Highway Patrol Light Bar Effects on Vehicle Fuel Efficiency

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ABSTRACT

The fuel efficiency of highway patrol vehicles is affected by light bars mounted on the roof. This effect is dependent on the light bar's size, mounting height, and design. A combination of six brands of light bars and three makes of automobiles was tested using a randomized complete-block design. An analysis of variance of data normalized for test run direction indicated that there was a significant difference among light bars and among vehicles. Interactions between light bars and vehicles were not significant. A least significant difference test was used to determine significant differences among the ranked means of both light bars and vehicles. The highest ranked light bar was associated with 5.1 percent greater fuel efficiency than the lowest ranked light bar, which amounts to a projected potential fuel savings of more than $500,000 for the Tennessee Department of Safety over a 10-year use expectancy.

Tennessee Department of Safety vehicles travel approximately 19 million miles per year. A large number of these vehicles are Tennessee Highway Patrol cars that have a light bar attached to the roof. Obviously, such light bars interfere with the air flow over the roof and thus decrease gas mileage. The shape and size of light bars vary and, therefore, the potential for differing wind resistance, which may be translated to fuel efficiency, exists.

Because of the complete depletion of light bars in stock and the need for replacing many light bars on operational vehicles, the Tennessee Department of Safety must procure a sizable number of light bars this year. These modules have a use expectancy of about 10 years. Thus the purchase of light bars that result in better vehicle fuel efficiency has long-term as well as immediate benefits.

This study is concerned only with vehicle fuel efficiency as affected by the tested light bars. Other light bar considerations such as cost of maintenance, long-term availability of parts, and internal light configuration and brightness, are not an objective of this study and will be mentioned only to give balance to the discussion.

MATERIALS AND METHODS

Six different light bars were tested on three different vehicles. The light bars tested are as follows (see Table 1 for specifications):

- Whelen, Model 91H-4;
- Federal Signal Corporation, Jetsonic Model JS-1;
- Smith & Wesson (S&W), Model 8884;
- Federal Signal Corporation, AeroDynic Model 24;
- Whelen, Edge Model 9308; and
- Public Safety Equipment, Force 4 LP.

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The light bars vary in size and in the distance the respective mounts place the light bar above the roof line. Figure 1 shows the Whelen Model 91H-4 and Figure 2 shows the Public Safety Equipment Model Force 4 LP. Note the greater height of the model 91H-4 compared with the Force 4 LP in terms of both light bar height and mounting height. Shape is also a factor in designing light bars to minimize wind resistance and turbulence. Figure 3 shows some of the light bars being transported for the test. In the foreground from left to right are the Edge, the Jetsonic, and the S&W 8884; the AeroDynic is shown in the background. The Edge and Jetsonic shown in Figure 3 and the Force 4 LP shown in Figure 2 are low-profile light bars of somewhat different designs. The S&W 8884 shown in Figure 3 is similar to the 91H-4 shown in Figure 1: both are considerably larger and are mounted higher than are the low-profile light bars. The AeroDynic shown in Figure 3 has a fairly high mounting and is fairly large, but its elliptical shape probably is a favorable factor in its design.

These light bars were tested on three new 1985 model year vehicles, specifications for which are given in Table 2:

- Ford Crown Victoria,
- Plymouth Gran Fury, and
- Chevrolet Impala.

Initial plans were to run the tests both on the highway and on a track. However, the available track was only 5/8 mi and preliminary tests indicated that there would be difficulty maintaining a speed of 55 mph comfortably for many laps. In addition, vehicle performance on such a heavily banked track would not simulate highway conditions. Therefore it was decided early in the study to run the entire test on the highway.

A 50-mi section of Interstate 24 from milepost 63 southeast of Nashville, Tennessee, to milepost 113 in Manchester, Tennessee, was the test site. Testing was done in the evening after daytime winds common to spring and early summer weather conditions had subsided. Testing was concluded each day by 7:00 a.m. This time schedule also avoided the heavier daytime traffic conditions and the unavoidable traf-

TABLE 1 Light Bar Specifications

	Whelen Engineering	Federal Signal Corporation	Smith & Wesson	Federal Signal Corporation	Whelen Engineering	Public Safety Equipment Corporation
Model	91H-4	Jetsonic JS-1	8884	AeroDynic 24	Edge 9308	Force 4 LP
Length (in.)	48	48 1/4	48	47 9/16	48	46 1/2
Height at dome (in.)	9	4 11/16	10 1/2	7 9/32	3 1/4	4 13/16
Height at speaker (in.)	N/A	6 5/8	N/A	N/A	N/A	N/A
Width at dome (in.)	11	11 3/16	15 1/2	12 1/64	10	11 1/4
Width at speaker (in.)	N/A	14 1/4	N/A	N/A	N/A	N/A
Weight (lb)	30	29	34	29	28	19

FIGURE 1 Whelen Model 91H-4 is typical of larger, fairly high-mounted light bars.

FIGURE 2 Public Safety Equipment Model Force 4 LP has a low profile.

fic interference caused by the unmarked vehicles with police light bars attached traveling at 55 mph. Officers driving the vehicles wore civilian clothes to reduce traffic reaction to the test. In addition, the three vehicles were run at 2-min intervals.

Each vehicle was equipped with an outboard marine test fuel tank mounted in the trunk and a cut-off valve to the regular gas line that could be activated by the flip of a switch. The vehicles were also equipped with radar guns and cruise control so that the speed could be set accurately and maintained at

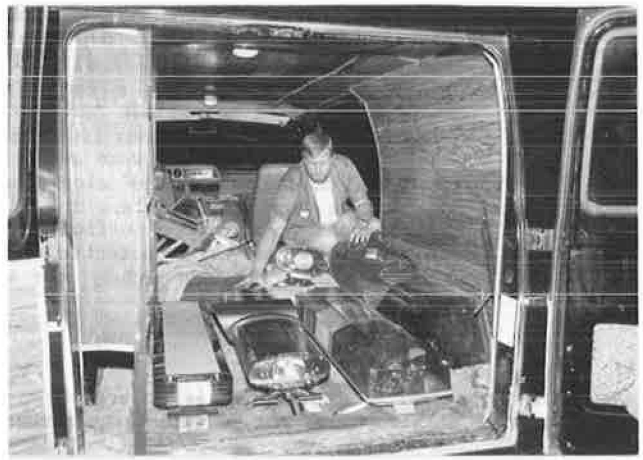

FIGURE 3 Light bars in transit are (left to right) Edge, Jetsonic, and S&W 8884; the AeroDynic is in the rear.

TABLE 2 Vehicle Specifications

	Ford Crown Victoria	Plymouth Gran Fury	Chevrolet Impala
Engine displacement (in.^{3})	351	318	350
Engine fuel system	Variable Venturi	4BBL	4BBL
Horsepower (S.A.E. net)	180	165	155
Torque (lb)	285	240	265
Compression ratio	8.3	8.4	8.2
Axle ratio	2.73	2.94	3.08
Transmission	PKA-A524	A999	700R4
Lockup torque converter	Yes	Yes	Yes
Transmission overdrive	Yes	No	Yes
Overall length (in.)	211.0	205.7	212.2
Overall height (in.)	55.3	55.3	56.4
Weight (lb)	4084	3888	3920
Wheelbase (in.)	114.3	112.7	116.0

55 mph. Vehicles were brought to stable operating temperatures and the cruise control was set before each run.

The test tanks were partly filled with sufficient gas for the 50-mi trip. The test fuel tank was weighed at the beginning and end of each 50-mi run on a KTRON KP-1 digital scale (Figure 4) capable of a weight precision of 0.002 kg when operated within the relevant weight range.

Because the Nashville area is approximately 365 ft lower in elevation than the Manchester area, the study was run in two parts so that the elevational difference associated with direction could be handled statistically. Because the tests were only run under near calm weather conditions and on dry pavement, these factors did not enter into the design. The effects of other unidentified factors that may have contributed to the results would tend to be cancelled out by the use of a randomized complete-block statistical design. In this design three replications

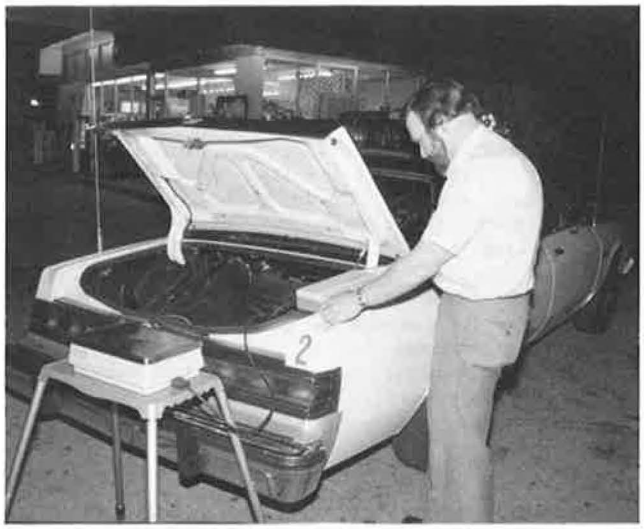

FIGURE 4 KTRON KP-1 scale used to weigh outboard marine fuel tanks at start and finish of each run.

were used with each of the six light bars run on each of the three vehicles in both directions.

RESULTS AND DISCUSSION

Because there was a 365-ft elevational difference between the beginning and end of each run, the data were maintained as two sets. These data could be analyzed as two separate tests, and the results of one part of the test could be used to collaborate or question the results of the other part. This type of analysis was used in a study report to the Tennessee Department of Safety (1).

The average fuel consumption for all light bars on vehicles uphill was 3.8 percent greater than in the downhill direction and all uphill runs used more fuel than did similarly configured downhill runs. This suggests the existence of a difference common to direction, which is most likely elevational. Because pavement conditions, traffic density, and the like appeared to be similar in both directions, the populations sampled in each direction are probably the same. If this is so, the data for the two directions may be combined. Also, because the data for each direction represent a similar data set, combining the data sets is facilitated.

The results reported in this paper are based on the combined data sets of each direction. The fuel consumption is the average of the two directions. The statistical analyses, however, should not be run on a combined raw data set because the differences introduced by the test run direction would enlarge the error term unnecessarily.

The approach used to obtain appropriate analyses of variance and means tests was to normalize each directional data set and then run the statistical tests on the combined normalized data. In effect this removes the average difference between directions without enlarging the error mean square.

The results of this study are given in Tables 3 and 4. The fuel consumption figures in gallons are based on data gathered in kilograms weight. A conversion factor of 2.79 kg = 1 gal of gasoline was used. The range of fuel consumption associated with light bars is from 17.42 to 16.58 mpg. This amounts to a 5.1 percent (0.84 mpg) increase in fuel efficiency offered by the top-ranked light bar compared with the bottom-ranked bar.

If a gas tank was filled with 18 gal of fuel, the top-ranked light bar would contribute to saving approximately 0.9 gal of gasoline per fueling compared with a vehicle equipped with the lowest ranked light bar. This is an appreciable fuel savings, especially given the many miles traveled and the years of use of such bars. The Tennessee Department of Safety estimates that Tennessee Highway Patrol vehicles travel in excess of 15 million miles annually. Based on a fuel price of $1.25 per gallon, the difference

TABLE 3 Fuel Consumption Associated with Light Bars (all vehicles)

Light Bar		Mean					
Code	Name	Kilograms	Gallons	Miles per Gallon	Difference (mpg)	Light Code	Homogeneous Subsets
B	Jetsonic	8.016	2.873	17.40		B	
					0.12		
F	Force 4 LP	8.072	2.893	17.28		F	
					0.04		
E	Edge	8.095	2.901	17.24		E	
					0.19		
D	AeroDynic	8.182	2.933	17.05		D	
					0.47		
C	S&W 8884	8.414	3.016	16.58		C	
					0.02		
A	91H-4	8.424	3.019	16.56		A	

Note: Conversion factor: 2.79 kg gasoline = 1 gal gasoline.

TABLE 4 Fuel Consumption of Vehicles (all light bars)

Light Bar		Mean					
Code	Name	Kilograms	Gallons	Miles per Gallon	Difference (mpg)	Light Code	Homogeneous Subsets
3	Chevrolet	8.057	2.888	17.31		3	
					0.43		
2	Plymouth	8.262	2.961	16.88		2	
					0.04		
1	Ford	8.282	2.968	16.84		1	

Note: Conversion factor: 2.79 kg gasoline = 1 gal gasoline.

TABLE 5 Analysis of Variance

Source of Variation	Degrees of Freedom	F-Test
Repetitions	5	
Light bars	5	18.64[a]
Vehicles	2	18.22[a]
Interactions	10	0.93[NS]
Error	85	
Total	107	

Note: Sum of squares and mean squares are not shown because they were performed on a transformed (normalized) data set.

[a]Significant at the 1 percent level.

in fleet fuel cost using the top-ranked light bar and the bottom-ranked bar would be in excess of $500,000 over a 10-year light bar use expectancy. At higher speeds, the difference among light bars would probably be even greater.

The range of fuel consumption for vehicles run with all light bars was from 17.32 to 16.84 mpg, a difference of 2.8 percent. It should be recognized that vehicle results are based on a single vehicle from each manufacturer. Unlike the light bars, a single vehicle is not representative of the population of similar makes and models. Therefore vehicle results are of limited importance.

Table 5 gives the analysis of variance for the normalized data. The sum of squares and mean square values have been omitted from the table because they are for the normalized data set and, therefore, have little intuitive value. The F-tests show that there is a significant difference at the 1 percent level among light bars and among vehicles. However, interactions are not significant. This means that light bar effects are not specific to a certain make of automobile. Thus generalizations concerning light bars may be made without reference to the vehicle used in this test.

Because the analysis of variance determined that there is a significant difference among light bars and among vehicles, the use of the least significant difference (lsd) test constitutes a protected Fisher's lsd (2,pp.174-176). In addition, testing of the mean values of the light bars and of the vehicles was planned so that the lsd test statistic is appropriate (2,pp.174-176).

Calculation of the lsd for the light bar analysis reveals three homogeneous subsets distinguishable at the 5 percent level. The lines to the right side of the identifying code in Tables 3 and 4 mark the homogeneous subsets. Any two means not scored by the same line are significantly different.

This means that for fuel consumption associated with light bars (Table 3) the Force 4 and Edge are not significantly different at the 5 percent level because they are commonly scored. Also, the S&W 8884 and the 91H-4 are not significantly different. The Jetsonic ranks as the light bar associated with the greatest fuel efficiency. The Force 4 and Edge are not separable and share the second-third ranking. The AeroDynic is the fourth-ranked light bar followed by the S&W 8884 and the 91H-4, which share the last positions. The fuel efficiency advantages associated with the new low-profile light bars are evident.

Other factors, however, may enter into the choice of a light module. For example, the larger module size and higher mounting of the AeroDynic might be more visible in city use. Other factors such as cost of parts, frequency of repair, and time to repair should possibly be considered.

Results of vehicle tests given in Table 4 for the three vehicles tested indicate that the Chevrolet ranks as the most fuel efficient followed by Plymouth and Ford, which have similar fuel consumptions. Testing the vehicles without a light module attached was not part of the test, but bare-roof data were gathered for the Ford and Plymouth. For these two vehicles only, the percentage reduction in fuel efficiency compared with bare-roof efficiency was approximately 6.6 percent for the top-ranked Jetsonic, 8.5 percent average for all six light modules, and 11.3 percent average for the last two modules, the 91H-4 and S&W 8884.

CONCLUSION AND REMARKS

The Jetsonic is the top-ranked bar followed by the Force 4 and the edge, which are not significantly different. The top three light bars are followed by the AeroDynic, which is followed by the S&W 8884 and the Whelen 91H-4 in an indistinguishable tie for the last positions. This study's determination of negligible light bar-vehicle interactions will allow more efficient future test designs using one make of vehicle. The greater fuel efficiency associated with the low-profile light bars is apparent.

As a result of this study, it is believed that testing at a speed greater than 55 mph would have made differences in fuel consumption associated with light bars more apparent. In addition, this test only gives information that may be used to determine potential fleet fuel savings. Initial light bar cost, maintenance time, replacement parts cost, and vehicle down time are other important factors to be considered in a comprehensive cost analysis.

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