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Relationship of the Color of the Highway Centerline Stripe to the Accident Rate in Arizona

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The problem considered in this study was that of the effect of changing the color of the centerline stripe from white to yellow on the accident rate on undivided, two-lane, two-way highways in Arizona. Only sections of roadway that had remained essentially unchanged (except for the color of the centerline stripe) for a period of 1 year before and 1 year after the color change were studied. Accident data on 74 sections of roadway, totaling 4587 km (2867 miles), were analyzed and statistically tested for differences between the accident rate with white centerlines and the accident rate with yellow centerlines under various road surface and light conditions. Of the eight accident-rate categories tested, the following four showed a significant increase: (a) the dawn or dusk accident rate, (b) the dawn or dusk accident rate during periods of wet pavement or poor visibility, (c) the nighttime accident rate during periods of wet pavement or poor visibility, and (d) the overall accident rate during periods of wet pavement or poor visibility. The following other four categories tested showed no significant change: (a) the nighttime accident rate, (b) the daytime accident rate, (c) the daytime accident rate during periods of wet pavement or poor visibility, and (d) the overall accident rate under all conditions combined. These data indicate that the currently used yellow centerline stripes are inferior to the previously employed white centerline stripes.

The most recent edition of the Manual on Uniform Traffic Control Devices, published in 1971, requires that all centerline markings on two-lane, two-way highways be yellow rather than the white previously in use. The expressed intent of this requirement is to further a new concept whereby the color difference between the markings of two-way and divided highways enables the motorist to be immediately aware of the danger of opposing traffic on seeing a yellow line. The lane markings remain white to eliminate any possible confusion.

The new centerline standard has an easily perceived safety objective. There can be no argument with its purpose; however, the questions to be asked are (a) has the desired result been achieved and (b) have any adverse conditions been created?

Some officials of the Arizona Highway Department have voiced an unsubstantiated belief that yellow striping may not be as visible as white striping, particularly in bad weather and at night. The purpose of this study

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is to provide a statistical basis for accepting or rejecting this belief. If it is true, the striping color change should have led to a higher accident rate.

The problem considered, then, is that of the relationship between the change of the color of the centerline stripe from white to yellow and the accident rate on undivided, two-lane, two-way highways in Arizona. Implied within this statement are the following subfactors that should be considered in evaluating the overall problem:

1. Did the dawn or dusk accident rate change significantly?
2. Did the nighttime accident rate change significantly?
3. Did the daytime accident rate change significantly?
4. Did the rate of accidents attributed to wet pavement or to poor visibility caused by bad weather conditions change significantly?
5. Did the overall accident rate change significantly?

HYPOTHESES EVALUATED

The following null hypotheses, based on the above subfactors, were tested:

1. The dawn or dusk accident rate before the color of the centerline stripe was changed is less than or equal to the dawn or dusk accident rate after the color was changed.
2. The nighttime accident rate before the color of the centerline stripe was changed is less than or equal to the nighttime accident rate after the color was changed.
3. The daytime accident rate before the color of the centerline stripe was changed is less than or equal to the daytime accident rate after the color was changed.
4. The rate of accidents attributed to wet pavement or to poor visibility caused by weather before the color of the centerline stripe was changed is less than or equal to the rate of accidents attributed to wet pavement or to poor visibility caused by weather after the color was changed.
5. The overall accident rate before the color of the centerline stripe was changed is less than or equal to the overall accident rate after the color was changed.

SCOPE AND LIMITATIONS

This study covers only undivided, two-lane, two-way highways of the Arizona State Highway System. The study was confined to the 12 months before and the 12 months after the striping change was accomplished. To eliminate the possible effects of the 1973 fuel shortage and the lowering of the maximum speed limit to 88.5 km (55 mph) in 1974, statistics on accidents and traffic volumes observed after September 30, 1973, were not considered. The reduction in vehicular travel due to the fuel shortage was first noticeable in October 1973 (1). An adequate sample size was provided by the use of the 24-month period of accident data.

Any portions of a highway undergoing changes in configuration other than changing the color of the centerline stripe—such as widening the shoulders, changing the roadway width, or adding lanes—during the time of the study were not included.

The validity of the findings in this study are limited by the accuracy of the data supplied by the various state agencies. Errors in accident data can result from the fact that the investigating police officer often must use judgment in filling out the accident report.

Many statistics and other information of interest to the traffic engineer are based on the unsubstantiated

statements of accident victims or the value judgments and recollections of the investigating officer. Nevertheless, the shortcomings associated with accident reports should not discredit them as a useful research tool. The errors in the reports can be expected to be consistent from year to year, thus permitting reasonably accurate comparisons between years.

REVIEW OF RELATED RESEARCH AND LITERATURE

Many articles and studies concerning accidents and accident rates as related to traffic volumes, elements of the roadway cross section, lane lines, roadside obstructions, and roadway surface were reviewed. The findings and comments from a few of these are given below. (The Arizona Department of Transportation computer input to the Transportation Research Information Service failed to find any literature relating accidents to the centerline stripe.)

However, Stieg (2) has made the following comment on the visibility of white versus yellow centerlines:

The yellow traffic line has an unfortunate tendency to disappear just when it is needed most.

The specified yellow color is generally believed to be highly visible, a belief that appears to have been substantiated by Air Force research which placed this color high on its list of those that provide easy recognition in the air for flying aircraft, and high visibility on the ground for downed fliers. These findings, however, are related to chromatic contrast against blue sky and green grass or other vegetation, in bright sunlight. These are definitely not the conditions that prevail on our highways during the dusk-to-dawn period of highest fatal accident density. . . .

The increased use of yellow markings on our highways has not taken into consideration the very real deficiencies of standard highway yellow as a visible warning device.

The normal human eye does not perceive the color as quickly as it does white because of its low reflectance, which derives from (a) low refractive index. . . . Furthermore, the normal dark-adapted human eye sees even less under critical twilight conditions.

The abnormal human eye, due either to congenital defects, or to those imparted by disease or by the use of alcohol, tobacco or drugs, may not perceive yellow as a color at all.

The causes of accidents are many and varied. Johnson (3), reporting on the findings of a research team, stated, "Among the 68 subjects studied, 289 contributing factors were identified—an average of 4.3 factors/case." (A factor was defined as any circumstance connected with a traffic accident without which the accident could not have occurred.)

The vehicle driver is undoubtedly the most important single component of the driving process and also the most difficult to understand and control [Conger (4)]. Numerous studies have attempted to isolate the human traits that are apparent in individuals involved in accidents. Although certain psychological traits, such as aggressiveness, intolerance, and resentment of authority are apparent in chronic traffic violators and accident repeaters, one study concluded that it would be difficult if not impossible to use human characteristics as reliable predictors of accident involvement [Goldstein (5)].

The roadway has been shown to have little direct causal relationship to automobile accidents. Michaels (6) reported, "in only 5 percent of accidents do observable characteristics of the highway play a significant causal role." Although the direct causal relationship may be low, the roadway undoubtedly influences the accident rate because the highway can require mental and physical responses beyond the abilities of the driver. The best evidence of such influences is the low-accident rates on modern, well-designed, fully access-controlled highways as compared with the accident rates on older, less expensive roadways [Burch (7)].

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In general, the ADTs are calculated as follows:

$$ADT = \frac{\sum(\text{road-section length})(ADT \text{ for that road section})}{\sum(\text{road-section length})} \quad (1)$$

For the before period, $ADT = [(29.18 \times 6404) + (39.82 \times 6662)] / (29.18 + 39.82) = 6554$ vehicles/d, and for the after period, $ADT = (0.31 \times 1972 ADT) + (0.69 \times 1973 ADT)$; i.e., $ADT = \{0.31 [(29.18 \times 7084) + (39.82 \times 7367)] / (29.18 + 39.82)\} + \{0.69 [(29.18 \times 3030) + (39.82 \times 4076)] / (29.18 + 39.82)\} = 4751$ vehicles/d.

STATISTICAL ANALYSES OF THE ACCIDENT RATES

The hypotheses to be tested were stated in a manner requiring a determination of whether the accident rate under various conditions changed significantly. It was necessary, therefore, to calculate several categories of accident rates for each of the 74 sections of roadway with the white centerlines in use and with the yellow centerlines in use.

Because the roadway sections comprising the sample were essentially identical except for the color of the centerline stripe, the statistical analysis required involves paired observations. If the difference between the sample variances is large or if it is otherwise unreasonable to treat the population variances as being equal, one method that can be used for significance testing is the paired-sample t-test. This test does not require an assumption of equal population variances; it applies two random samples of the same size, which need not be independent. When n pairs of such observations are selected from two nonnormal populations, for large n (n > 30), the distribution of the mean of the differences is approximately normal, and tests of hypotheses concerning the means may be carried out by using the statistic

$$T = (\bar{D} - d_0) (n)^{1/2} / S_d \quad (2)$$

where

- \bar{D} = mean of the differences of n pairs of observations,
- d_0 = value to which the difference of the two sample means is being compared,
- S_d = standard deviation of the differences of n pairs of observations,
- n = number of paired observations in the sample, and
- $\nu = n - 1$ = number of degrees of freedom.

There were 74 paired observations. By using a level of significance of 0.05, the critical region was found to be $T > t_{\alpha, \nu} = t_{0.05, 73} = 1.645$.

The table below shows the actual changes in the related accident rates for the conditions tested.

Condition	Change (no. of study sections)		
	Decrease	None	Increase
Light			
Dawn or dusk	23	21	30
Nighttime	39	5	30
Daytime	38	2	34
Wet pavement or poor visibility			
Dawn or dusk	6	53	15
Nighttime	20	28	26
Daytime	25	26	23
Overall	23	17	34
Combined	34	2	38

Table 1 gives the magnitudes of the before-and-after rates, the differences, and the significances for all 74 sections of roadway.

Of the eight accident-rate categories tested, four showed no change in the accident rate with the yellow centerline stripes in use, and four showed an increased accident rate with the yellow centerline stripes in use. The four categories showing no change were the nighttime related accident rate, the daytime related accident rate, the daytime related accident rate during periods of wet pavement or poor visibility, and the overall related accident rate under all conditions combined. The four categories showing an increase were the dawn or dusk related accident rate, the dawn or dusk related accident rate during periods of wet pavement or poor visibility, the nighttime related accident rate during periods of wet pavement or poor visibility, and the overall related accident rate during periods of wet pavement or poor visibility.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The results of the eight statistical tests performed do not provide a clear-cut answer to the relationship between the color of the centerline stripe and the accident rate in Arizona. In general, the data seem to indicate that the yellow markings have had a detrimental effect on the related accident rate. Four of the related-accident-rate tests showed no change, and four showed a significant increase in the related accident rate.

As work on this project progressed and conclusions were drawn, a number of questions were raised for which no answers were evident. Many of these questions could be solved only by additional, and often specific, studies that were beyond the scope of this project.

The following eight conclusions refer to the specifically named accident rate with yellow centerlines in use at the 5 percent level of significance:

1. The dawn or dusk accident rate increased significantly.
2. The dawn or dusk accident rate under conditions of wet pavement or poor visibility caused by bad weather increased significantly.
3. The nighttime accident rate under conditions of wet pavement or poor visibility caused by bad weather increased significantly.
4. The overall accident rate under conditions of wet pavement or poor visibility caused by bad weather increased significantly.
5. The nighttime accident rate showed no significant change.
6. The daytime accident rate showed no significant change.
7. The daytime accident rate under conditions of wet pavement or poor visibility caused by bad weather showed no significant change.
8. The overall accident rate under combined conditions of dawn or dusk, nighttime, daytime, and wet pavement or poor visibility caused by bad weather showed no significant change.

If a true evaluation of the white versus yellow centerline accident rate comparisons is to be made, it must be assumed that the proportions of the traffic volumes for each light condition to the ADT volumes remained fairly constant from year to year. Although no data are available on traffic volumes by time periods within a given day, it can be reasonably assumed that these proportions did in fact remain constant. The same assump-

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