Abridgment

Road Markings as an Alcohol Countermeasure for Highway Safety: Field Study of Standard and Wide Edgelines

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Reflectorized road markings have long been recognized as a cost-effective means of reducing road accidents, particularly at night. In recognition, first, of the need to reduce the 50 percent of fatal road accidents that involve alcohol-impaired drivers, and second, of the high incidence of alcohol impairment at night, this study sought to determine whether wider-than-standard edgelines would serve as an alcohol countermeasure. A vehicle positional study was conducted on two-lane rural roads in northern New Jersey in which four edgeline width conditions (0, 4, 6, and 8 in) were evaluated. From lateral position measurements taken photographically every 100 ft, driver performance was analyzed by using six different methods. The 16 male test subjects each drove twice—once after they consumed placebo drinks [0.00 blood alcohol concentratrion (BAC)], and the other time after they consumed either placebo drinks or a controlled alcohol dosage (0.05 or 0.08 BAC). Prior research was corroborated in that the test subjects showed improved driving performance when edgelines were present and reduced performance when they were alcohol impaired. The presence of wider-than-standard edgelines was found to incrementally enhance the benefits derived from standard 4-in wide edgelines for both unimpaired and alcohol-impaired drivers. When alcohol is present, even at the relatively low BAC levels examined in this research, the visual communication link between the roadway and the driver is interrupted. The improved driving performance of the test subjects in the presence of wide edgelines indicates that strengthening the visual signal at the road edge may compensate to some degree for alcohol impairment and hence reduce the risk of accidents. Since the effects of alcohol on driver vision are similar to the effects of fatigue, drugs, and reduced visual ability due to old age, wide edgelines are likely to also benefit those with these other types of impairment.

Alcohol is a factor in up to 50 percent of all fatal accidents (1) and has historically been counteracted in the United States by highway safety programs based on law enforcement, health therapy, and public education. However, despite the best efforts of these programs, the alcohol problem still frustrates highway safety planners, and it is likely that, if major progress is to be made, new approaches to solving the problem must be developed.

Recent highway safety research has developed two basic propositions that are relevant when considering new solutions (2):

1. It is the ability of the driver to negotiate a highway that is the ultimate consideration in whether or not an accident will occur, and
2. The most-important single effect on driver behavior is the safety potential of the road itself.

By using these two propositions as a starting point, researchers at Potters Industries asked whether a traffic engineering approach to the road environment would be effective in combating the safety problems of the alcohol-impaired driver.

RESEARCH REVIEW

A review of research on alcohol impairment indicates that, although the unimpaired driver generally maintains good visual communication with the roadway, the presence of even small quantities of alcohol tends to block this visual linkage. Since at least 90 percent of all guidance information received by drivers comes from visual sources (3), this blockage creates a critical problem.

Previous research indicates that alcohol affects drivers through various mechanisms, all of which interreact with one another. For example, the alcohol-impaired driver has relatively low sensitivity to contrast, so that all objects seen along the highway tend to merge into the same shading, and the driver's ability to distinguish one object from another is reduced. In addition, alcohol impairment reduces peripheral vision, so that the driver tends to receive visual information only from the center of the roadway.

Another result of alcohol impairment is a tunnel-vision effect, in that the driver sees the road as if he or she were looking at it from inside a tunnel. Simultaneously, the impaired driver's visibility distance is shortened, so that visual search is concentrated on objects close to the front of the vehicle. Hence, the driver is not able to anticipate situations as well as when in an unimpaired condition.

These problems are compounded because alcohol reduces the ability to process information. In addition, the impaired driver has a relatively inflexible searching strategy when viewing objects in the roadway. He or she concentrates his or her visual search strategy on a few items for relatively long periods of time; in an unimpaired searching strategy he or she acquires information from many objects, each viewed for relatively short time periods. The alcohol-impaired driver also suffers some loss of dynamic visual acuity, so that objects in the periphery that are in motion relative to the vehicle, such as signs and signals, appear blurred. Finally, the alcohol-impaired driver is relatively indifferent to deviations in the driving path. All drivers tend to weave to some extent in the driving lane, but the weaving on the part of an impaired driver is much more pronounced, as a result of taking corrective action rather late, and such corrections tend to be over-corrections.

All of these effects of alcohol impairment directly impact the visual link between the road and the driver. Potter's researchers hypothesized that improved delineation, particularly at the edge of the roadway, would improve the visual linkage between the roadway and the alcohol-impaired driver and reduce the probability of road accidents. Controlled tests conducted in both the United States and Europe have shown that continuous 10-cm wide (4 in) reflectorized road markings at the road edge are a highly cost-effective means of reducing road accidents. Since these markings are particularly effective at night, when the highest incidence of alcohol impairment occurs, it is likely that they are already acting as an alcohol countermeasure; the presence of a stronger pattern at the road edge was considered likely to have an incremental benefit for the alcohol-impaired driver.

STUDY DESIGN

In order to safely conduct a realistic controlled study, it was decided not to conduct either a before-and-after accident study or a simulator study. Instead, surrogate measures of driver performance on two-lane rural roads were studied. Vehicle position reflects driver performance, and prior research has shown positional data to be usable in place of before-and-after accident data to predict accident probability.

Research conducted at Pennsylvania State University in 1969, by the Federal Highway Administration (FHWA) in 1977, and by Illinois in 1978, showed accident rate to be a function of the driver positional variability, vehicle positioning in the center of the lane, and driver-to-driver grouping (4, pp. 276-283; 5, pp. 85-99; 6). The Potters Industries research analyzed these performance measurements as well as measures of driver path range and average vehicle speed. In a refinement of the techniques used in the prior research, this study evaluated vehicle position photographically every 100 ft in each of the 14 0.8-km (0.5-mile) test sections. The prior research had measured vehicle position electronically at only two locations in each test section.

The study evaluated four edgeline conditions--no edgelines and edgelines 10, 15, and 20 cm (4, 6, and 8 in) in width. Three dosage levels of alcohol were applied--a placebo level of 0.00 blood alcohol concentration (BAC) and 0.05 and 0.08 BAC. Sixteen test subjects were selected from among male students aged 21-25, who were representative of the highest-risk group in the driving population.

During the conduct of the test between midnight and 3:00 a.m., the test course was closed to traffic by the police, who were positioned out of sight of the test subjects. These subjects drove in dual-controlled test cars and were accompanied by licensed driving instructors. Each subject drove twice, and his trials were separated by one week. One trial was in a control condition with the subject only having placebo (0.00 BAC) drinks; the other trial was conducted after the subject consumed either another placebo or a controlled alcohol dosage (0.05 or 0.08 BAC).

DATA ANALYSIS

More than 9200 measurements of vehicle position were collected from the 14 test sections, and the results of the data analysis illustrate the vital role that reflectorized edgelines play in visual communication between the roadway and the driver. These beneficial effects are apparent in the following analysis of the six measures of driving performance for the 10 curved test sections. Since examination of the data for the 4 tangent test sections yielded no strong conclusions, they have been omitted from the subsequent discussion.

Analysis of the driving range was conducted by segmenting the range into its central 70 percent increment as well as separate consideration of its left and right 10 and 5 percent extremes. The effect of alcohol on the drivers, regardless of edgeline condition, was to increase the range at both the left and right extremes (Figure 1). When edgeline width was considered, it was apparent that the effect of increasing edgeline width was to move the drivers away from the edgeline toward the centerline. This occurred for both the placebo-dosed drivers (0.00 BAC) and drivers dosed to the 0.05 and 0.08 BAC levels. However, this shift toward the centerline did not increase the number of centerline incursions. Rather, the range was compressed against the centerline, so that more driving was in the lane and centrality of positioning was greater.

When analyzing the statistical significance of these data (Figure 2), it can be seen that, when the edgeline width increases from 10 cm (4 in) to 20 cm (8 in), there are no statistically significant positional changes at the left extreme of the range. Conversely, only at this increased width of 20 cm does the right extreme 5 percent of the range show a statistically significant movement away from the edgeline and toward the centerline. This indicates that, for the best improvement in driving performance, the minimum incremental width desired is a further 10 cm rather than merely a 5 cm (2 in) increment.

The results confirm that alcohol is a safety hazard, and that a standard 10 cm-wide edgeline, when compared with no edgelines, improves road safety. However, the analysis also shows that wider edgelines serve to decrease the driving range even further than does a standard edgeline, and this benefit does not cause incursions into the opposite lane.

When considering positional variability, or the amount of vehicle weaving along the roadway, it is apparent that the affect of alcohol is to increase the amount of weaving (Figure 3). This, again, confirms prior research, and similarly, the benefits of standard edgelines compared with no edgelines are confirmed in that a 10-cm wide line reduces variability for both unimpaired and alcohol-impaired drivers. The presence of a wider edgeline serves to decrease variability even further. The maximum reduction occurs in the presence of a 20-cm edgeline. This incremental reduction in variability is only found consistently in the presence of a 20-cm wide edgeline; with a 15-cm (6-in) wide edgeline there are some instances where no reduction in variability occurs.

Earlier studies indicate that road safety is promoted when drivers centralize their position in the driving lane. Analysis of vehicle mean position indicates that alcohol acts as a decentralizer by moving drivers toward the edgeline. However, for both the placebo and dosed drivers, the presence of standard and wider edgelines was found to move the driver away from the edgeline and toward the centerline (Figure 4). However, this movement reaches its maximum when a 15-cm wide edgeline is present. As the edgeline width increases to 20-cm, drivers shift back toward the edgeline, although their final positions were found to be closer to the centerline than they had been in the presence of 10-cm edgelines. The Potters researchers believe that this movement results from drivers being actively aware of the presence of a 20-cm wide line at the left side of a two-lane roadway. As drivers approach the centerline, they are probably responding to the presence of this left side and hence shift back in their lane toward a central position. This effect was apparent for all groups of drivers and indicates the superior benefits derived from a 20-cm wide edgeline for both the alcohol-impaired and the unimpaired drivers, as compared with the lower-incremental benefits of a 15-cm wide edgeline.

Research conducted at Pennsylvania State University indicates that, when drivers perform like one another, the road involved has a high safety potential because drivers are perceiving the road similarly and hence respond similarly. In this study, similarity or grouping of performance was analyzed in terms of individual mean positions. When evaluating these groupings, two effects are apparent (Figure 5). First, the location of the group shifts toward the centerline as edgeline width increases, with the same maximum shift in the presence of a 15-cm wide edgeline as noted when analyzing individual driver mean positions. Second, the size of the group is sharply reduced in the presence of wider lines for both the alcohol-impaired and the unimpaired drivers. In contrast, when standard-width edgelines or no edgelines are present, the size of the group either does not change or, in fact, shows some increase in size due to alcohol impairment. The reduced group size again demonstrates the benefits of wider edgelines.

Finally, the average speed of drivers in the test sections was analyzed by subject grouping. No correlations of speed with either average position or driver variability were found; the only significant conclusion was that, with edgelines of any width, fewer drivers exceeded the posted speed limit than when no edgelines were present.

Figure 1. Driver path range: effect of edgelines.

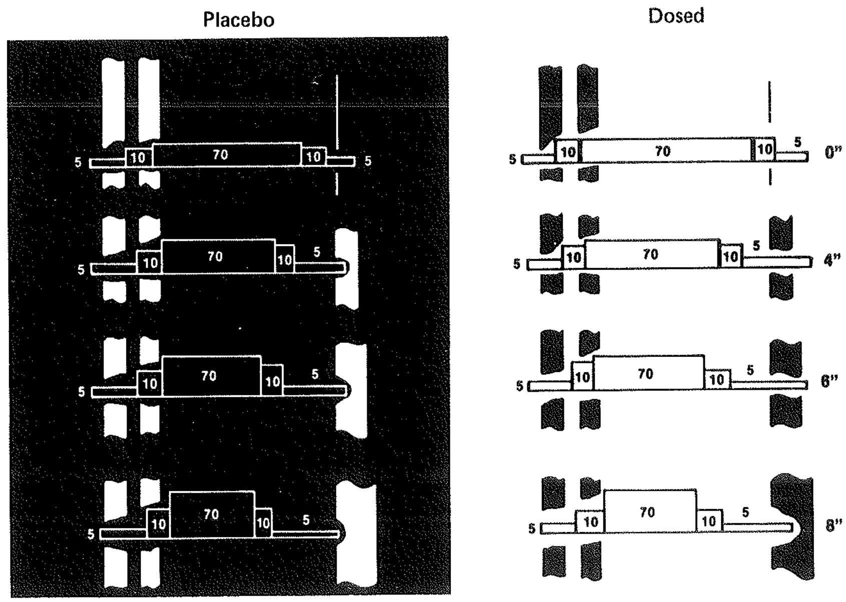
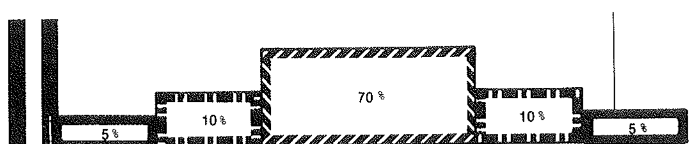


Figure 2. Driver path range: analysis of positional changes at the 80 percent confidence level.



Change In Edgeline Width	Left Extreme 100%	Left Extreme 90%	Left Extreme 70%	Right Extreme 70%	Right Extreme 90%	Right Extreme 100%
0" → 4"	N.S.	-1.4	N.S.	-2.0*	-3.6*	N.S.
4" → 6"	-0.9	0.7	0.6	-1.1*	-1.1*	N.S.
4" → 8"	N.S.	N.S.	N.S.	-0.9*	-1.0*	-2.0*

N.S. Not Significant at 80% Level
* Significant Change at 90% Level or Above

Figure 3. Driver variation.

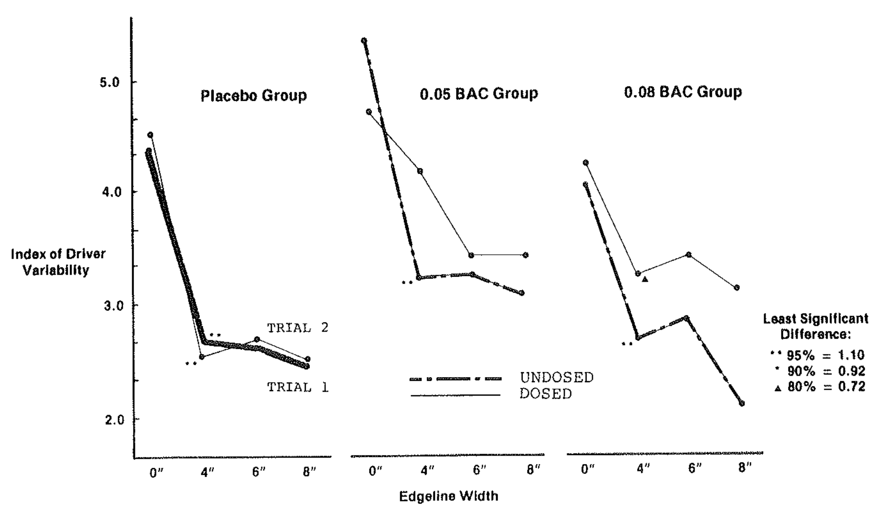


Figure 4. Driver mean position.

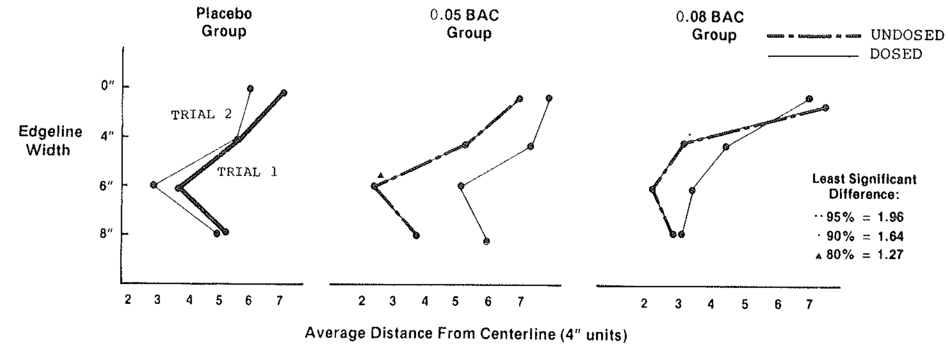
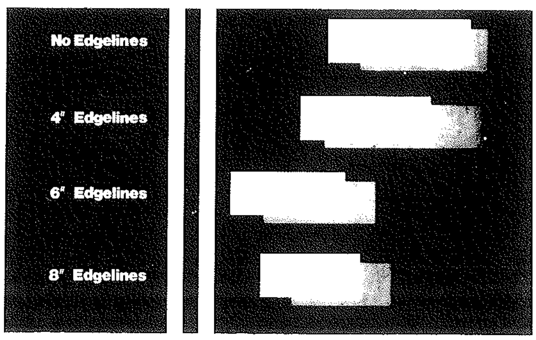


Figure 5. Driver to driver grouping.



Following the conclusion of the Potters positional and speed analysis, FHWA performed their own evaluation of the base data. A measure of good driving was created and analyzed in terms of edgeline width and degree of alcohol impairment. Two conclusions were drawn:

1. When drivers were undosed, the presence of edgelines of any width resulted in more good driving then occurred without edgelines; and
2. When drivers were dosed to the 0.05 or 0.08 BAC level, there was more good driving in the presence of wide edgelines than in the presence of either standard or no edgelines.

CONCLUSION

If further major progress is to be made in reducing the annual toll of fatal highway accidents, then new efforts must be made to eliminate that half of all fatal accidents that involve alcohol. This research examined an engineering approach to what has traditionally been considered a law enforcement, health, and public education problem.

Alcohol impairment is known to have an adverse effect on road safety. The data analysis confirmed that, for all performance measures, there was a detrimental effect on driver performance when alcohol was present. A standard 10-cm (4-in) wide edgeline, when compared with no edgeline, was found to provide significant safety benefits, and this confirmed the results of earlier before-and-after accident studies on the effectiveness of edgelines. Wide edgelines, particularly those 20 cm (8 in) wide, were found to provide incremental benefits as compared with standard-width edgelines, and these benefits were provided for both the alcohol-impaired and the unimpaired driver (see table below).

Driver Performance	Alcohol Effect	Effect of 10-cm Edgeline	Effect of Wide Edgeline
Position			
Range	Increase	Decrease	Decrease further
Variability	Increase	Decrease	Decrease further
Average position	Shift toward edgeline	Shift toward centerline	Further shift toward centerline
Grouping			
Dispersion	Mixed	Mixed	Tighter grouping
Location	Move right	Move left	Move further left
FHWA data	Reduces good driving	Maintains good driving	Maintains more good driving
Overall	Adverse	Beneficial	More beneficial

Alcohol impairment may well relate to other forms of impairment, such as fatigue, the use of drugs, and the reduced visual ability common among older drivers. Hence, the beneficial effects of wider edgelines found for the alcohol-impaired driver may well extend to drivers who have other types of impairment, since the improved driver performance of our test subjects in the presence of wide edgelines indicates that strengthening the visual signal at the road edge may compensate to some degree for impairment and, therefore, reduce the risk of accidents. These results not only corroborate prior research, but also provide new insight into the safety benefits of roadway delineation.

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