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Detection of Reflectorized License Plates

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ABSTRACT

This paper contains data on the detection distances of reflectorized white license plates. Detection distances were obtained for a car heading angle and a driver's line of sight in 5 different treatments with 12 drivers. The order of presentation of the five treatments for a given heading angle was basically random and approximately balanced. Each driver sat in a stationary car on a 2,000-ft long runway and detected an approaching target configuration under low beam conditions against a background containing a number of luminaires and other light sources. There were three parallel approach paths on the runway and for each treatment, three approaches were made on each path toward a driver. The results of this study indicated that the average detection distance increase from treatment 1 to treatment 5 was 39 percent for the -3-degree heading angle and 85 percent for the 10-degree heading angle. Based on the detection distances obtained in this study and calculations that involve stopping sight distances and/or decision sight distances, the potential for significant safety benefits when using reflectorized license plates in addition to the red rear cube corner vehicle reflectors can be demonstrated. These potential safety benefits are especially significant for an 84-CIL license plate combined with two red rear reflectors.

Reflectors and reflectorized license plates have been in use for many years as a means of aiding the driver in the initial detection, recognition, and identification of stationary vehicles on or off the roadway at night with no lights on. Several studies have been conducted that compare accident rates of vehicles with reflectorized versus nonreflectorized license plates. Henderson, Ziedman, Burger, and Cavey reviewed and summarized a number of these studies (1). In the past, Hulbert and Burg, Cook, and Sivak and Olson reviewed license plate and reflectorization studies (2-4).

Although most of these studies indicated a reduction in the accident rate because of reflectorized license plates, some of the studies indicated that there was no statistically significant reduction. It could be argued, however, that if the reflectivity of the license plates used in these studies had been higher, the results would have been more positive. In the review cited previously, the authors state

> Almost every accident study reviewed showed a reduction in accidents when conspicuity was improved. This near-unanimity tends to outweigh the problems of interpretation of these studies. In addition, the finding that poor driver information processing is related to higher accident rates further strengthens a conclusion that improving conspicuity, and thereby reducing information processing loads, will reduce accidents (1).

On similar lines, Vanstrum and Kotnour state in their unpublished report on the Tennessee accident data and the effect of reflectorized license plates

> Despite the fact that state accident data in general is difficult to work with in establishing the effect of a single variable, a careful analysis shows that a small but significant accident reduction can be attributed to the introduction of reflective sheeting license plates in the state of Tennessee.

It is well established that drivers get their visual information through a series of discrete eye fixations at different objects and roadway features and, therefore, the initial detection of an object in the driving scene at night most often occurs a few degrees away from the fovea in the peripheral visual field. Eye scanning data for straight road driving at night such as that reported by Zwahlen (5) indicates that the range of horizontal eye fixations is approximately 13 degrees and the range of vertical eye fixations is approximately 6 degrees.

In spite of the fact that the initial detection of objects at night while driving will most likely occur peripherally rather than foveally, most visual conspicuity studies reported in the literature provide results for foveal detection, recognition, or identification only. Some authors, however, have recognized the importance of peripheral viewing such as Matson who stated: "The accuracy of identification of traffic signs increases as the angle between the axis of vision and the line drawn from the traffic sign to the motorist's eye decreases (6). He also suggested that the target should fall within a visual area of 10 to 12 degrees on the horizontal axis and 5 to 12 degrees on the vertical axis for better effectiveness. Recognizing the fact that the visual detection of objects while driving at night can occur either foveally or peripherally and taking into account the ranges of the horizontal and vertical eye fixations during night driving on straight roads, a car heading angle and a driver's line of sight of -3 degrees to the left was chosen as a representative condition for a near foveal detection, and a car heading angle and a driver's line of sight of 10 degrees to the right was chosen as a representative upper limit for a peripheral detection.

The objective of this study was to determine the detection distances at night for low beam conditions for near foveal (-3 degrees) and peripheral (10 degrees) detection for five experimental treatments. The five treatments were:

1. Two Chevette red rear reflectors,
2. One 24-CIL white license plate,
3. Two Chevette red rear reflectors, and 1 24-CIL white license plate,
4. One 84-CIL white license plate, and
5. Two Chevette red rear reflectors and 1 84-CIL white license plate.

METHOD

Subjects

Twelve subjects participated in the experiment; 9 males and 3 females. The average age of the subjects was 21.4 yr with a standard deviation of 2.35 yr. They had an average driving experience of 6 yr and drove an average 8,000 miles/yr, the respective standard deviations being 2.3 yr and 6,000 miles/yr. All the subjects were students, they all had normal visual acuity, normal reaction times, normal information processing capabilities, and were paid to participate in the experiment.

Apparatus

A 1979 Mercury Bobcat was used as the experimental car. The headlamps (General Electric 6052) of this car were 24.25 in. above the ground, and had a horizontal center-to-center distance of 48.45 in. The electrical system of the car operated at 14.15 volts. The theoretical location of the hottest spot of these headlamps (30000 cp at 12.8 volts, 55 watts) is approximately 2 degrees to the right and approximately 2.25 degrees down. The actual measured location of the hottest spot for the left low beam was 2.48 degrees to the right and 1.55 degrees down, and the actual measured location of the hottest spot for the right low beam was 0.95 degrees to the right and 1.72 degrees down. The average distance from the longitudinal vertical center plane of the car to the center of the subject's eyes in the driver position was 13.5 in. The average horizontal distance from the headlamps to the subject's eyes was 82.25 in. and the average subject eye height was 41.5 in. above the ground.

A black 5-horsepower Dune Kart was used as the target vehicle. On the front of this vehicle, two Chevette red rear reflectors and/or 1 white 24-CIL license plate or 84-CIL license plate was mounted in such a manner that its location and configuration were exactly identical to those on a 1979 Chevette. The center-to-center distance between the reflectors was 27.63 in. and the horizontal centerline was at a height of 26.75 in. above the ground. The reflectors were fixed in such a way that their reflecting surfaces made an angle of -10 degrees with the transverse axis of the Dune Kart to simulate the situation of a vehicle parked at a slight angle along a road. During the experiment, the target vehicle was driven by a person wearing dark clothing at a speed of about 10 mph.

License plates (size: 6 in. x 12 in.) of two levels of reflectivity were used: 24 CIL (measured 23.5 cd/fc per license plate at a 0.2-degree observation angle and -4 degrees entrance angle) and 84 CIL (measured 83.6 cd/fc per license plate at a 0.2-degree observation angle and -4 degrees entrance angle). The two Chevette red rear cube corner reflectors were randomly selected from 6 Chevette reflectors obtained from different Chevette vehicles from the year 1979. The two reflectors had a total red reflecting area of 0.047 ft^2. They were 4.25 in. x 3.063 in. with an inner nonreflecting rectangular area of 3.125 in. x 2 in. The left red reflector had a CIL value of 4.0 cd/fc and the right red reflector had a CIL value of 7.1 cd/fc (measured at a 0.2-degree observation angle and 0 degrees entrance angle).

Experimental Site

A 75-ft wide, 2,000-ft long section of a concrete airport runway no longer in use located at the edge of the city of Athens, Ohio, and near a shopping mall was used as the experimental site. A 2-lane state highway with moderate traffic was located parallel (about 200 ft away) to the runway. A number of luminaires, a few advertising signs, and other light sources were within the field of view (mainly in the left peripheral field) of the subjects. There were three approach paths parallel to the runway axis.

The front center of the test car was placed above the center line of the runway. Looking forward from the car, path 1 was 12.5 ft to the left of the runway centerline. Path 2 was 6.25 ft to the right of the runway center line. Path 3 was 25 ft to the right of the runway centerline. The purpose of having three paths was to determine how the lateral location of the approach path of the oncoming target configuration would affect, if at all, the detection distances. Moreover, the inclusion of three paths in the experiment was intended to introduce some uncertainty to the subject about the lateral location of the approaching target configuration. For a subject to fixate the eyes at an object in the -3- or 10-degree direction, two red cube corner reflectors mounted on stakes 3 ft above the ground were placed at appropriate locations in the grass on the left and right side of the runway (40 ft to the left of the runway centerline at 763 ft for -3 degrees, 80 ft to the right of the runway centerline at 454 ft for 10 degrees). Figure 1 shows the layout of the experimental site.

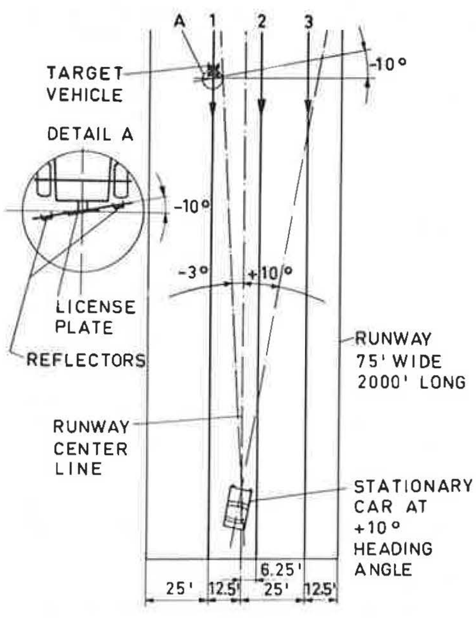

FIGURE 1 Layout of experimental site and arrangements.

Experimental Design

The independent variables for this experiment were

1. Two Chevette red rear reflectors,
2. One 24-CIL white license plate,
3. Two Chevette red rear reflectors and one 24-CIL white license plate,
4. One 84-CIL license plate, and
5. Two Chevette red rear reflectors and 1 84-CIL white license plate.

The dependent variable was the detection distance measured in feet.

Each subject was presented either all five treatments for the -3-degree heading angle first, or all five treatments for the 10-degree heading angle first. One-half of the subjects started with the -3-degree heading angle while the other one-half started with the 10-degree heading angle. The order of presentation of the five treatments for a given heading angle for each subject was basically random and approximately balanced considering that a perfect balancing scheme was not possible with 12 subjects and five treatments. Within a given treatment, nine observations were made. Each path approach was presented three times. The nine observations were grouped into three blocks of three observations each. Each path approach was presented randomly and only once within a block.

Procedure

The car was positioned on the runway by using plum bobs attached to the center of the front bumper and to the center of the rear bumper. Two 25-ft long lines were painted on the runway to indicate the direction of the car centerline for the -3- and 10-degree heading angles. The front center of the car was placed exactly above the runway centerline, and the car was placed to make an angle of either -3 or 10 degrees with the runway centerline. The subject sat comfortably in the driver's seat, and one experimenter sat beside the subject. At the beginning of each experiment, the subject's eye-height, the horizontal distance of the eyes to the headlamps, and other dimensions were measured.

To conduct the experiment, a group of experimenters positioned themselves at various locations along the side of the runway and signaled to the experimenter who was sitting in the car at the beginning of each trial, by using a flashlight. Another experimenter drove the target vehicle. At the beginning of the experiment, the experimenter sitting in the car briefed the subject about the purpose of the experiment and gave the subject a copy of the experimental instructions to read. During the experiment, the low beams of the car were always on, and the engine was kept idling. The experimenter in the car recorded the time, battery voltage, weather conditions, and subject responses. At the beginning of each trial, the subject was asked by the experimenter to start fixating the eyes at the red cube corner reflector positioned ahead either on the left (-3 degrees) or right (10 degrees) side. The subject was instructed to be prepared to detect the approaching target configuration while fixating the eyes at the reflector. The target vehicle would approach the stationary car along any one of the three paths. As soon as the subject had the initial sensation of detection of the target configuration in the peripheral or near foveal field of vision, he or she would switch immediately from the low beams to the high beams and keep the high beams on for a few seconds. As soon as the driver of the target vehicle noticed the high beams, he or she would drop a small sand bag on the runway that indicated the detection distance. The measurement crew would then measure and record the detection distance. They would also pick up the sand bag and return it to the target vehicle driver.

After everybody cleared the runway and the target vehicle had moved back to the end of the runway and was positioned in a perpendicular direction to the runway centerline, the measurement crew would give the signal to the experimenter sitting in the car indicating the beginning of the next trial. The correct approach path of the target vehicle and a subject's continuous eye fixation at the fixation point were checked by the experimenter sitting in the car. The experimenter also recorded for each trial the subject's response with regard to what the subject thought was actually detected first (e.g., red reflectors, license plate or both). The time to conduct the 45 trials (5 treatments x 9 observations) for 1 car heading angle condition usually took approximately 1 hr and 15 min.

RESULTS

Table 1 gives data on the group detection distance averages, standard deviations, minimums and maximums for all paths combined for all treatments for the -3- and 10-degree heading angles. Tables 2 and 3 give data on group detection distance averages, standard deviations, minimums and maximums for each path for all treatments for the -3- and 10-degree heading angles. Table 4 gives data on the percentage increments in average detection distances from lower to higher treatment combinations for the -3- and 10-degree heading angles.

Figure 2 shows the detection distance averages, standard deviations, minimums and maximums for all paths combined for all experimental treatments for the -3- and the 10-degree heading angles. Figures 3 and 4 show the detection distance averages, standard deviations, minimums and maximums for each path for each treatment for the heading angles of -3 and 10 degrees.

Figures 5 and 6 show the cumulative detection distance distributions for all paths combined for each treatment for the -3- and 10-degree heading angles. Figures 7 and 8 show the minimum recommended values for the decision sight distance (DSD) for the speeds of 25 mph, 35 mph, and 55 mph against the actual values of the average detection distances, and against the 50-percent values of the actual average detection distances (reduced to adjust for factors such as subject alertness, information processing load, driver age, cleanliness of the windshield, and so forth) for each treatment for the

TABLE 1 Group Detection Distances—all Treatments

	Treatment				
Heading Angles	T-1	T-2	T-3	T-4	T-5
-3 degree (left)					
Mean	1,293	1,480	1,571	1,750	1,794
Standard deviation	246	245	214	203	179
Minimum	742	881	1,021	1,115	1,205
Maximum	1,949	1,949	1,973	1,998	2,013
10-degree (right)					
Mean	480	552	680	799	890
Standard deviation	117	161	163	210	229
Minimum	276	329	322	402	464
Maximum	784	1,089	1,019	1,242	1,401

Note: For averages, standard deviations, minimums, and maximums for all 3 paths combined, and for -3- and 10-degree heading angles, N = 108; all distances are in feet; and T-1 is vehicle rear reflectors only, T-2 is 24-CIL license plate only, T-3 is 24-CIL license plate and vehicle rear reflectors, T-4 is 84-CIL license plate only, and T-5 is 84-CIL license plate and vehicle rear reflectors.

TABLE 2 Group Detection Distances—for Each Path, for -3 Degrees

Treatment	Path 1	Path 2	Path 3
T-1			
Mean	1,421	1,281	1,193
Standard deviation	232	227	215
Minimum	900	879	742
Maximum	1,949	1,635	1,668
T-2			
Mean	1,601	1,432	1,434
Standard deviation	214	217	253
Minimum	1,142	970	881
Maximum	1,949	1,823	1,818
T3			
Mean	1,668	1,506	1,516
Standard Deviation	218	196	202
Minimum	1,073	1,021	1,085
Maximum	1,973	1,738	1,783
T-4			
Mean	1,778	1,727	1,737
Standard deviation	207	216	190
Minimum	1,130	1,115	1,344
Maximum	1,998	1,972	1,982
T-5			
Mean	1,851	1,774	1,761
Standard deviation	159	174	193
Minimum	1,230	1,227	1,205
Maximum	2,012	2,013	1,997

Note: For averages, standard deviations, minimums, and maximums for each treatment, N = 36; all distances are in feet; and T-1 is vehicle rear reflectors only, T-2 is 24-CIL license plate only, T-3 is 24-CIL license plate and vehicle rear reflectors, T-4 is 84-CIL license plate only, and T-5 is 84-CIL license plate and vehicle rear reflectors.

TABLE 3 Group Detection Distances—for Each Path, for 10 Degrees

Treatment	Path 1	Path 2	Path 3
T-1			
Mean	476	472	562
Standard deviation	184	99	100
Minimum	248	348	357
Maximum	623	626	644
T-2			
Mean	561	626	745
Standard deviation	159	131	157
Minimum	303	384	399
Maximum	1,017	922	1,089
T-3			
Mean	596	668	778
Standard deviation	152	153	135
Minimum	386	376	652
Maximum	887	926	999
T-4			
Mean	739	763	908
Standard deviation	209	195	182
Minimum	402	403	557
Maximum	1,187	1,202	1,242
T-5			
Mean	840	840	992
Standard deviation	249	216	195
Minimum	448	541	600
Maximum	1,346	1,232	1,401

Note: For averages, standard deviations, minimums, and maximums for each treatment, N = 36; all distances are in feet; and T-1 is vehicle rear reflectors only, T-2 is 24-CIL license plate only, T-3 is 24-CIL license plate and vehicle rear reflectors, T-4 is 84-CIL license plate only, and T-5 is 84-CIL license plate and vehicle rear reflectors.

TABLE 4 Matrix Showing Percentage Increments in Average Detection Distances from Lower to Higher Treatment Combinations

Treatment	T-1	T-2	T-3	T-4	T-5
-3-Degree Heading Angle (left)					
T-1	–	14	22	35	39
T-2	–	–	6	18	21
T-3	–	–	–	11	14
T-4	–	–	–	–	3
T-5	–	–	–	–	–
10-Degree Heading Angle (right)					
T-1	–	15	42	66	85
T-2	–	–	23	45	61
T-3	–	–	–	18	31
T-4	–	–	–	–	11
T-5	–	–	–	–	–

Note: T-1 is vehicle rear reflectors only, T-2 is 24-CIL license plate only, T-3 is 24-CIL license plate and vehicle rear reflectors, T-4 is 84-CIL license plate only, and T-5 is 84-CIL license plate and vehicle rear reflectors.

heading angles of -3 and 10 degrees. Figures 9 and 10 show the recommended values for the stopping sight distance (SSD) for the same speeds against the actual values of the average detection distances and against the 50-percent values of the actual average detection distances (adjusted for subject alertness, and other variables) for the heading angles of -3 and 10 degrees.

DISCUSSION OF RESULTS

From Table 1 and Figure 2, it can be observed that the detection distances increase consistently from treatment 1 to treatment 5. The increase from treatment 1 to treatment 5 was 39 percent for the -3- degree heading angle and 85 percent for the 10-degree heading angle (from 1,293 to 1,794 ft for -3 degrees, from 480 ft to 890 ft for 10 degrees). The detection distance increases from any lower reflectivity treatment to any higher reflectivity treatment are all statistically significant at the 0.05 level with the exception of the increase from treat-

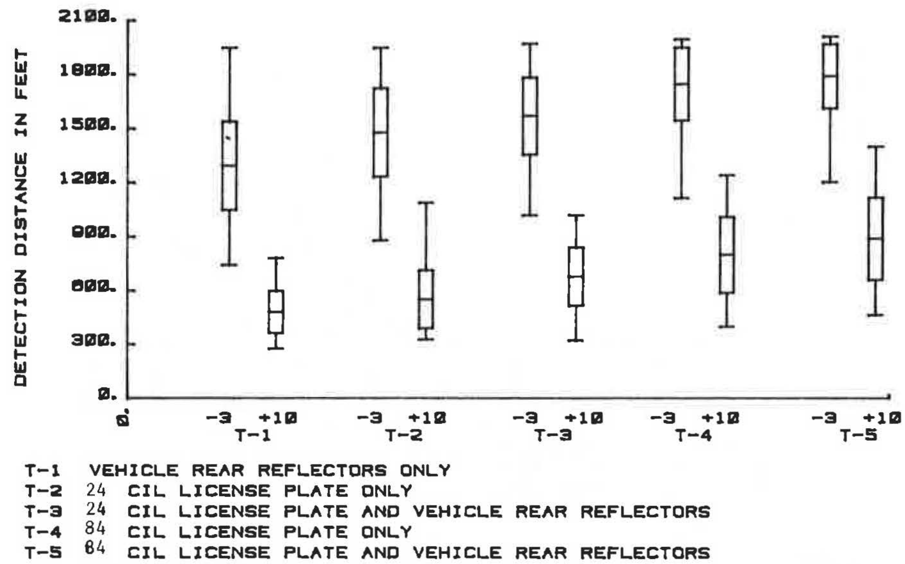

FIGURE 2 Detection distance means, standard deviations, minimums, and maximums for heading angles of -3 and 10 degrees.

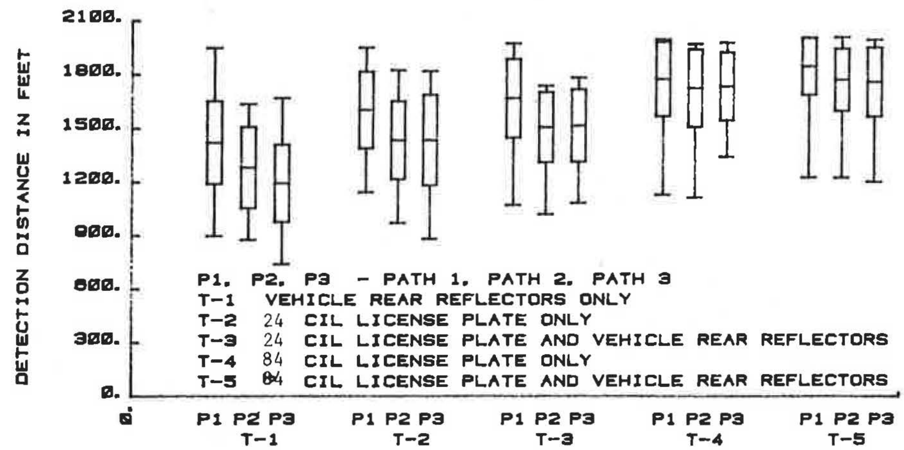

FIGURE 3 Detection distance means, standard deviations, minimums, and maximums for a heading angle of -3 degrees.

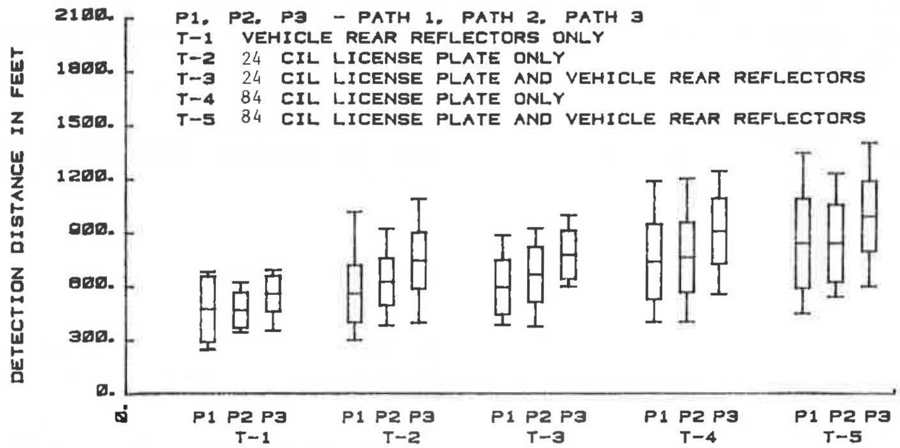

FIGURE 4 Detection distance means, standard deviations, minimums, and maximums for a heading angle of 10 degrees.

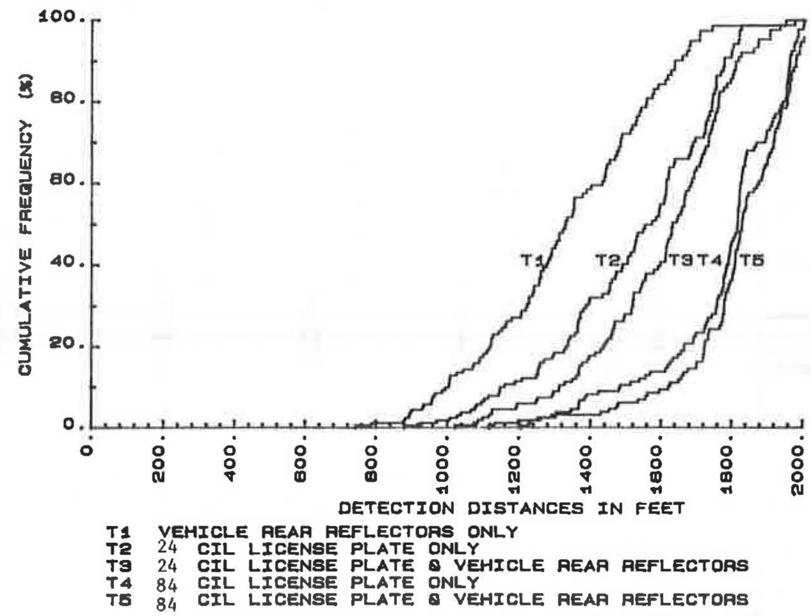

FIGURE 5 Cumulative detection distance distribution with all paths combined—heading angle of -3 degrees.

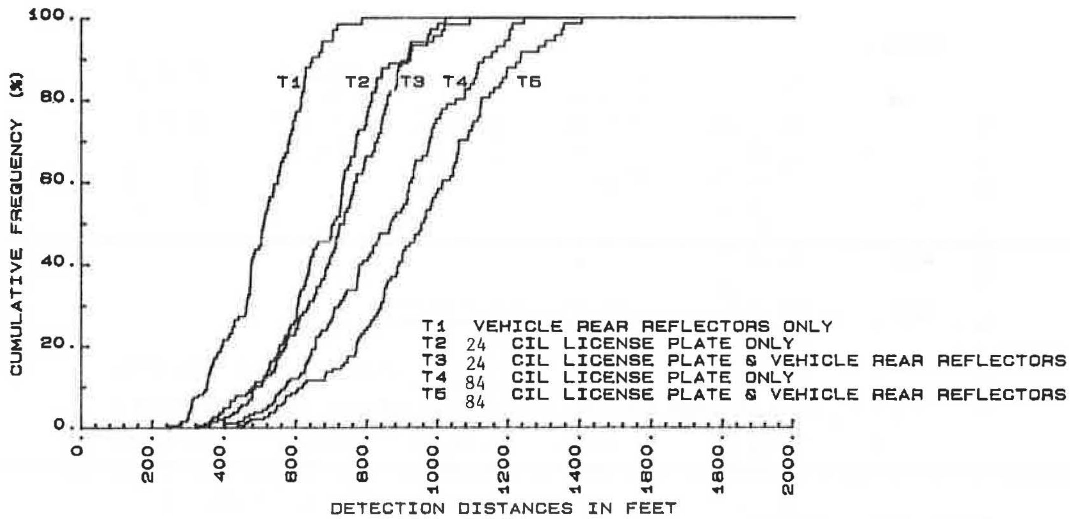

FIGURE 6 Cumulative detection distance distribution with all paths combined—heading angle of 10 degrees.

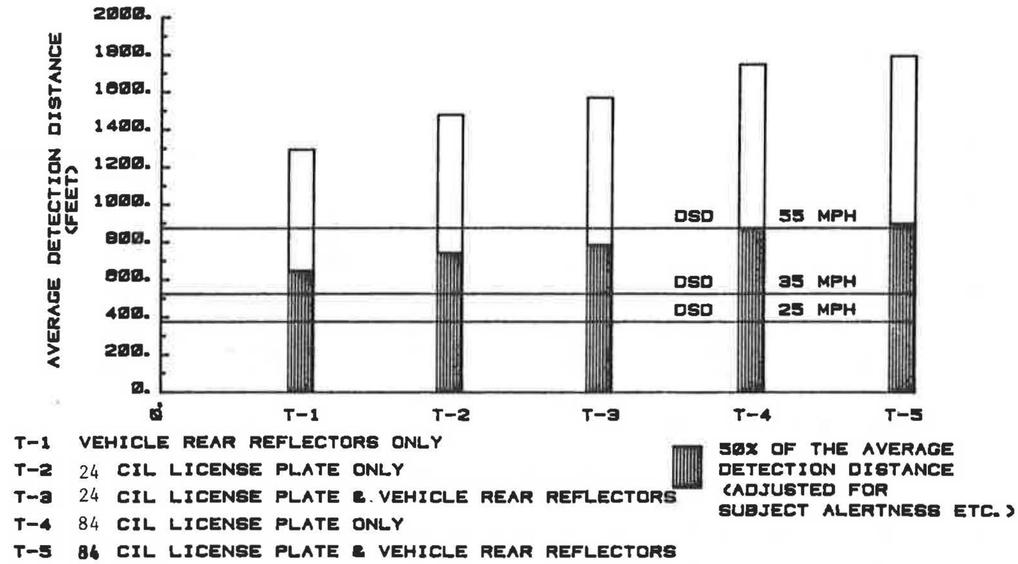

FIGURE 7 Comparison between average and 50 percent-detection distance for 25, 35, and 55 mph for a heading angle of -3 degrees.

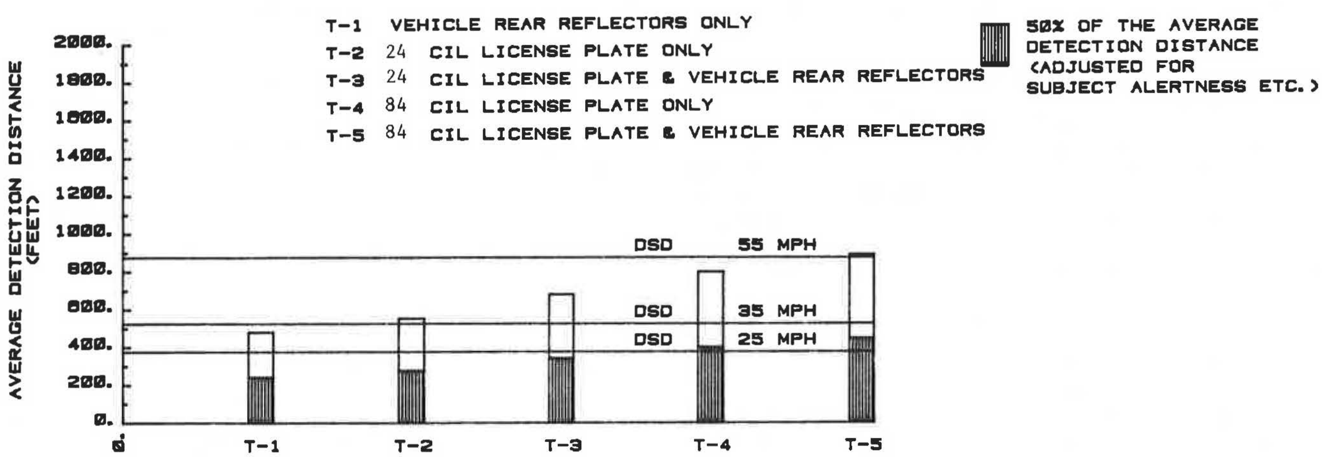

FIGURE 8 Comparison between average and 50 percent-detection distance for 25, 35, and 55 mph for a heading angle of 10 degrees.

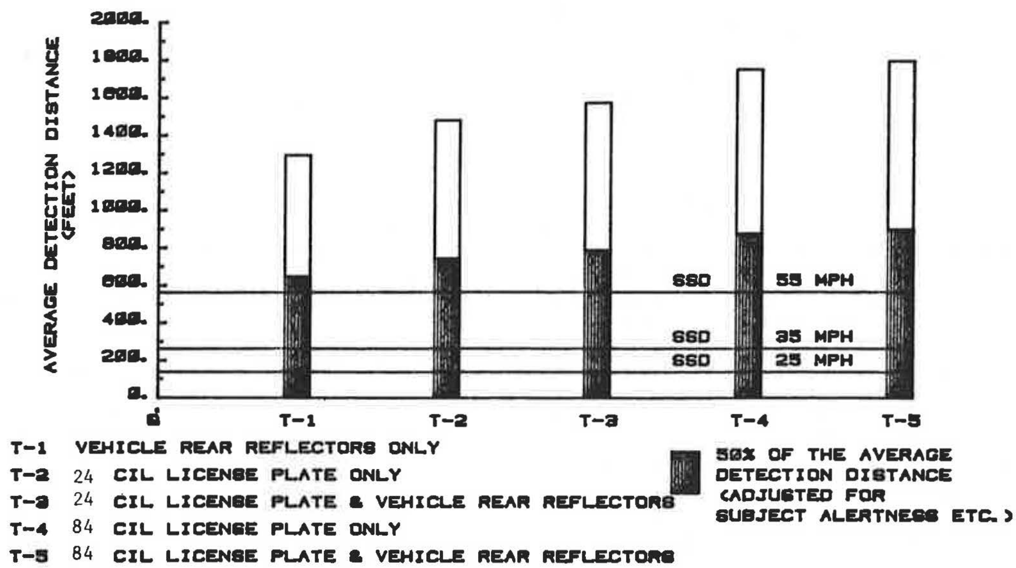

FIGURE 9 Comparison of average and 50 percent-detection distance and stopping sight distance for 25, 35, and 55 mph for the heading angle of -3 degrees.

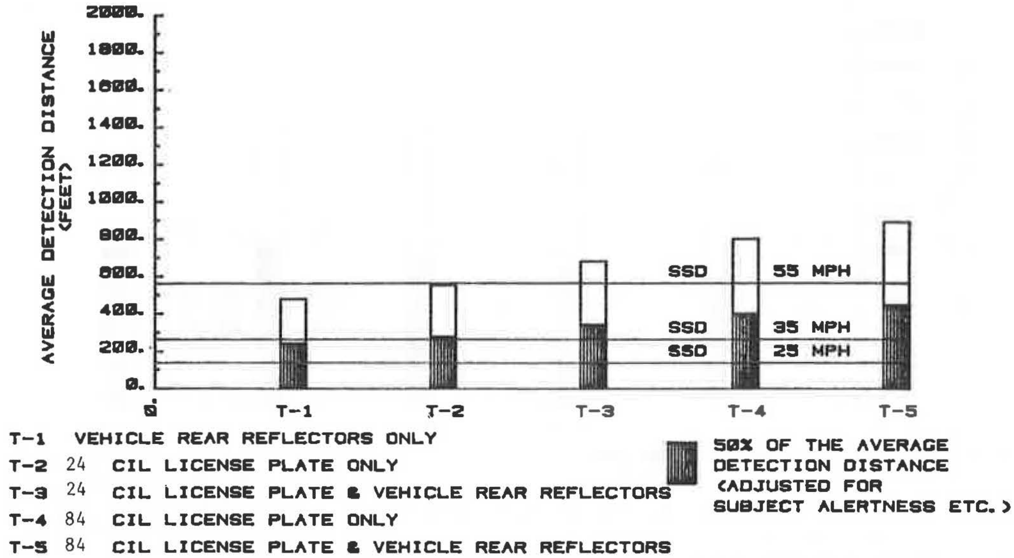

FIGURE 10 Comparison of average and 50 percent-detection distance and stopping sight distance for 25, 35, and 55 mph for the heading angle of 10 degrees.

ment 4 to treatment 5 for the -3-degree heading angle.

A runway longer than 2,000 ft would most likely have resulted in somewhat longer detection distances and somewhat longer and less truncated standard deviations and ranges for treatments 4 and 5 for the -3-degree heading angle and thus could have resulted in a statistically significant detection distance increase from treatment 4 to treatment 5. From Table 1 and Figure 2, the relatively large standard deviations and ranges for the detection distances can also be observed. Figure 2 especially shows the large variability that is typical for human detection of a reflectorized target configuration in a real-world urban night environment.

From Table 1 and Figure 2, it can be further observed that there was a consistent large increase in the detection distances for each treatment from the 10-degree heading angle to the -3-degree heading angle. For example, for treatment 1, the average detection distance increased approximately 2.7 times from 480 ft for 10 degrees to 1,293 ft for -3 degrees. The hottest point of the left low beam was actually aimed at an angle of 2.48 degrees to the right and 1.55 degrees down, and the hottest point of the right low beam was aimed at an angle of 0.95 degrees to the right and 1.72 degrees down. The effect of the aims of the two low beams was that when the car heading angle was -3 degrees to the left of the centerline, the low beams were practically aimed straight down the runway centerline providing just about the most optimal low beam conditions for the detection of a target configuration straight ahead. In this situation, the detection of the target took place only about 3 degrees away from the fovea or line of sight in a visual region, which is still efficient from a detection point of view when compared to the periphery.

Also, the relative high voltage level (14.15 volts) of the car's electrical system and the relatively high candle power intensity level of the two low beams might have contributed to the observed long detection distances for the -3-degree heading angle condition. On the other hand, the much shorter detection distances for the 10-degree heading angle are partly caused by the low beams pointing 12.48 degrees (left beam) and 10.95 degrees (right beam) to the right of the runway centerline. This fact, coupled with the significant fact that a subject had to detect the target at about 10 degrees in the periphery where the efficiency of the visual system with regard to detection is slightly lower when compared with the fovea.

It can also be observed from Table 1 and Figure 2 that there is always a small but consistent increase in the average detection distance when a white license plate was used in conjunction with the two Chevette red rear reflectors. These reflectors, themselves, produced considerably shorter detection distances (the increase for the -3 degree heading angle was 6.2 percent for the 24-CIL license plate and 2.5 percent for the 84-CIL license plate; the increase for the 10-degree heading angle was 23.2 percent for the 24-CIL license plate and 11.3 percent for the 84-CIL license plate). Zwahlen reported a similar phenomenon indicating that longer detection distances result when a reflective surface was cut in half and presented as two reflectors instead of one (5).

From Tables 2 and 3 and Figures 3 and 4, it can be observed that a rather consistent pattern exists among the detection distances for the three paths for each of the five treatments. In the case of the -3-degree heading angle detection distance results, the detection distances for path 1 (path 1 is on the left side of the runway centerline) are consistently the longest, while the direction distances for paths 2 and 3 (on the right side of the runway centerline) are consistently the shortest. These consistent patterns are the result of aiming the low beams practically straight down the runway. In the case of the 10-degree heading angle detection distance results, the detection distances for path 3 are consistently the longest, while the detection distances for path 1 are usually the shortest. Again, because the low beams are aimed at an angle of more than 10 degrees to the right of the runway centerline, it would be expected that the best detection performance would occur along path 3 and the worst detection performance would occur along path 1.

Turning to Figures 5 and 6, the large variability can be observed in the detection performance for each treatment. In Figure 5, it can clearly be seen that the cumulative detection distance distributions for treatments 4 and 5 are truncated at the longer detection distances. This truncation is attributed to the limited length of the runway (2,000 ft). Figures 5 and 6 are useful illustrations because they allow a reader to determine for a given detection distance the proportion of the population that has detection distances below this value. In addition, these figures can also be used to determine any set of percentile values of interest such as the detection distance value for which 95 percent of the population have equal or shorter detection distances.

It should be noted that the lower detection distance values shown in these cumulative detection distance distributions are the values where accidents are most likely to occur. It is therefore important to increase the level of reflectivity sufficiently to effect a significant increase in these lowest detection distance values. In looking at the cumulative detection distance distributions in Figures 5 and 6, it can clearly be observed that there exist the slight but consistent and significant increases between treatments 2 and 3 and between treatments 4 and 5. As was discussed earlier, these increases were somewhat unexpected and indicate that human detection does not simply follow optical and photometric calculations alone and has more than just an illumination dimension to it.

In Figure 7 (for the -3-degree heading angle), it can be observed that for the 50-percent adjusted average detection distances, only treatment 5 exceeds the minimum recommended DSD for 55 mph. (The DSD is the distance at which drivers perceive a potentially hazardous situation and react to the impending danger efficiently.) As given in the research report by McGee, et al., for a design speed of 25 mph, the recommended DSD is between 375 ft and 525 ft; for a design speed of 35 mph, it is between 525 ft and 725 ft; and for a design speed of 55 mph, it is between 875 ft and 1,150 ft (7). As observed in Figure 8 (for 10-degree heading angle), only treatments 4 and 5 for the 50-percent adjusted average detection distances exceed the minimum recommended DSD for 25 mph.

In Figure 9 (for -3 degree heading angle), it can be seen that even for the 50-percent adjusted average detection distances, all treatments exceed the recommended SSD for the 55 mph speed. The recommended values for SSDs for 25 mph, 35 mph, and 55 mph are 137 ft, 263 ft, and 563 ft, respectively. In looking at Figure 10 (for 10-degree heading angle), it can be observed that for the 50-percent adjusted average detection distances, all treatments with the exception of treatment 1 exceed the recommended SSD for the 35 mph speed. Figures 7 through 10 are useful in providing the reader with close-to-ideal and 50-percent adjusted average detection distances for each treatment that can then be evaluated in terms of either the minimum recommended DSDs or the SSDs for the three speeds from 25 to 55 mph.

CONCLUSIONS AND RECOMMENDATIONS

This study clearly demonstrates that reflectorized license plates with 24-CIL or especially 84-CIL specific intensity levels do increase the conspicuity and the detection distances of a car parked along a highway at night in a statistically and practically significant manner. The obtained longer detection distances mean that a driver will detect earlier a parked car with no lights on at night, and will therefore have more time for recognition, decision making and proper control actions. On the basis of the results of this study and calculations involving SSDs and DSDs, it can be demonstrated that the potential exists for significant safety benefits when using reflectorized license plates in addition to the vehicle red rear reflectors. The potential for these safety benefits is especially significant for the 84-CIL license plate combined with two red rear reflectors. Therefore, an increase of the initial reflectivity level of license plates to 84 CIL is highly recommended, and with such a level of reflectivity a decrease in reflectivity as a result of wear and exposure over time would be assured and would still result in an adequate conspicuity level, which would lead to significant safety benefits.

Also on the basis of the results of this study, it may be concluded that having a second reflectorized license plate of 24 CIL, or especially 84 CIL, attached to the front of a car will greatly increase the conspicuity and detection distance of a parked car along a road at night in the case where the front end of such a car faces an approaching vehicle. The probability of early detection leading to potential safety benefits in such a case is greatly enhanced because there are usually no vehicle reflectors placed on the front of cars.

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