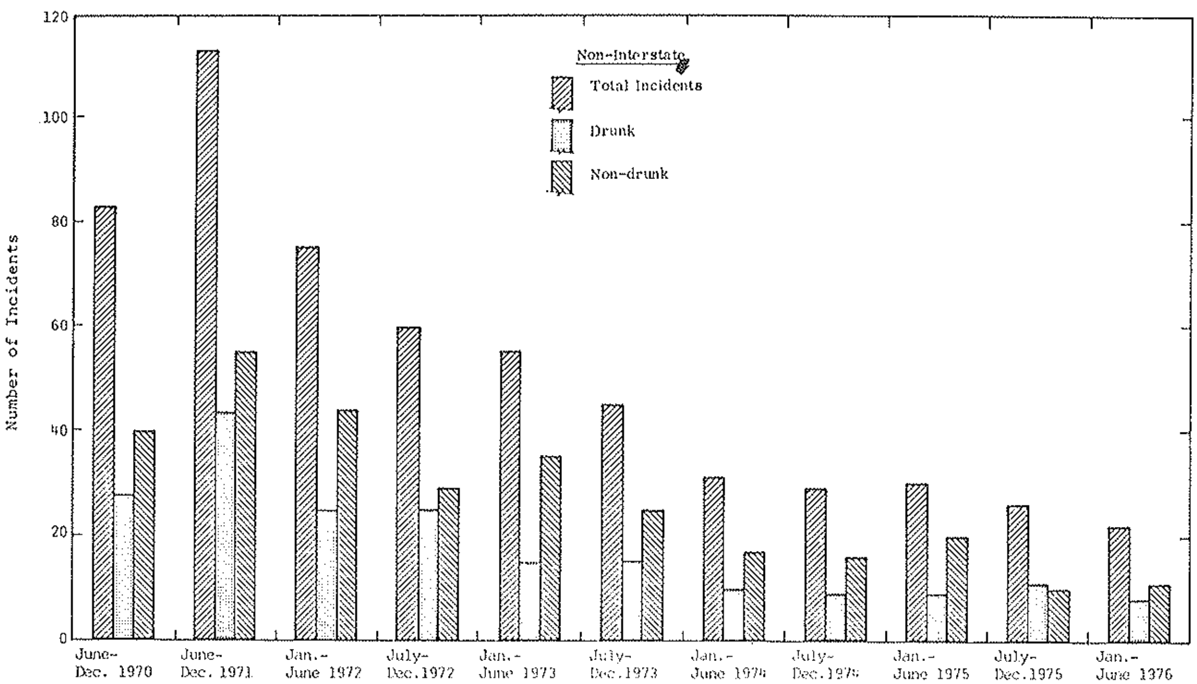


Figure 5. Wrong-way incidents and drunk and nondrunk drivers on noninterstate four-lane divided Virginia highways.



(Figure 8) apparently discourages drivers from quickly turning left onto the wrong side of the median and also increases visibility on the primary highway. A driver who needs more visibility distance crosses the stop line and comes to a stop at the corner of the flare marking.

Other examples of removing flares are given elsewhere

Figure 6. Pavement arrow markings near stop line (no incidents).

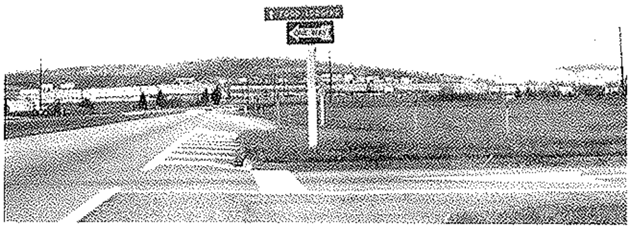


Figure 7. Junction of exit ramp and primary highway before marking left flare (six incidents).

Figure 8. Junction of exit ramp and primary highway after marking left flare (note that driver ignores stop line to get better view of crossroad; no incidents after marking).

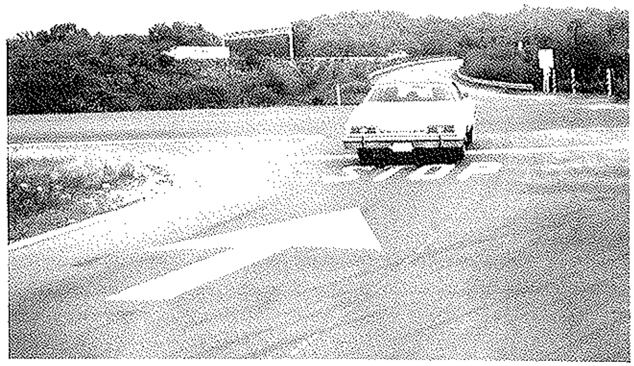
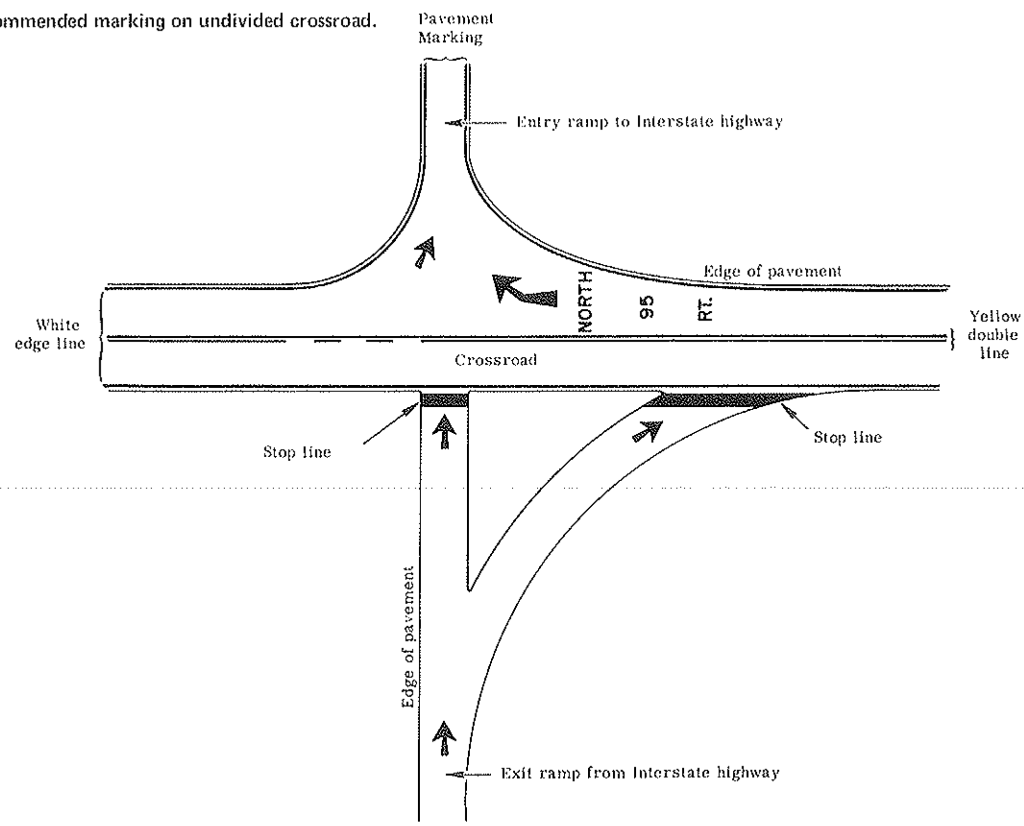


Figure 9. Visibility of stop line from a considerable distance on crossroad (no incidents after marking).

Figure 10. Recommended marking on undivided crossroad.



(3), and Scrifes has also recommended flare removal to reduce wrong-way driving (4).

Stop Line

Traffic on one-way exit ramps of all partial interchanges must stop at the ramp's junction with the crossroad. During field investigations it was observed that many exit ramps that had been involved in wrong-way entries onto the crossroad or onto the interstate highway did not have stop lines.

The stop line probably has the following two advantages:

1. More drivers tend to stop for a stop line than for a stop sign only, and
2. The stop line probably discourages the driver on the crossroad from entering the exit ramp.

During our investigations we found that at a few locations the stop line was very close to the crossroad and exit ramp intersection. Such lines were found to be very clearly visible from considerable distances ahead of the intersection while driving along the crossroad during the day and at night under low-beam headlights.

In Figure 9 a stop line placed very close, say, within 1.5 m of the junction of the crossroad and the exit ramp, is visible to the driver on the crossroad day and night and will be of immense help in preventing wrong-way entries into the exit ramp. Figure 10 shows the placement of a stop line at an intersection.

Continuation of Pavement Edge Line

Drivers are now so accustomed to the pavement edge line that they seem to use it as a guide. Drunk drivers or drivers with poor responses probably depend on this line because of their restricted ranges of vision. If this line were continued across the exit ramp (see Figure 10) it would make the ramp inconspicuous to such drivers on the crossroad, especially at night. In fact, not continuing the pavement edge line is very dangerous, because in Virginia it has been observed that the line has usually been continued into the exit ramp.

One intersection where there was a wrong-way entry into the exit ramp at night had a line continued into the exit ramp that encouraged a driver with a low response to enter the exit ramp. An exit ramp with no stop line visible to the driver is even worse.

Double Yellow Lines on Two-Lane Undivided Crossroads

Undivided crossroads at interchanges are provided with double yellow lines with very wide gaps opposite exit ramps. In one case a wrong-way drunk driver entering this gap caused an accident in which six were killed (2). There is a strong possibility that a gap in the lines opposite the exit ramp encourages wrong-way entry through the gap onto the exit ramp. I therefore recommend that no gap be provided in the double yellow lines and that double yellow lines be continued opposite the exit ramp as shown in Figure 10.

Some undivided crossroads at interchanges provided with solid double yellow lines have had no reported wrong-way entries. It has also been observed that continuous double yellow lines do not cause any inconvenience to drivers who cross these lines to negotiate an interchange. Providing continuous double yellow lines is not expensive, and I am of the opinion that they prevent some wrong-way entries without interfering with normal traffic.

Added Guidance at Unfamiliar Interchanges

Wrong-way incidents are more common at interchanges during the first year or two after construction than in later years. It has been found that it is local drivers who are involved in such wrong-way incidents, probably because they have had no previous experience with interchanges. More facilities for guiding drivers need to be provided during the first two years after construction.

The most economical measure would be pavement markings (on crossroads) that would fade after a year or two. Instructions and an arrow, as shown in Figure 10, are likely to be helpful to a driver who is confused by a new interchange.

Reduced Width of Crossover Opposite the Exit Ramp at Interchanges

The width of the crossover opposite the exit ramps is often many times more than that needed by a vehicle making a left turn around the nose of the crossroad median from the exit ramp. This excess has contributed to a number of wrong-way maneuvers onto and from the exit ramps. Virginia's traffic engineers realize the need for channelizing crossovers, and the state is encouraging such programs.

I investigated locations where the widths of the crossovers were reduced and found that even after extension of the nose of the median there was often an ample gap between the nose and the largest truck.

A photograph showing this gap at one of the interchanges is given in Figure 11. The left median in this photograph was recently extended to reduce the width of the crossover. A simple method has been developed (5) to help the traffic technician locate the nose for a channelized crossover. By this method the shape and location of the two noses on either side of the crossover can be determined, and the crossover can be properly channelized.

Optical Illusions at Night

Wrong-way entries can be caused by drivers experiencing optical illusions. I have observed two such wrong-way entries, one of which is shown in Figure 12, a photograph of the intersection. On inquiry, the driver (local, sober) said that he did not see the lane on the far side of the median. This is a level intersection, and unless a person is very observant he or she is unable to see these lanes.

A divided highway sign on the left before a left turn will inform the driver of the geometry of the intersection. An additional turn sign at the left nose of the median would provide further guidance (Figure 13). These signs have been installed on an experimental basis at 72 intersections over a 92-km (57-mile) stretch of a primary highway in Virginia.

Our divided highway sign is the same as that used in Delaware to reduce wrong-way entries. This sign has been used in Delaware for several years, and engineers there say that it has been very effective. They claim that in 1967 wrong-way incidents were reduced to five accidents, or 0.004/million (0.006/million vehicle/miles) vehicle kilometers traveled. This number was far below the national average.

T-Intersections Without a Crossover

Small business areas, such as gas stations, clubs, restaurants, and motels, and small residential areas are not provided with exits through the medians of divided highways. At such locations an exiting driver

Figure 11. Extension of median nose at wrong-way entry site (note ample gap between nose and truck).

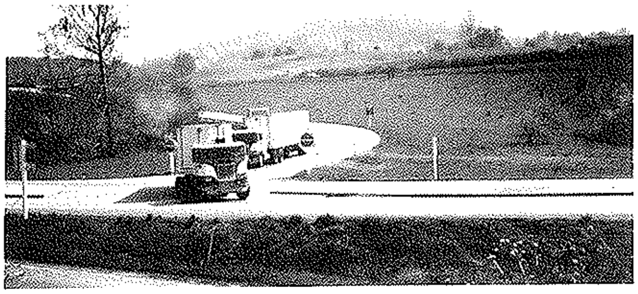


Figure 12. Poor visibility of lanes across median at wrong-way entry site.

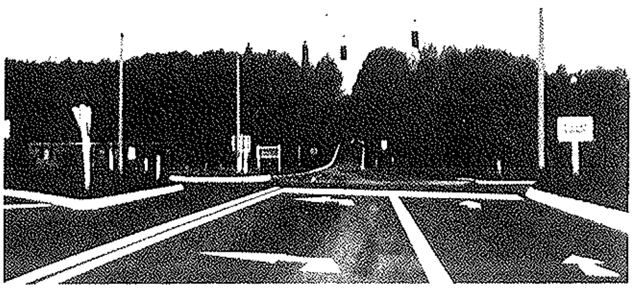


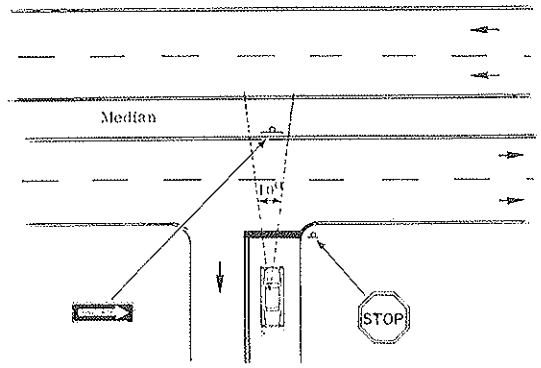
Figure 13. Location of divided highway and turn signs.

assumes the road to be a two-lane highway and sometimes makes a wrong-way entry. In most cases, there are one-way arrow signs opposite these exits. A survey has shown that there is no definite pattern in the location of the signs, and in many cases they are not visible with low-beam headlights. The best use of this sign might be obtained by placing it opposite the vehicle coming out of a business or residential area as shown in Figure 14.

Raised Pavement Markers

In addition to the investigations leading to the above improved signs and pavement markings, one of the other noteworthy recommendations has been to provide raised pavement markers spread over the width of the pavement on a short section of the exit ramp. The feasibility of such markers has been determined (6), and they have now been placed at two exit ramps for further study.

Figure 14. Recommended sign placement in small residential or business area.



CONCLUSIONS

1. Data show that in Virginia incidents of wrong-way driving on interstate highways decreased by more than 50 percent in the 4 years following 1970; on noninterstate four-lane divided highways the reduction was more than 70 percent.
2. The reduction in wrong-way incidents was probably the result of engineering measures and increased public awareness of the wrong-way driving problem.

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