Texas DOT Vehicle Fleet Warning Light Policy Research

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This paper presents an overview and preliminary results of current research being conducted by the Texas Transportation Institute (TTI) and the Texas Department of Transportation (TxDOT) to improve the latter's vehicle fleet warning light policy and procedures. Although the need for vehicle warning lights is well understood and mandated by law, the large number of design options available (types of lights, lens colors, mounting positions, and combinations thereof) to transportation agencies such as TxDOT makes establishment and maintenance of a consistent policy regarding vehicle warning lights difficult. Also, there is considerable and growing pressure to incorporate into maintenance and service vehicles lighting technologies that are visually similar to those implemented on police and other emergency vehicles (e.g., light bars or blue flashers).

Research conducted by TTI and TxDOT and presented in this paper includes the results of a national survey of vehicle warning light policies by state DOTs, a review of human factors and driver behavior research that has influenced warning light policies over the years, and studies of motorist comprehension and driving responses to different warning light configurations. Specifically, studies are being conducted in several cities statewide to determine the types of vehicles (police, fire, maintenance, tow services, and so forth) and the relative degree of concern or caution drivers commonly associate with different vehicle warning light color configurations. Field studies are also being performed to determine the differences in driver behavior (measured in terms of speed, lane choice and lane changing, and brake application) as drivers approach a vehicle parked on the shoulder with one of three different vehicle warning light configurations displayed (red-blue-yellow configuration, blue-yellow configuration, or all-yellow configuration). These objective data on motorists' perceptions and responses will help TxDOT policymakers to ensure that the vehicle warning light systems utilized fulfill a real need, that they are credible to the public, and that they elicit correct and consistent reactions by drivers.

INTRODUCTION

The Texas Department of Transportation (TxDOT) has the responsibility of establishing policy and rules regarding the provision and utilization of special flashing warning lights on all vehicles and equipment used for highway construction and maintenance operations in the state (*1*). This policy specifies such items as the types of vehicles that require special warning lights, appropriate mounting locations for the lights, situations where the lights are to be used, and basic features of the lights themselves (color, size, type, and performance characteristics).

Maintaining this vehicle warning light policy is an ongoing challenge for the Department. Warning light technology continues to improve, and new devices are constantly being introduced into the marketplace. It has become increasingly difficult for the Department to differentiate between true improvements in warning light technology and vendor “hype” for a particular product. Some degree of warning light technology standardization is necessary within TxDOT, both to achieve economies of scale during purchasing and to promote driver understanding and anticipation of lights to be seen on TxDOT (and other construction or maintenance) vehicles. However, such standardization must not impede real opportunities to improve worker and motorist safety. Because of these and other concerns, TxDOT has sponsored research by the Texas Transportation Institute (TTI) to examine its current vehicle warning light policy and to determine recommendations for improvement. This paper presents some of the significant findings that have arisen from that research effort.

BACKGROUND

Flashing vehicle warning lights have two primary functions. The first is to attract the attention of nearby drivers and pedestrians, in order to alert them to the situation they are approaching, or to one that is approaching them. The second function is to provide those drivers and pedestrians with information about the situation so that they can take whatever action is needed and appropriate. With respect to the first function, a significant amount of research has gone into the understanding of human visual perception and detection of flashing warning lights. This research has shown that the detection (or conspicuity) of a light is predominantly dependent on the effective intensity of its flash, with generally higher flash intensities associated with increased conspicuity (*2*). However, a flash too intense can have a deleterious effect by temporarily blinding an individual, particularly at night.

Other characteristics of a light, such as the flash rate, on-off cycle, flash pulse shape, and flash duration, also influence human detection capabilities (*2*). With respect to flash pulse shape and duration, a significant difference exists between rotating or flashed incandescent lights, which have a rather long duty cycle, and gaseous-discharge lamps (strobe lights), which emit an extremely intense light over a very small time duration (generally around 0.001 second). Whereas strobe lights tend to be more efficient at converting electricity into light than are incandescent lights (*3*), evidence suggests that the extremely short duration of the flash hinders some drivers’ ability to estimate distance from and movement toward the light. To counter this effect, strobe manufacturers have developed multiple-flash units, spreading the total flash intensity out over two or more closely-spaced flashes. Originally used in roadway applications beginning in 1968, strobe lights have become an integral part of warning light systems used for many emergency warning, highway construction, and highway maintenance vehicles. In order to benefit from the strong points of both types of lighting technologies, departments of transportation (DOTs) make use of combinations of incandescent and strobe lights.

Likewise, the color of the light also has some effect on its conspicuity. In daylight conditions, red lights have been shown to be more conspicuous than are blue lights, whereas the opposite is true under nighttime conditions. Interestingly, the conspicuity of yellow lights generally falls between that of blue and red lights in both daytime and nighttime viewing conditions (*4*).

In addition to the above characteristics, the number of flashing lights on a vehicle also affects the likelihood of detection and perception of that vehicle by a driver. Theoretically, each light added to a vehicle increases the probability that it will be seen under a given viewing condition. Of course, space limits the number of lights that can be added to a given vehicle. Perhaps more importantly, the additional conspicuity (detection potential) gained through the addition of more lights, different lighting types, or mounting of configurations may reach a practical maximum. For example, does the ability to detect a vehicle from 1 mile away offer substantial safety advantage over the ability to detect it from .5-mile away? Similarly, does a reduction in detection time from 0.25 to 0.23 seconds (these are purely hypothetical values) help improve safety to a significant degree? The real question is whether an improvement in safety justifies the additional expense and complexity associated with installing and operating a more complex lighting system.

Studies conducted in the late 1980s lent some insight into the practical differences that can be expected from certain alternative warning light systems for maintenance (service) and construction vehicles (*5*). Researchers conducted some experiments to determine motorists' ability to estimate speeds of maintenance vehicles outfitted with each of the alternative systems, as well as their ability to judge the rates at which they were closing in on each of those vehicles. Other experiments examined the effects of lighting systems on driver lane-changing behavior relative to the location of the maintenance vehicle. The study examined several factors related to light design (flash rate, flash intensity, flash mounting location, flash type) but limited the evaluation of light color to yellow (or amber). This was done because yellow is used almost exclusively for maintenance vehicle applications throughout the United States, and because many states restrict the use of other colors to authorized emergency vehicles only.

Although a limited number of alternatives were examined, the results did show that factors such as flash rates (between 60 and 100 cycles per minute), flash intensities, and flash mounting locations did not have measurable effect on the performance measures examined in the study. Combining different types of flash technologies (e.g., four-way flashers with a flashing warning light, combinations of rotating and flashing warning lights together on a single vehicle) did result in slightly improved responses. Strobe lights, although superior for conspicuity purposes, did not yield good judgments about vehicle speed or closure rates in comparison to those achieved with incandescent flashing lights. This was true for both the single- and the double-flash strobes tested.

Another interesting finding was that the most effective vehicle warning light system differed depending on whether the study was performed at a short-term stationary lane closure or as part of a continuously moving operation. For moving operations, an all-yellow light bar system (with rotating elements) was effective. However, this system did not work as well in a stationary lane closure environment. The researchers hypothesized that some motorists incorrectly associated the light bar with a moving operation (such as tow truck), and so did not change lanes until they were almost on top of the work zone. The rotating beacons and flashing strobe light combination system worked well in both the stationary and the moving work zones.

This last set of findings illustrates some of the issues associated with the other function of vehicle flashing warning lights, that of proper information transfer to motorists and pedestrians. Whereas detection or perception of a warning light is primarily physiological, information transfer is primarily cognitive. Here, the sensory information received through the visual system is converted to something meaningful through a pattern recognition process. Among other things, this process is highly dependent on driver expectations developed through past experiences, the means by which those experiences are coded in memory, and the context in which the information is received (*6*).

Color plays an important role in the memory coding and pattern recognition process. This fact is well accepted in the traffic engineering community, and is the main reason why traffic signs utilize standard colors to indicate different types of information (regulatory, warning, guide, and so forth). A similar rationale exists for assigning warning light colors to certain applications (hence, the restriction of certain light colors to emergency vehicles, and yellow to maintenance and construction vehicles). However, the assignment of a single color (yellow) to all maintenance vehicle applications implies to motorists that all types of situations in which these vehicles are used are equal in terms of their severity, hazard potential, and expected response. Whereas it may be perfectly appropriate to convey a single message for emergency vehicles (e.g., high-hazard emergency situation approaching), service vehicles are used to perform many different activities, some much more hazardous to motorists and workers than others. At the very least, it seems logical that some distinction is appropriate between those situations and activities that pose lower risk to workers and motorists and those that pose higher risk (such as those in which workers are out next to traffic, with little or no advance traffic control signing present).

In recent years, TxDOT has allowed a combination of yellow and blue lights to be used on certain vehicles during activities that are believed to be more hazardous to workers and motorists. In addition, light bars incorporating red, yellow, and blue rotating beacons and flashing lights have been allowed for use on TxDOT courtesy patrol vehicles in urban areas. Because red and blue have traditionally been limited to emergency vehicles, these practices have been questioned by law enforcement agencies out of concern for the possibility of an eventual degradation in public perception of and response to emergency vehicle warning light systems. From TxDOT's perspective, a policy allowing more frequent use of colors other than yellow for certain applications is obviously more complicated to maintain and administer and requires more effort to ensure compliance. Therefore, it is important to ensure that the use of additional colors provides a true safety benefit to workers and the public.

Over the past year, TTI and TxDOT have worked to determine whether the use of multiple colors is appropriate and justifiable for certain applications in TxDOT's vehicle fleet. These efforts have included a nationwide review of warning light color applications by other state DOTs, an investigation of motorist interpretations and perceptions of various warning light colors and color combinations, and studies to determine whether motorists respond differently to different color combinations in actual driving situations. The results of each of these efforts are summarized in the following sections.

NATIONWIDE WARNING LIGHT COLOR USAGE

Researchers contacted all 50 state departments of transportation (DOTs) by telephone to determine current warning light policies and practices for construction and maintenance vehicles, particularly with respect to the use of colors other than the standard yellow (or amber). As expected, every state indicated that yellow was the primary warning light color utilized in its vehicle fleets. However, 12 states (24 percent) utilize at least one other color besides yellow on some equipment. Colors mentioned during the survey were as follows: blue (mentioned by seven states), red (mentioned by five states), and white (mentioned by five states). Although seven states indicated that they did utilize blue lights, four of them noted that this color was limited to use on snow removal equipment. Others indicated that the color was included in the light bar assembly mounted atop courtesy patrol vehicles.

Another question asked during these state surveys was whether the state agency had developed an official state policy regarding special vehicle warning lights for its fleet. Only 14 states (28 percent) responded in the affirmative to this question. Of course, since most states utilize yellow lights exclusively, they may have little need to establish formal warning light policies. Nonetheless, the survey results do suggest that most state DOTs consider their current vehicle warning light practices to be adequate.

MOTORIST INTERPRETATIONS OF WARNING LIGHT COLORS

Survey Description

One of the reasons for considering the use of colors and color combinations other than just yellow for special flashing warning lights on certain types of maintenance and construction vehicles is the assumption that these other colors imply a greater sense of danger or hazard to motorists. Traditionally, yellow flashing lights have been employed on vehicle warning lights, intersection beacons, and flashers mounted on signs and barricades in work zones. The level of hazard associated with these uses varies dramatically. Conversely, most states (including Texas) restrict the color of certain lights to authorized emergency vehicles. Intuitively, one expects that these restrictions teach motorists a flashing light color hierarchy over time (as they encounter the different types of emergency vehicles and their associated warning light combinations). However, it does not appear that these assumptions have ever been investigated in an objective manner.

Consequently, TTI researchers conducted a small survey of Texas motorists to determine their perceptions of different warning light colors and color combinations. The survey consisted of two parts. In the first, motorists were asked the following questions for each of several warning light colors or color combinations:

- If you saw flashing (color or color-combination) warning lights mounted atop a vehicle, how hazardous would you consider the situation you were approaching to be?
- What driving action, if any, would you take?

Possible responses to the first question were as follows: not hazardous at all, somewhat hazardous, moderately hazardous, very hazardous, or extremely hazardous. Possible responses to the second questions were as follows: no action, take foot off accelerator, tap brake, apply brake gently, or apply brake firmly. Researchers queried motorists on each of the following colors and color combinations: yellow, blue, red, yellow-blue, yellow-red, blue-red, and yellow-blue-red. Researchers ordered the presentation of the various colors and color combinations to eliminate potential biases or the implication of increasing or decreasing hazard associated with a given order of presentation.

Survey Results

Motorist Perception of Warning Light Colors

Researchers conducted the survey at driver licensing stations in Houston and Fort Worth. In total, 209 survey responses were obtained. Table 1 summarizes the responses to the question about the level of hazard associated with each light color or color combination. The results do indicate that Texas drivers have learned a definite color hierarchy with respect to special flashing vehicle warning lights. When presented individually, yellow conveyed the least degree of hazard to motorists, followed by blue, and then red. When two colors were combined in one display, the yellow-blue combination represented a lesser degree of hazard than did the yellow-red combination or the red-blue combination. However, the yellow-blue combination appeared to represent a slightly more hazardous situation than did yellow considered alone. Finally, the red-blue-yellow combination was viewed as indicative of the most hazardous situations.

TABLE 1 Levels of Hazard Associated with Various Light Colors or Color Combinations

Flashing Warning Light Color or Color Combination	Percent of Motorists Responding			
	Not Hazardous	Somewhat Hazardous	Moderately Hazardous	Very Hazardous or Extremely Hazardous
Yellow	12	46	34	7
Blue	18	31	34	17
Red	1	11	20	67
Yellow-Blue	11	34	36	19
Yellow-Red	8	24	36	32
Red-Blue	4	12	33	51
Red-Blue-Yellow	3	13	28	56

Corresponding to the results shown in Table 1, Table 2 presents a summary of survey responses as to the actions drivers should take when they encounter each flashing vehicle warning light color or color combination. The relative trends shown in Table 2 are similar to those in Table 1. Specifically, the responses associated with both the yellow and the blue lights tended to be less dramatic driving actions (e.g., no action or take foot off accelerator) than were the responses associated with the red lights (e.g., nearly 80 percent of the motorists surveyed felt they should apply their brakes gently or firmly when they encounter a vehicle with special red flashing warning lights on top). Furthermore, the yellow-blue light combination resulted in more frequent responses claiming the need for some type of braking action than did either the yellow or blue lights alone. However, the yellow-red light combination generated a slightly higher percentage of braking action responses than did the yellow-blue light combination. Finally, the driving actions associated with both the red-blue light combination and the red-blue-yellow light combination were nearly identical.

TABLE 2 Driving Actions Associated with Various Light Colors or Color Combinations

Flashing Warning Light Color or Color Combination	Percent of Motorists Responding			
	No Action	Take Foot Off Accelerator	Tap Brake	Apply Brake Gently or Apply Brake Firmly
Yellow	10	35	14	42
Blue	15	28	15	42
Red	1	13	8	78
Yellow-Blue	9	25	18	48
Yellow-Red	6	21	16	57
Red-Blue	3	14	13	70
Red-Blue-Yellow	3	13	11	72

From the responses presented in Tables 1 and 2, it does appear that motorists associate less hazard or danger with yellow flashing warning lights than they do with other colors and color combinations. As a result, they also seem to perceive less of a need to slow down when approaching vehicles with flashing yellow lights than they do when approaching vehicles that have yellow combined with either red or blue lights (or both red and blue). For many activities that utilize construction and maintenance vehicles in a manner that does not present unusual risk either to workers or to the motoring public, this perception and response to yellow lights may be entirely appropriate. However, as stated previously, there also are many other maintenance or construction situations that pose significant risk to workers or motorists or both. For these situations, the use of yellow lights alone may not adequately convey the appropriate sense of hazard and urgency to motorists.

Motorist Association of Warning Light Colors to Specific Vehicle Types

The second phase of the survey was designed to investigate the types of warning light colors and color combinations motorists tend to associate with different types of emergency and other vehicles. For each vehicle type of interest to the surveyors, survey respondents were asked to write down the warning light color or colors they would expect to see mounted atop the vehicle. The vehicles examined in this phase of the survey included the following: police vehicles; ambulances; tow trucks; highway construction, maintenance or service equipment; fire trucks; and motorist assistance or courtesy patrol vehicles.

A summary of the major colors and color combinations that motorists associated with each of the above vehicle types is provided in Table 3 (the remaining responses were distributed among various other color combinations or were not filled in by survey respondents). The results are consistent with Texas' current special vehicle warning light policies regarding color. Most motorists associate the color yellow with basic service vehicles (construction and maintenance, motorist assistance, or tow trucks). However, the percentage was somewhat lower for the motorist assistance vehicles (only 36 percent of motorists associated yellow with these vehicles). Approximately 10 percent of motorists also associate a combination of red and yellow flashing lights with tow truck operations.

TABLE 3 Warning Light Colors Associated with Various Vehicle Types

Vehicle Type	Flashing Warning Light Color–Color Combination	Percent Responding
Construction, Maintenance, or Service Vehicles	Yellow	72
Motorist Assistance Vehicles	Yellow Blue	36 14
Tow Trucks	Yellow Yellow-Red	70 10
Police Vehicles	Red-Blue Red-Yellow-Blue Red-White-Blue	50 14 11
Ambulances	Red Red-Yellow Red-White Red-Blue	36 22 13 12
Fire Trucks	Red Red-White Red-Yellow	54 16 11

With respect to emergency vehicles, it is interesting to note that motorists do seem to associate slightly different light color combinations with the different classes of these vehicles. For example, motorists cited a red-blue light combination most often for police vehicles (50 percent of those surveyed), whereas the single color red was more often cited for ambulances and fire trucks. In fact, only 12 percent of motorists associated the red-blue light combination with an ambulance, and less than 10 percent did so for fire trucks.

MOTORIST RESPONSES TO ALTERNATIVE WARNING LIGHT COLOR SCHEMES

Study Description

The survey responses suggest that motorists do indeed perceive differences in vehicle warning light color configurations, and that they believe they should respond differently to them. To determine whether these perceptions actually translate into differences in driver behavior, researchers conducted a series of field studies on five urban freeway sections in Houston and San Antonio, Texas. In each study, TxDOT maintenance or courtesy patrol vehicles were outfitted with different vehicle warning light color combinations and placed, one at a time, on a shoulder next to moving traffic with the lights activated. Color combinations examined in this phase of the study were as follows: yellow lights only, yellow-blue lights, and yellow-blue-red lights. A fourth combination, consisting of yellow and blue strobes mounted in the back window of a TxDOT sport utility vehicle and strobes mounted in the rear taillight assemblies (operating in a simultaneous double-flash mode), was also tested at two of the sites.

Researchers videotaped traffic approaching the vehicle from 150 to 450 meters (500 to 1,500 feet) upstream (depending on viewing conditions) to determine vehicle speeds, traffic distribution by lane, lane-changing activity, and brake activations under each of the flashing vehicle warning light configurations. Vehicles were tested on either the left or the right shoulder at each site in either daytime or nighttime conditions (both daytime and nighttime conditions were evaluated at one site). Brake applications could only be determined during the nighttime studies, however.

Study Results

Effect of Warning Lights on Vehicle Speeds

Figure 1 presents a comparison of average speeds of vehicles passing the test locations when the different vehicle warning light configurations were being displayed. Sites are labeled 1 through 4, with letters in parentheses for each site location denoting whether the study was conducted during daytime or nighttime conditions (both daytime and nighttime data were collected at site 1). Because of poor lighting conditions, it was not possible to determine vehicle speeds from the videotape at the fifth test site.

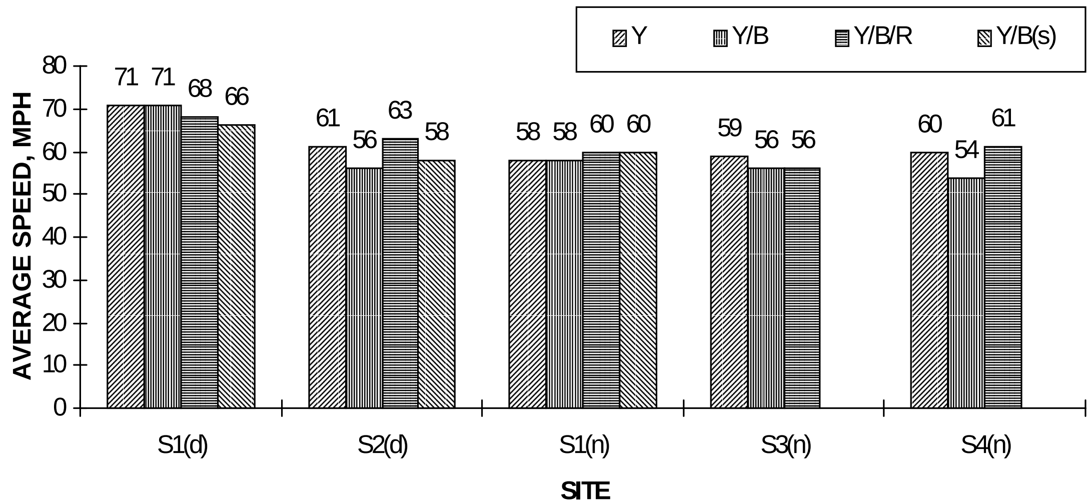

FIGURE 1 Effect of vehicle warning light colors on average speeds.

At two of the five sites tested, vehicle speeds when the yellow and blue light combination was displayed were significantly (5–6 mph) lower than when only a yellow light was displayed. At the other three sites, speeds were not significantly different under these two warning light configurations. Interestingly, no statistically significant differences were found in average speeds at any of the sites when the yellow-blue-red warning light configuration was compared to the yellow-warning-light-only configuration. The yellow and blue strobes with red strobes in the vehicle taillights yielded a significantly lower speed at S1(d) relative to the yellow-only configuration. However, traffic volumes at this location had increased significantly during the time period in which this configuration was tested. Consequently, the reduction in speeds may have resulted in large part from traffic interferences rather than from the effects of that particular warning light configuration.

Effect of Warning Lights on Driver Lane Choice

Driver lane choices were also examined as a potential measure of performance regarding different vehicle warning light colors. Lane choice was evaluated both in terms of the percentage of traffic in the lane closest to the vehicle warning lights, and in terms of lane-changing rates away from the lights (within the camera field of view). Figure 2 presents the percentage of traffic in the lane closest to the flashing warning lights. Generally speaking, the different warning light color configurations had very little effect upon this performance measure. The only statistically significant differences detected occurred at S1(n), where lane percentages adjacent to the various warning light configurations slightly decreased relative to the yellow light only configuration.

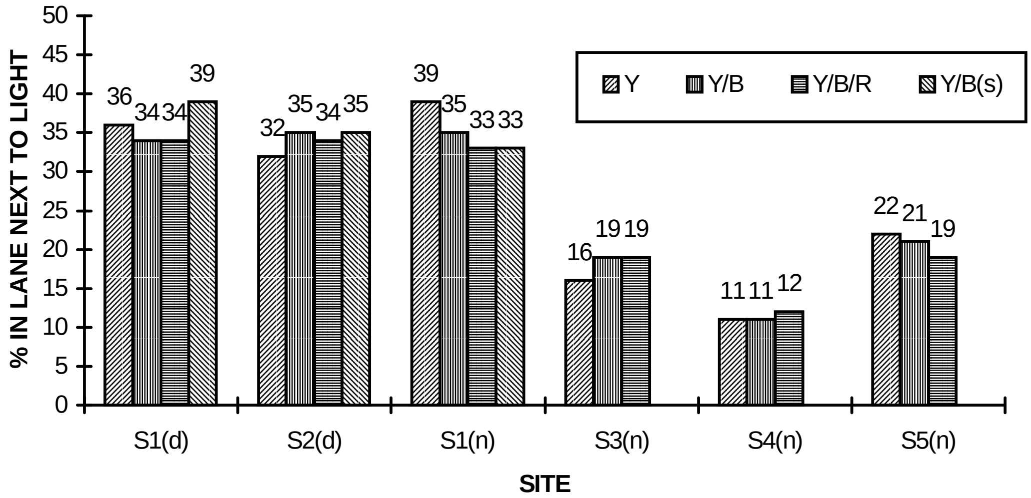

FIGURE 2 Effect of warning light colors on lane distributions.

Similar results were obtained when researchers examined lane-changing rates (within the video camera's field-of-view) as a function of the vehicle warning light color configuration displayed. As depicted in Figure 3, no clear trends in this performance measure are evident. One site did display higher lane-changing rates away from the lights when blue and red colors were used in conjunction with yellow light (in comparison to the all-yellow light configuration). However, this was not repeated at the other sites.

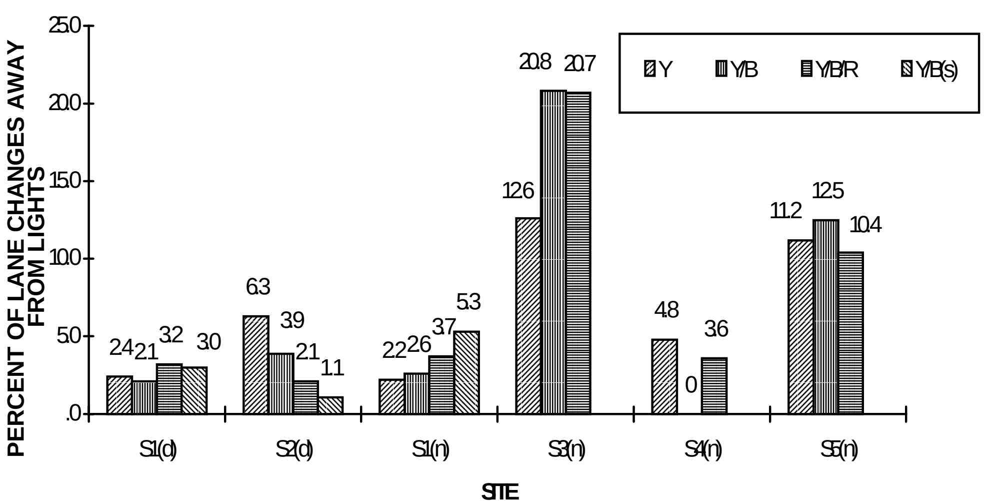

FIGURE 3 Effect of warning light colors on lane changing away from lights.

Effect of Warning Lights on Brake Activations

The final performance measure examined was the frequency of brake light activations for motorists approaching the various vehicle warning light color configurations. Because of viewing angles and video camera quality, these comparisons could only be made for those studies conducted at night. Figure 4 presents the percent of brake light applications under each configuration at each of the nighttime study sites. Unlike the lane-choice data, these data trends were more consistent. At three of the four sites, the yellow-blue-red warning light configuration resulted in a higher braking percentage than the yellow light only. The yellow-blue configuration also resulted in a significantly higher braking percentage (relative to the yellow-only configuration) at one site. Although pavement illumination levels were not measured during these studies, it should be noted that fairly substantial overhead lighting was present at sites S1 and S4, and less so at sites S3 and S5. Furthermore, the study site S5 was located just over the crest of a hill, which further limited sight distance to the test vehicle. Interestingly, these sites were where the more significant differences in performance were observed as a function of warning light color. Researchers hypothesize that the relatively lower overhead lighting levels (and limited sight distance at one site) made it more difficult for motorists to determine the type of vehicle that was associated with the different warning light color configurations, thus causing more motorists to brake before they reached the vehicles. When overhead lighting was higher, motorists could see the type of vehicle and its location on the roadway ahead. In this situation, the warning light color configuration may have become a less critical information source for motorists, resulting in little differences in braking applications.

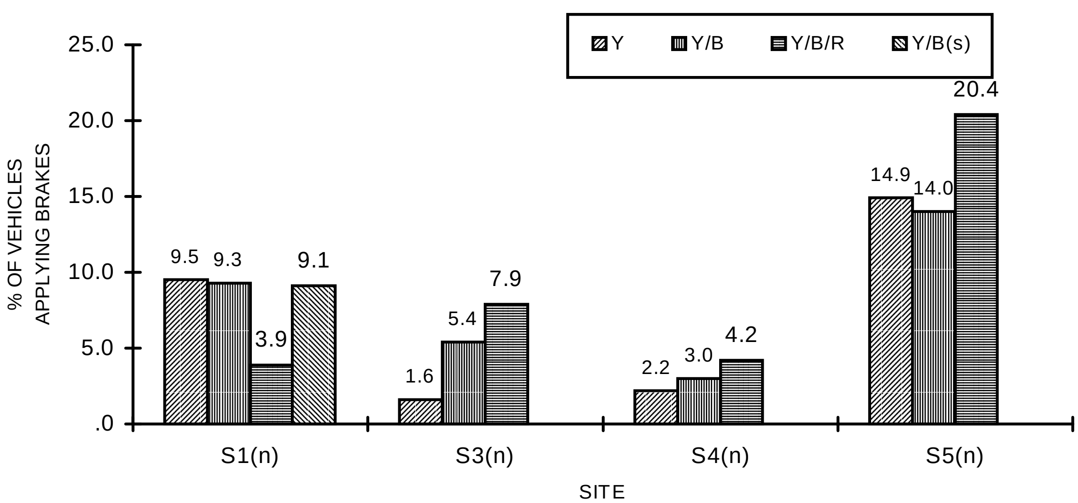

FIGURE 4 Effect of warning light color configurations on vehicle braking

Although significant differences by warning light color configuration were not always present at each site, the presence of warning lights in general did affect braking application relative to a normal (no-warning-light) condition. This is evident in the fact that brake application rates at three of the four sites were significantly greater than zero for all warning light color configurations, including yellow only. At site S3, the braking percentage associated with the yellow light only was not significantly greater than zero, but the braking percentage was significantly greater than zero for the yellow-blue and yellow-blue-red configurations.

SUMMARY AND CONCLUSIONS

The goal of the studies performed for this research project was to determine whether the use of warning light colors other than the standard yellow (amber) on construction and maintenance vehicles offers any potential safety benefit to workers or to the traveling public. Nationally, utilization of colors other than yellow is rather limited, although some states do use blue or red lights, or both, in conjunction with yellow lights for certain applications (such as courtesy patrol vehicles). Within Texas, survey results indicate that most motorists do associate yellow lights with highway construction and maintenance vehicles as well as with tow trucks, whereas light combinations involving red (red and blue, red and white, and red and other colors) are associated with the various types of emergency vehicles. Interestingly, motorists do appear capable of differentiating amongst different emergency vehicles because of the specific light color combinations that are used. In addition, motorists do appear to associate different levels of hazard and appropriate driving responses to different warning light color configurations. As expected, motorists seem to perceive yellow-only warning lights as indicative of less hazardous situations, in comparison to situations where vehicles utilize a combination of yellow lights with either blue or red lights. In turn, more motorists indicate a belief that these higher hazard situations necessitate some degree of braking action, in comparison to situations where vehicles use yellow lights only.

Field studies conducted in San Antonio and Houston examined the effect of yellow-only, yellow-blue, and yellow-red-blue vehicle warning light configurations on several operational traffic measures. Study results at two of the sites found that average speeds when a yellow-blue light configuration was displayed were 5–6 mph lower than when only yellow lights were displayed. However, speeds at the other three sites indicated no significant differences between those two configurations. Somewhat puzzling was the fact that similar results were not obtained for the red-yellow-blue light configuration. At all five sites, average speeds for that light configuration were not significantly different from the speeds measured when the yellow-light-only configuration was displayed. The yellow-blue-red taillight strobe configuration yielded lower average speeds at one site relative to the yellow-only configuration, but not at the other two sites where it was displayed.

Lane-choice performance measures examined in these studies were inconclusive as to any effects as a function of warning light color configuration. However, analysis of brake light applications did indicate a trend towards increased brake usage for the red-yellow-blue light configuration relative to the yellow-light-only configuration. There also was evidence that the yellow-blue light configuration may result in slightly greater frequency of brake applications, although not as dramatic as for the red-yellow-blue configuration.

From the perspective of a transportation agency such as TxDOT, concerned with the safety and welfare of its workforce performing tasks out in or near moving traffic, the results of these studies suggest that the use of yellow-only flashing warning lights may not correctly convey the true level of hazard associated with certain types of construction and maintenance activities. In particular, those activities that place workers out in traffic without the provision of advance warning signing or positive traffic separation with concrete or other barriers are particularly hazardous, and should be indicated to motorists as such. The results of these studies indicate that TxDOT and other transportation agencies should consider using more than simply the yellow vehicle warning lights during maintenance or construction that is particularly hazardous to workers or the motoring public.

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