Emergency Responder Roadside Safety Study and Lighting Demonstration

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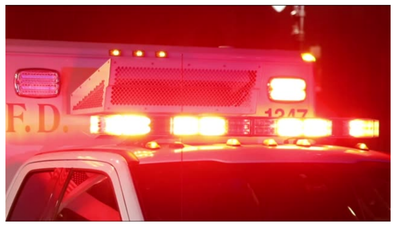
Abstract

The application of light emitting diodes (LED) for emergency warning lights has now proliferated to nearly all first responder agencies in the United States. LEDs have demonstrated significant advantages over traditional emergency lighting in many aspects. However, what is less understood is the impact of LED's on nighttime driver visibility and their contribution toward struck-by vehicle crashes. This study investigates the impact of warning light intensity and color on drivers' behavior, specifically focusing on the moth-to-flame effect. This data will be used to develop predictive crash frequency models to analyze and forecast struck-by crashes. Then, working concurrently with a student research team at Rensselaer Polytechnic Institute (RPI), Embry-Riddle students will pilot a prototype emergency lighting system in full-scale demonstrations to emergency response personnel and stakeholders to address the deficiencies identified following the completion of the first task. As part of this collaboration.

Background

The introduction of light emitting diodes (LED) for application in emergency warning lights began in the early 2000s. Since then, nearly 90 percent of emergency vehicle lighting now employs LED as the primary light source. LEDs have demonstrated significant advantages over traditional emergency lighting by providing better reliability, reduced amperage, and a smaller lighting footprint. A growing concern among first responder agencies is the belief that LED lights induce a "moth effect". The "moth effect" theory postulates that significant light sources near the edge of a roadway could have a tendency to attract driver's attention and have a potential to drawl the vehicle toward the light source. This believe is fostered by the high occurrence of drivers departing the roadway and colliding with emergency vehicles and personnel. Commonly referred to as "struck-by" incidents, these types of crashes have accounted for 122 police officer fatalities between 2009 and 2018. The goal of this research is to investigate struck-by vehicle crashes within the state of Florida and pilot a new LED emergency lighting apparatus designed to reduce the "moth-to-flame" effect.



Methodology

The RPI was to prepare lighting modules and controllers to present light sources differing in color (red, white, blue and yellow), intensity, flash rate, and the amount of modulation. The figure below shows the prototype of the lighting apparatus:

Using the prototype, the RPI team will conduct a nighttime outdoor field study using instrumentation to assess driver behavior in response to lights mounted on a mock-up of an emergency vehicle, varying in intensity and color. For a limited subset of conditions, two flash modulation levels (on/off and high/low) and two reflective marking schemes (present and not present) will be incorporated to assess responses to these factors. Lateral acceleration will be measured to determine whether the so-called "moth-to-flame" effect is observed among participants as they drive along a test road toward a scene with different emergency flashing light conditions, and also measure driving speed, ratings of discomfort glare, and driver confidence while approaching each condition.

The ERAU team will first identify factors that increase the occurrence of emergency responder struck-by crashes. This will be accomplished by accumulating quantitative data from FDOT Signal-4 Analytics software that can be used to determine the lighting and other roadside situations, which could influence the occurrence of struck-by collisions. Predictive crash frequency models have been developed by traffic engineers to analyze and forecast roadway crashes. An appropriate crash frequency model will be identified. The ERAU team will then bring and set up the flashing light prototype for demonstration to relevant stakeholders (e.g., firefighters, police, and/or emergency medical services).

Experimental Plan

A human-subjects experimental protocol was submitted to Rensselaer's Institutional Review Board (IRB) to check for safety and well-being of experimental subjects and the protocol has been assigned Rensselaer IRB #1896. The protocol has undergone expedited review and notice of approval was provided in February 2020. This was put onto hold due to the COVID-19 outbreak. For the experiment, all combinations of intensity and color will be used with a rapidly flashing pattern commonly used on fire apparatus. The initial planned conditions for the lighting apparatus were as follows:

Table 1. Planned Experimental Conditions

No.	Color	Intensity	Modulation	Flashing Speed	Markings	Notes
1	Red	High	On-Off	Standard	None	Parametric combinations of Color and Intensity
2	Red	Low	On-Off	Standard	None	
3	Blue	High	On-Off	Standard	None	
4	Blue	Low	On-Off	Standard	None	
5	Yellow	High	On-Off	Standard	None	
6	Yellow	Low	On-Off	Standard	None	
7	White	High	On-Off	Standard	None	
8	White	Low	On-Off	Standard	None	
9	Red	High	High-Low	Standard	None	Versus 1, tests Modulation
10	Red	Low	High-Low	Standard	None	Versus 2, tests Modulation
11	Red	High	On-Off	Slow	None	Versus 1, tests Flashing Speed
12	Red	Low	On-Off	Slow	None	Versus 2, tests Flashing Speed
13	Red	High	On-Off	Standard	Yes	Versus 1, tests Markings
14	Red	Low	On-Off	Standard	Yes	Versus 2, tests Markings

An apparatus was designed simulating a pair of vehicle mounted warning beacons. The pair of lights was suspended from an overhead track and was designed to travel a distance equivalent to 300 m in scale (1:100). simulated roadway surface was located under the simulated warning lights. Motion of the lights was provided by an electrical gear motor and belt. The simulated warning lights consisted of a pair of amber light emitting diodes (LEDs) that were mounted at a simulated distance of 2.5m. The test groups characteristics were the following:

	Instructed	Towards	Away	# Subjects	Age	Sex
Group 1	No	1 Hz	4 Hz	8	2:>50|6:18-30	3 Female/ 5 Male
Group 2	No	4 Hz	1 Hz	9	2:>50|7:18-30	4 Female/ 5 Male
Group 3	Yes	1 Hz	4 Hz	9	2:>50|6:18-30	5 Female/ 4 Male
Group 4	Yes	4 Hz	1 Hz	7	2:>50|5:18-30	4 Female/ 3 Male

The results of this laboratory study, taken together, suggest that flash frequency can be used as a reliable tool for communicating to drivers about the intended motion of a service vehicle. Even when subjects in the first experiment were not instructed about the relationship between frequency of flashing and the eventual direction of travel, they were able to make predictions about the direction of travel with greater than 50% accuracy, and their performance improved slightly throughout the experiment. Further studies and investigation will be done into the other factors that effect the "moth effect" theory.

Conclusion

Due to COVID-19 in person testing has been put on hold. The RPI team is in the process of working on field studies. Following the field studies the ERAU team will be doing demonstrations with the lighting bar to stakeholders. The format of these demonstrations will be drive through due to COVID-19 and is in the process of being deigned.