LITERATURE REVIEW
The Use of Blue Warning Lights for Highway Maintenance and Construction Equipment

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Overview

Road construction and maintenance equipment is often used within the highway right-of-way, and is equipped with warning lights to alert drivers and pedestrians to a potential hazard. The color and arrangement of these lights are often dictated by legislation. In Oregon, ORS 816.350 allows for the use of "public vehicle warning lights" for such equipment, but section (4) of that statute states:

> "Vehicles operated by a police officer and used for law enforcement may be equipped with any type of police lights, but *only these vehicles may be equipped with blue lights*" (italics mine).

However, ORS 816.370 states that road machinery is exempt from the lighting equipment prohibitions in 816.350, leading to a discussion of the appropriateness of using blue lights on road maintenance equipment.

A survey of states by TTI found that all 50 states used amber warning lights on their highway fleets, and 12 states supplemented these with an additional colored warning light, primarily blue, red or white. Only 14 states had formal policies regarding lighting for highway fleets. (G. Ullman, Ragsdale, & Chaudhary, 1998). This study looked at the emerging practice in Texas of adding a blue light to the existing amber hazard lights for road work and service vehicles; the researchers recommended that the policy of allowing blue lights to be used with yellow/amber lights on selected vehicles be continued. However, current (October, 2017) TxDOT maintenance and service vehicle lighting standards limits the use of the combination blue/amber light to work within or adjacent to travel lanes, and not in a work zone situation. It further states that any vehicle equipped with a blue light must have that light powered by a separate switch from the amber ones. (Texas Dept. of Transportation, 2017)

Since the TTI/TxDOT study was completed in 1998, additional research on the use of different colored lights has been done. Most notable of these studies was NCHRP Project 13-02, which resulted in the publication in 2008 of *NCHRP Report 624: Selection and Application of Warning Lights on Roadway Operations Equipment* (Gibbons, Lee, Williams, & Miller, 2008b), and AASHTO's summary of the report in 2009: *Guidelines for the Selection and Application of Warning Lights on Roadway Operations Equipment.*(AASHTO, 2009) , which included extensive appendices detailing the study. This study found public perception strongly linked flashing amber lights with road maintenance equipment. In tests using amber, blue, red and white lights in different combinations under different conditions, researchers found the amber and white lights to have the highest impact factor, and they recommended that when an additional color was desired, that the combination of amber and white be used.

Discussion

The purpose of hazard warning lights is to relay information to approaching motorists, in order for the driver to formulate an appropriate response. The conspicuity of such a warning – how quickly and effectively the warning can be seen and identified – affects how the response will be given. Color is an important component

of how we process information; hence the standards for color and configuration of traffic signs. (G. L. Ullman, 2000). Our reactions are in large part learned behavior – when we see brake lights applied in front of us, we know to begin slowing down. The reaction time is shorter to a certain event – one that we have encountered before or might anticipate – than to an uncertain one. (Gibbons, Lee, Williams, & Miller, 2008a). From that perspective, it makes sense that drivers would respond more appropriately when they encounter a situation that they can relate to past experience. The NCHRP study confirmed that motorists strongly associate amber lights with road work, and blue lights with emergency vehicles, so introducing an unexpected color in a non-emergency situation could create confusion. Robert Cameron, in his 1997 conference paper, stated that maintaining a recognized standard for lighting was reasonable, since "the overuse of warning lights would dilute the urgency and meaning of the signal."(Cameron, 1997). Law enforcement officials have also expressed a concern that the widespread use of blue lights for road work would affect a driver's general response to law enforcement and emergency vehicles, which in part gave rise to the TTI study in the 1990s. No long-term research was found that addressed this concern; in fact, the Texas study showed that motorists seemed to be able to differentiate fairly easily between different types of vehicles by the combination of colors and light arrangements. (Ulman & Lewis, 2000). Certainly, the actual presence of law enforcement in a work zone has been shown to be an effective speed deterrent, as brought out in a 2014 Vermont research project (Lee, Azaria, & Neely, 2014), a recent Florida study (Gan, Wu, Orabi, & Alluri, 2018), and one done by ODOT (Gambatese & Zhang, 2015).

On the other end of the spectrum, just as public perception associates amber flashing lights with road equipment, it also associates this color with the least hazard potential. By allowing only amber lights for all maintenance and construction work, motorists could make the assumption that all such work has a relatively equal hazard potential, when in reality road work covers a whole gamut of hazard levels. (Ulman & Lewis, 2000). Some agencies have addressed this by having different combinations of colors for lights based on how the vehicles are used. For example, Minnesota uses blue lights in conjunction with amber on supervisory equipment, which often is used to respond to incidents (Howell, Pigman, & Agent, 2015).

An Australian report cited a 1967 study by Allen, Strickland and Adams which stated that the sensitivity of human vision peaks in the yellow-green portion of the spectrum, with white being the most visible color for warning lights, followed by green, amber and red (Chidlow, 2012) (Allen, Strickland, & Adams, 1967). Another consideration is the fact that colors themselves can filter the intensity of a light, a condition that increases with more concentrated colors. A clear lens put over a light can reduce the intensity by 10%; amber and blue lenses by up to 30%, while a red lens can reduce the output by up to 80%. (Cameron, 1997). This may be less of a factor with the increased usage of LED and strobe lights. Recent studies have investigated the addition of green lights. Ohio was the first state to use green lights on their snowplows, having a combination of amber, white and green. Missouri DOT released a research report on green lights mounted on truck-mounted attenuators (TMAs). This study found the amber/white combination had the highest visibility, but also had the highest disability glare. The green-only had low disability glare, but the least visibility, while the green/amber combination fell between these, and was generally the favored choice. (Brown, Sun, Edara, & Zhang, 2018). The 2015 study by Kentucky surveyed states and vendors; the researchers expressed an interest in exploring the viability of a green-yellow light, but found that that color was not offered by vendors. (Howell et al., 2015). The final recommendation of this study was to follow the guidelines proposed in the NCHRP/AASHTO report.

Snow removal equipment faces a unique set of challenges, generally operating in inclement weather and low-visibility conditions. A number of studies have been done to improve the safety and visibility of the plows, and some states allow other colors of lights to increase visibility for this type of equipment only. (Muthumani, Fay, & Bergner, 2015; Smahel, Arch, Pearsall, Eng, & CVS, 2017)

Table 1.3.1 Color usage on emergency and warning vehicles by state

State	Maintenance	Emergency vehicles	Note
Alaska	amber, blue	n/a	use different colors for maintenance vs. emergency
Illinois	n/a	amber	prevent glare
Indiana	amber	n/a	tested range of weather and lighting conditions
Iowa	amber	n/a	can use white, blue, red to complement amber
Maine	amber	n/a	amber for maintenance
Massachusetts	amber, white	red	use different colors for maintenance vs. emergency
Michigan	amber	n/a	amber for maintenance
Minnesota	amber, blue	n/a	to promote safety
Missouri	amber, white	red, blue	use different colors for maintenance vs. emergency
New Hampshire	amber	n/a	amber for maintenance
Ohio	green, white, amber	n/a	to improve truck visibility
Oklahoma	amber, blue, red, white	n/a	4 colors used for maintenance
South Dakota	amber	n/a	amber for maintenance
Texas	Amber/yellow	red	use different colors for maintenance vs. emergency
Washington	amber, red	blue	use different colors for maintenance vs. emergency

Table from *Evaluation of Green Lights on TMAs*, Page 19

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