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Effectiveness of Contrast Markings on Roadways and Orange Markings in Work Zones

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16. Abstract

Lane departure crashes are a leading cause of fatalities and injury crashes on roadways. To solve this problem, innovative marking in the form of contrasted white on concrete sections and orange marking in work zones were evaluated for their safety benefits. A highway safety manual approach was taken to evaluate the crash reduction benefits from each marking design. Orange marking in work zones were also evaluated for their speed, lane keeping, and lane choice effects. A survey of drivers was conducted on orange markings to ascertain public opinion, the survey indicated the potential for wide public acceptance of the new marking color on Indiana roadways. The overall findings suggest that contrast pavement markings decrease lane departure crashes from between 42% and 44%. For orange markings, a speed reducing effect of 4 mph was found in work zones and a 74% reduction in lane departure crashes. Lane centering and lane position in work zones with orange marking was also investigated.

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EXECUTIVE SUMMARY

Introduction

The research objectives for this project were to quantify the safety impact of contrast pavement markings on concrete pavement and orange pavement markings in work zones. The approach taken was a cross-sectional before-after comparison method. A quantitative approach was taken to estimate crashes using safety performance functions (SPF's) from the *Highway Safety Manual*, which were compared to crash data at each site. The overall goal was to reduce lane departure crashes common on roadways.

Contrast pavement markings have been installed at select locations on Indiana roadways, mainly near high volume interchanges with concrete segments. Orange colored pavement markings are believed to provide better delineation in work zones. However, the color orange is currently not an approved standard and is considered experimental. As such, formal research into its effectiveness was required by the Federal Highway Administration (FHWA).

An extensive literature review helped guide the research by identifying gaps in knowledge and identifying the best research approach. Topics related to the research project were reviewed including marking detection technology, work zone safety, pavement markings, and driver behavior.

Findings

Contrast pavement markings were found to substantially reduce lane departure crashes from between 42% and 44%, resulting in an average CMF of 0.57.

Orange pavement markings were also evaluated and found to have several safety benefits when used in work zones. Crash reductions at the two tested sites averaged 74% for lane departure crashes, resulting in a CMF of 0.26. A speed reduction of 4 mph was found on sections with orange markings versus sections with typical white and yellow markings. Drivers in orange marked sections were also found to keep near the center of their lane at a higher rate than white and yellow marked sections. A sample of autonomous vehicles was used to detect orange pavement markings in work zones. It was determined that orange markings were detected at a rate of 100% by the sample of level 1 and 2 autonomous vehicles used in testing. Ghost markings were also evaluated using autonomous vehicles, and the machine vision does not detect ghost markings when located in the center of a lane or crossing the lane lines at an angle.

Implementation

Increasing the use of contrasted pavement markings on concrete sections of roadway has the potential to reduce the number of lane departure crashes. Orange pavement markings have the potential to improve driver compliance with posted speed limits and reduce work zone lane departure crashes by keeping drivers more focused and centered in their lane of travel. Further studies at more sites will provide a better understanding of the continuing effect that contrast and orange markings have on driver behavior and safety.

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1. INTRODUCTION

Lane departure crashes encompass multiple crash types and account for approximately 50% of fatal roadway crashes (FHWA, 2023). Many proven countermeasures are available to reduce roadway departure crashes, however the effects of some designs are still unclear. The Indiana Department of Transportation (INDOT) in conjunction with the Joint Transportation Research Program (JTRP) of INDOT with Indiana State University (ISU) investigated the safety benefits of marking types including contrast and orange markings. While contrast pavement markings have been used for many years the safety benefits are only recently becoming realized and their use is relatively new in Indiana. Orange pavement markings are still considered experimental with the Federal Highway Administration (FHWA) and require experimental approval, with only two previous states testing orange markings at the beginning of this project.

Contrast pavement markings are believed to provide increased visibility to lane lines in certain lighting conditions and are believed to decrease lane departure crashes by 29% (Williamson & Singh, 2022). Implementing contrast pavement markings in areas with a high number of lane departure crashes has the potential to decrease crash rates, delays, and improve mobility.

Common problems in work zones include speeding, and weaving resulting in sideswipe and lane departure crashes. Orange pavement markings are intended to increase drivers awareness of work zones, resulting in increased compliance of posted speed limits, improved lane keeping, and crash reductions. Work zone crashes cause increased delays and commonly result in injury or death. Orange pavement marking use is currently being tested by multiple agencies under the supervision of the FHWA.

This report describes the results of the evaluation of contrast pavement markings safety benefits and the orange pavement marking experimentation results including service life, color fastness, retroreflectivity, speed effects, lane keeping, safety benefits, public opinion, and detection by autonomous vehicles. The results are intended to provide engineers with information to make informed decisions related to safer roadway and work zone design.

2. STUDY OBJECTIVES AND SCOPE

The scope of the work for this project included an evaluation of contrast pavement markings on freeways and orange pavement markings in work zones. The first objective of this study was to evaluate the safety benefits of contrast pavement markings on freeways by creating a crash modification factor (CMF) that could be used to design safer roadways in Indiana. The second objective was to evaluate experimental orange pavement markings in work zones including color fastness, retroreflectivity, and crash reduction benefits in the form of a CMF.

3. RESEARCH METHODOLOGY

The research consisted of two main parts contrast pavement markings and orange pavement markings, beginning with establishing a research basis, followed by data collection, and ending with data analysis. The contrast pavement marking methodology used was to identify sections of roadway for analysis, obtain crash history, and evaluate each site using a statistical method approach. Orange pavement markings in work zones are considered experimental and require a more in-depth study approach. The overall methodology consisted of five main steps: an extensive literature review of topics relevant to the project, obtaining experimental permission from the Federal Highway Administration (FHWA), collecting data on experimental test sites, data analysis, and drawing conclusions. Figure 3.1 shows the order of the overall research procedure.

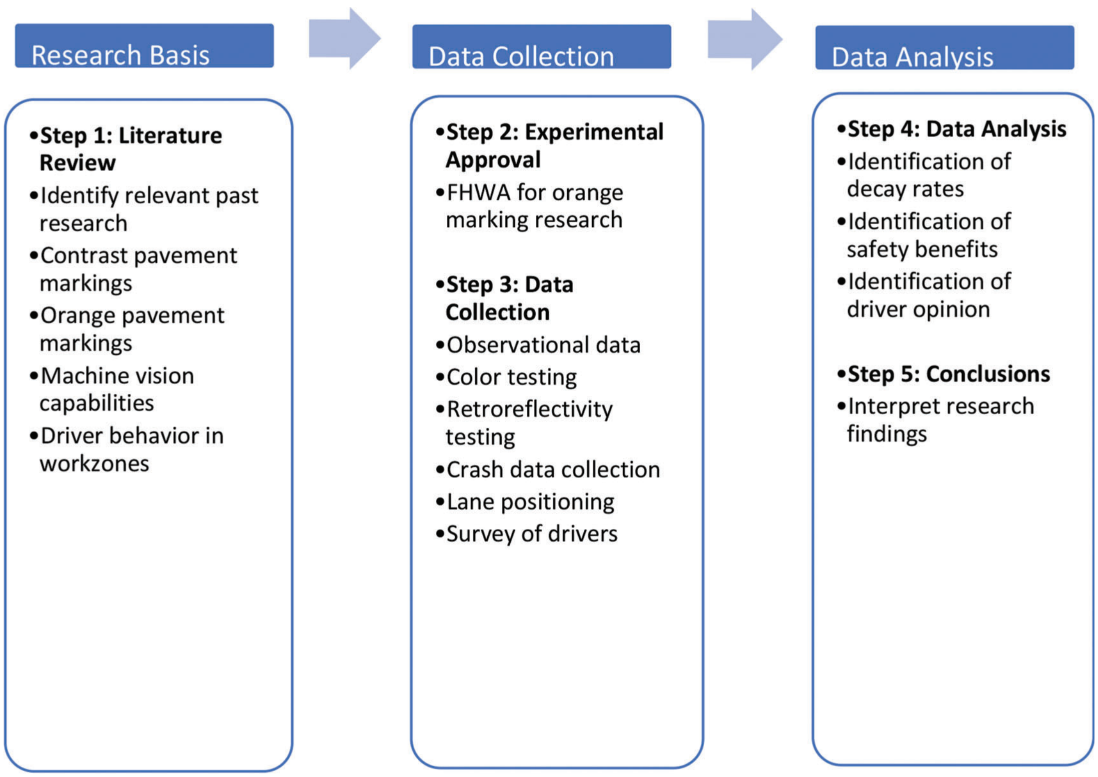

Figure 3.1 Research methodology.

4. LITERATURE REVIEW

4.1 Machine Vision Detection of Pavement Markings

Pavement marking detection is an important topic for two reasons, drivers must be able to identify the lane of travel and machine vision systems that provide lane assist must be able to detect lines to provide adequate warnings or corrections. A recent study (Babić et al., 2021) compared the marking detention quality in daytime and nighttime conditions taking into consideration the age of the markings. Findings suggest that nighttime detection is slightly higher than daytime in dry conditions. While the age of marking was considered further research is needed to understand at what point detection is affected.

Past studies (Lundkvist & Fors, 2010) have identified that machine vision systems require that pavement marking luminance be at least 5 mcd/lx/m^2 greater than the roadway surface with a minimum luminance value of 85 mcd/lx/m^2 for adequate detection.

Machine vision systems (3M, 2022) analyze the luminance or pixel density of roadway surfaces and roadway edges. Based on the contrast values computer algorithms are able to identify the proper lane position for the vehicle. Maintaining a contrast difference between the roadway surface and the marking is vital for CAV's to traverse roadways safely. When detecting contrast differences gray scale can be used to limit the cost of the detection system. Some systems can detect color differences, this allows the computer to process the type of marking on the roadway, for example color detection can distinguish the difference between a white and yellow line.

Some advanced lane detection systems (Alarcon, 2020) classify the marking type and can detect objects off the roadway. This advancement provides a smoother transition at roadway mergers and can help navigate complex intersections on urban streets.

In recent years, researchers (Davies, 2016) have focused on machine vision capabilities related to lane identification, which relies on the ability of machine vision systems to identify lane markings. Potters beads recently tested the capabilities of machine vision systems under ideal conditions at both low and high speeds. The research identified the optimum detection distance to be 25–45 feet on 35 mph roadways and 25–55 feet on 70 mph roadways. Tests were also conducted in daytime and nighttime conditions. It was determined that retroreflectivity has little impact on machine vision system during the daytime, however retroreflectivity was a found to be essential for machine vision detection. The most important factor for daytime machine vision was found to be the luminance contrast ratio between the marking and the pavement. An increase in detection confidence was seen as the contrast ration increased for both day and night. Width of marking was also tested, overall, 6-inch marking out preformed 4-inch marking in both daytime and night-time conditions. The tests were also performed with simulated rain, with the 6-inch strip having less retroreflectivity than the 4-inch strip, additional testing may show varying results. In each scenario tested, the 6-inch strip returned more retroreflectivity.

Researchers (Pike et al., 2018) at Texas A&M recently evaluated machine vision systems ability to detect marking under various conditions and identified the contrast ratio necessary for adequate detection. The testing includes the evaluation of contrasted white strips. The markings design was a 4-inch white marking with 2 inches of black border. Mixed results were reported, the north bound lanes testing showed improved detection with contrasting, however the southbound lanes showed decreased detection with contrast. Overall findings suggest the key is having enough contrast between the pavement and the pavement markings. More research in needed on the contrast effectiveness.

4.2 Lane Keeping

Lane keeping assist technology (NSC, 2022) provides drivers with warning when their vehicle drifts out of the lane of travel. The warning may include beeping, flashing lights or vibrations. Some vehicles will correct the vehicle position to the lane of travel if drivers do not respond. Most systems are primarily designed to work on high-speed roadways with limited access points. Machine vision relies on contrast between the pavement and marking. Detection systems are not currently able to process markings in fog or snow. Additionally faded, covered, disrepair, or overly complicated pavement markings will also cause detection system failures. Some vehicles (Toyota, n.d.) are also equipped with radar detection systems, that assists in keeping a safe distance between the leading vehicle and can be used to maintain lane position when lane lines are not visible due to weather or disrepair.

There are three levels of lane keeping currently available on vehicle lane-departure warning, lane-keeping assistance, and lane-centering assistance (Chokse, 2021). Lane-departure warning systems is the simplest, where drivers are given an alert if the vehicle drifts out of the lane of travel without using a turning signal. Lane-keeping assistance provides an additional component, besides providing a warning to drivers auto correction of lane position or braking if necessary will be enacted if drivers do not respond to the lane position warning. Lane-centering assistance is the highest-level current technology and capable of hands-free driving, where the vehicle can drive itself on certain roadways.

The effect of low lighting at dawn, dusk and rain conditions was evaluated and compared to mid-day in Wisconsin (Shaw et al., 2018). One-hour videos for the treatment and control sites were taken and analyzed during low light condition mentioned versus mid-day full sun. Limited effects were found when comparing light conditions.

4.3 Vehicle Speed in Work Zones (Wisconsin)

Speed was also evaluated in work zones with orange markings with 2-hours of data collected at each site during cloudy daylight conditions (Shaw et al., 2018). The results show that the average speed was 2 mph higher in the work zone with orange marking when compared to the control sites, however it was noted that this speed difference could come from geometric differences between the control and test sites. The study approach used forward fire radar guns mounted in the work zone. Speed were collected for 125 vehicles at the treatment site and 93 vehicle speeds were collected at the control site. Lead vehicles were evaluated approaching and entering the work zone with the speed difference calculated. Lead vehicles were considered to be in free flow condition and had a minimum headway of four seconds.

4.4 Marking Width

Pavement marking width has been studied in recent years in response to connected and autonomous vehicles (CAV) technology. Cameras and machine vision show improved detection with an increase in pavement marking width, for this reason the Michigan Department of Transportation (MDOT, n.d.) decided that beginning in 2020 all high-speed roadways will be converted to 6-inch-wide markings, moving away from the traditional 4-inch-wide markings. The additional width has increased the cost of marking projects but has improved the ability of CAV's to process the necessary data under adverse visibility conditions. To improve CAV guidance at exit and entrance ramps dotted line extensions are being added. In 2021 MDOT also decided to improve non-freeways to 6-inch-wide markings, the conversion of marking width is expected to take place over a 4-year period.

4.5 Life of Marking

Research has been conducted on the service life of pavement markings with focus on visibility from new down to a minimum acceptable level. A study in Croatia (Babić et al., 2019) set a minimum level of visibility at 100 mcd/lx/m^2 and studied the service life of three different types of solvent-borne paint, thermoplastics, and cold agglomerate plastics. Field measurements ranged from 174 to 548 mcd/lx/m^2 with average life in the field declining to 100 mcd/lx/m^2 ranging from 754 to 1,581 days. Solvent paints lasted the least amount of time with cold agglomerate plastics lasting the longest. The results can be seen in Table 4.1.

The Wisconsin (Shaw et al., 2018) study found that after 3 months of use the temporary markings became hard to see due to fading and covering with dirt or other construction debris.

TABLE 4.1
Croatia Study Results

Model	Data Set	Average Retroflection		Average Road Marking Service Life in Days	
		Measured	Modelled		
		mcd/lx/m^2		100 mcd/lx/m^2	150 mcd/lx/m^2
Solvent-Borne Paint	30	173.97	170.96	753.61	393.60
Thermoplastics	10	291.20	252.89	1,097.76	884.09
Cold Agglomerate Plastics	10	547.10	482.79	1,581.14	1,436.21

4.6 Effects of Marking

Extensive research by Babić et al. (2020) was conducted on driver behavior and safety benefits of marking. A recent study by Babić et al. (2021) reviewed over 70 research records focusing on driver behavior and safety related to markings. Variables of interest were found to mainly focus on speed and lateral position including both driving simulators and observational data collection methods. Factors that were found to impact driving behavior were marking with which reduced lane weave and rumble transverse lines that were found to be effective at reducing vehicle speeds and lateral position in areas of curves.

Many of the findings of past studies (Chang et al., 2019; Charlton et al., 2018; Coutton-Jean et al., 2009; Ding et al., 2016; Hussain et al., 2019; Zhao et al., 2018) on road markings in relation to safety have seen inconclusive results. Key findings were determined to be related to retroflectivity levels where levels of 200 or more have been shown to reduce crashes. With minimum levels of 100 for dry conditions and 150 for wet conditions recommended. Simulation has shown lane position to be somewhat effected by marking type and width. Retroflectivity life is dependent on product and exposure to elements. Further research is needed to identify the safety impact, product life, and driver behavior effects.

4.7 Orange Pavement Markings

When long-term lane shifts are required in work zones markings must be removed and replaced with temporary markings. The removal process tends to leave phantom or ghost markings that are still visible to drivers and often cause confusion. Orange markings are believed to have started in Germany (Kehrein, 1989) and are now widely used in Europe, Canada, Australia, and New Zealand have been experimenting with their use (Shaw et al., 2018).

The orange pavement marking trials in Auckland New Zealand (Cottingham, n.d.) took the approach of leaving old markings in areas of lane shifts and instructed drivers to follow the orange temporary markings while in the work zone. Leaving the old markings prevented confusing ghost markings, but still caused driver confusion as to which marking to follow. Other benefits realized included reduced construction cost and alleviated pavement damage caused by grinding old markings.

The Kentucky Transportation Cabinet (KYTC) is said to be one of the first to install orange pavement markings in work zones (AASHTO, 2020). In addition to orange pavement markings, the speed limit was posted on the pavement in orange letters. The use of orange marking is in response to the high number of crashes in work zones. The hope is that orange markings will catch motorist attention and command a safe driving behavior while traversing work zones. After receiving FHWA approval, KYTC (Heydorn, 2020) began testing orange pavement markings in work zones in 2019. Waterborne paint and thermoplastic materials were both tested, visi-ultra beads, which are four times larger than standard beads, were used in conjunction with the paint to improve visibility. The hope is that highly visible orange markings will improve driver awareness in work zone, while reducing confusion of lane configurations.

The KYTC (Lammers, Hemphill, & Carlson, 2021) tested different marking types over the 24-month pilot project. Waterborne paint was used in the form of hardware store orange paint that included Kentucky's typical bead package applied at 15 mil thickness. While the waterborne paint was effective at achieving the desired color it did not hold the beads, resulting in poor retroreflectivity ranging between 51 and 132 mcd/lx/m^2. The waterborne paint wore off the roadway within 100 days, it was determined that this painting configuration was best for short term projects. The next product tested to replace the waterborne paint was spray thermoplastic, applied between 60 and 75 mils with a larger bead package to increase retroreflectivity. This configuration proved to be more durable and visible, however the retroreflectivity at installation was only at 136 mcd/lx/m^2 and decreased rapidly to 80 mcd/lx/m^2 between 75 and 100 days in the field, and to 75 mcd/lx/m^2 at 300 to 375 days in the field. The next marking package tested was waterborne paint applied at a greater thickness of 30 mils, with a high gradation bead package. This configuration out preformed the previous two with retroreflectivity readings as follows: 40 day 220 mcd/lx/m^2, 100 day 179 mcd/lx/m^2, and 160 day 209 mcd/lx/m^2.

KYTC (Lammers, Hemphill, & Carlson, 2021) also studied the speed effect of orange markings, but with inconclusive results. Crashes were found to increase by

20% with sideswipes as the most common. Public perception was sought through a survey with 51% of drivers preferring orange in daytime and 49% preferring orange at night.

The final report (Lammers, Hemphill, & Carlson, 2021; Lammers, Staats, & Agent, 2021) from the KYTC on orange pavement marking experiment provides some valuable information for other DOTs pursuing orange marking use. While initial deployments of orange markings found retroreflective deficiencies, KYTC identified that high-end bead package use would allow retroreflectivity thresholds to be maintained. Crashes were also evaluated for the duration of orange marking deployment. Results indicate an increase in crashes, but crash severity decreased. Vehicle speed was also analyzed in the orange marking sections. Overall, the average vehicle speed was nearly 10 mph above the posted work zone limit of 55 mph. No effect of speed was found compared to a work zone with standard marking. Public input was sought through an online survey that received 233 responses. Public preference between standard white versus orange markings were nearly equal with slightly more preferring orange in daylight and slightly more preferring white at night.

The Wisconsin Department of Transportation (WisDOT) made the decision in 2014 to try orange pavement markings in work zones in hopes of providing better guidance for lane shifts (Heydorn, 2017). It had been observed that drivers often struggled to follow lane shifts with white pavement markings in work zones, a problem that is elevated when snow, ice, and salt were present on roadways. The FHWA granted permission for use on a multiyear project that included over 100 lane shifts. A survey was sent to drivers who passed through the work zone seeking to identify their acceptance of orange markings. Results indicated that 75% of survey participants were acceptant of the orange markings, while 25% felt the orange markings were to dark and blended into the pavement. A DuPont representative indicated that orange markings might be difficult to see by some drivers due to the temporary markings having limited retroreflective beads. Two major issues arose on the project—fading of the temporary markings and reflective bead retention.

The North Texas Tollway Association (NTTA) recently tested orange thermoplastic marking in work zones (Hemphill, 2021). Thermoplastics were selected for their durability and potential ability to cover ghost markings. Field tests on retroreflectivity show orange markings to have higher mcd's than yellow but less than white. Retroreflective properties maintained higher than yellow until approximately 120 days in the field.

In 2020 the California Department of Transportation (CalTrans) began testing orange temporary marking in work zone, building on the previous knowledge presented by other DOTs (Hadley & Lee, 2020). CalTrans proposed marking plan consisted of using orange as a contrast to standard temporary marking. The proposed marking is water-based paint due to its lower cost and higher ultraviolet light (UV) resistance. Two designs are to be tested. The first consists of a 12-foot white retroreflective 6 inches wide (standard marking) contrasted with a 16-foot orange marking, that is 6 inches wide. The second design consists of bordering all standard white lane lines with 2 inches of orange. Data collection includes the following.

- Using CCTV to observe motorist behavior in the work zones.
- Dashboard camera recordings through the work zone in daylight, evening, and night conditions to obtain driver perspective on delineation.
- Surveying public opinion on delineation preference between the two designs.
- Collision rates, speeds, and speed differentials between designs.
- Vehicle lateral position in lanes.
- Retroreflectivity values of the orange contrast at installation and in 6-month intervals.

4.8 Lateral Lane Position

Lateral lane position was evaluated in work zones with orange markings in Wisconsin (Shaw et al., 2018). No effect on lateral lane position was found between orange and white marking after evaluating nearly 200,000 samples. It was noted that drivers in orange pavement marking sections tended to track slightly to the right side of their lane of travel of a distance between 4 and 6 inches, but the difference was not a statistically significant. The data was collected two ways; trailer mounted cameras and laser distance meters (rangefinders).

4.9 Driving Behavior in Work Zones

The Wisconsin study also evaluated the lane choice behavior by taking 1-hour video recordings at dawn, mid-day, dusk, and rain. Mid-day was used as a base with the other three time periods thought to be the most difficult time for drivers to maintain lane position. Vehicles were placed in one of the following four groups:

1. right lane,
2. left lane,
3. straddlers, and
4. lane changers.

An analysis of the Wisconsin (Shaw et al., 2018) study site show a fairly even distribution across the four study groups. The dawn group did see slightly more right lane users. Lane changing in the work zone were more prevalent in the dawn (0.3%) and mid-day (0.5%) periods, but there was not much difference between dusk and rain conditions both at 0.8%. Straddlers defined as vehicles taking up part of both lanes without the intent of making a lane change were found to be most common at dawn (9%), followed closely by mid-day (7.3%). Straddlers at dusk and rain conditions were found to be 2.6% and 4.3%, less than half of the other two periods.

4.10 Paint Color

Various shades of paint in any one color are available. The WisDOT (Shaw et al., 2018) found that certain shades of orange paint specifically non-florescent epoxy paint appeared to be yellow at night under high-pressure sodium (HPS) lighting. To eliminate this problem LED light was installed for the duration of the construction project.

Public input was sought through a series of surveys comparing orange markings to fluorescent orange markings (Shaw et al., 2018). The results indicate that the public preferred fluorescent orange markings and feel they are more visible then white markings. The public opinion on the visibility of orange versus white was nearly even. Overall public opinion on what color to use in work zones was 85% fluorescent orange, 15% white, and 5% orange.

4.11 Retroreflectivity

Standard levels of retroreflectivity have been set by past studies and are not included in American Society for Testing and Materials (ASTM) standards. The minimum level (FHWA, 2010) that must be maintained on roads with posted speeds of 55 mph or greater is 100 millicandelas per meter squared per lux (mcd/m2/lux). Additional guidance is now available in the latest version of the *Manual on Uniform Traffic Control Devices* (MUTCD). The recommended The Minnesota Department of Transportation (MnDOT) suggests maintaining a minimum level of retroreflectivity to ensure drivers have adequate visibility (Pike & Barrette, 2020). The level is set at 50 mcd/m2/lux in wet conditions.

5. CONTRAST PAVEMENT MARKINGS

5.1 Site Locations

Contrast pavement markings were evaluated on I-65 southbound from the I-465 south junction and on I-70 near the Indianapolis International Airport. The section on I-65 used bordered contrast marking and was installed to reduce the number of sideswipes, fixed object, and overturned crash types, Figure 5.1 displays striping configuration. The contrast marking on I-65 were installed in 2017, a 3-year before and after the evaluation was conducted. The location on I-70 is located near the Indianapolis International Airport, the contrast pavement markings were installed in early 2022, limiting before data to a 6-month analysis period. The 3 years of before data were obtained and averaged into 6-month periods for comparison with the after data. Figure 5.2 displays the marking configuration on the I-70. A map of the locations and graphs of crash history can be found in Appendix A.

5.2 Safety Benefits

The evaluation of the contrast pavement markings followed a quantitative Highway Safety Manual (HSM) approach, prediction models were used to estimate the number of expected crashes and compared to the observed crashes at each test site to estimate the safety benefits. The equations presented below (Equations 5.1 to 5.8) display the quantify method used in the safety benefit analysis of contrast pavement markings, resulting in the development of CMFs.

$$SPF_s = \mu_i = (SL)_i \times e^a \times (AADT_i)^b \qquad \text{(Eq. 5.1)}$$

Where, SPF = safety performance function, μ_i is the expected number of crashes for given segment i, SL_i the segment length in miles of segment i, $AADT_i$ is the Average Annual Daily Traffic of segment i, a and b are the regression coefficients unique to roadway type.

$$W = \frac{1}{1 + \frac{\mu b * Y}{d}} \qquad \text{(Eq. 5.2)}$$

Where, W = weight, μ_b = predicted number of crashes using the SPF, d = overdispersion perimeter unique to each set of regression coefficients, Y = number of years in the before periods.

$$E_b = P * W * A * (1 - W) \qquad \text{(Eq. 5.3)}$$

Where, E_b = estimated number of crashes in the before period and A = observed number of crashes in the before period.

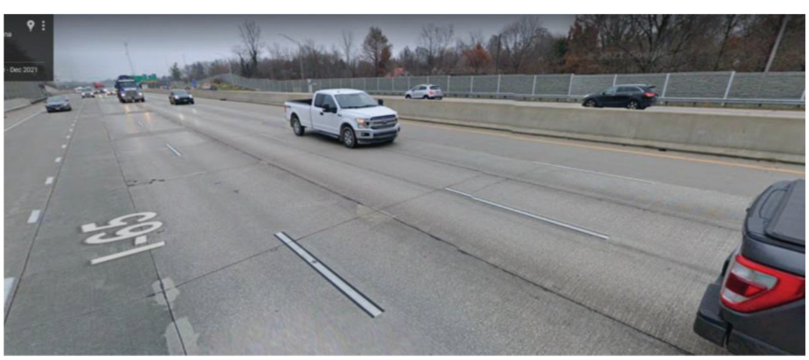

Figure 5.1 Contrast marking I-65 at the I-465 south junction.

Figure 5.2 Contrast marking I-65 at the I-465 south junction.

$$N_{expTB} = W * (N_{preTB}) + (1 - W) * N_{obsTB} \quad \text{(Eq. 5.4)}$$

Where, N_{expTB} = expected number of crashes before treatment, N_{preTB} = predicted number of crashes before treatment, and N_{obsTB} = observed number of crashes before treatment.

$$\sigma = \sqrt{((1 - W)) * E_b} \quad \text{(Eq. 5.5)}$$

Where, σ = standard deviation.

$$S = \frac{1}{\sigma^2} \quad \text{(Eq. 5.6)}$$

Where, S = standard error.

$$E_a = E_b * \frac{\mu_a}{\mu_b} \quad \text{(Eq. 5.7)}$$

Where, E_a = expected crash frequency after if no treatment, E_b = expected crash frequency before treatment, μ_a = predicted after period (without treatment), μ_b = predicted before period.

$$CMF = \frac{N_{obsAT}}{E_a} \quad \text{(Eq. 5.8)}$$

Where, CMF = crash modification factor and N_{obsAT} = number of observed crashes after treatment.

The site at I-65 and I-465 junction had a relatively low crash history for lane departure crashes in the before and after periods, possibly due to the short length of the analysis segment. The crash history and AADT for each analysis period can be seen in Table 5.1. The I-70 location information can be seen in Table 5.2.

Pavement markings evaluated in Indiana included one section with bordered centerlines and one with lead/lag and bordered edge lines. Sites previously evaluated at the national level did not include sections with boarded edge lines. While a limited number of crashes were available for analysis the results provide some insight into the effect of contrast pavement markings on Indiana roadways. Table 5.3 displays the CMFs developed for two different roadway sections in Indiana with a comparison to the CMF developed at the national level. The installation of contrast markings in Indiana suggests a decrease in roadway departure crashes of 42 for bordered centerlines and a 44% for lead/lag with bordered edge lines. The results suggest a slightly better benefit than the national level, it should be noted that the national level CMF was developed with data from multiple states and a larger crash database. The average CMF for Indiana was found to be 0.57.

TABLE 5.1
Crash and AADT History I-65

Installed Jan 2017	AADT	Period	Crash History
Jan 2014 to Dec 2016	44123	Before	7
Feb 2017 to Jan 2020	47445	After	4

5.3 Discussion of Results

The purpose of analyzing contrast pavement markings was to determine if safety benefits followed the national trend in reducing lane departure crashes.

TABLE 5.2
Crash and AADT History I-70

Installed Jan 2022	AADT	Period	6-Month Crash History
Jan 2016 to Dec 2019	50926	Before	3.5
Jun 2022 to Dec 2022	66430	After	3

TABLE 5.3
Developed CMFs

Location	CMF Total	No. of Crashes	Marking Design
Indiana I-65	0.58	11	Bordered centerline
Indiana I-70	0.56	10	Lead/Lag centerline with bordered edge line
National Level	0.71	426	Bordered centerline

Based on the analysis, crash reducing benefits are similar to the nationally reported benefit of a 29% reduction in lane departure crash types. Two locations in Indiana were analyzed, the I-65 location had bordered contrast markings and saw a 42% reduction in lane departure crashes after the installation of the contrast markings. The I-70 location had lead/lag contrast marking with bordered edge lines and saw a 44% reduction in lane departure crashes after installation of the contrast marking.

While both Indiana sections evaluated found a reduction in crashes it is important to note that after periods were shorter than preferred for analysis at one site. Additional analysis of 3 years of after data when available will provide a stronger understanding of the contrast marking benefits on Indiana roadways.

6. ORANGE PAVEMENT MARKINGS

6.1 Site Locations

The location of orange pavement marking sites were on interstates in work zones near the urban areas of Sellersburg and Lebanon Indiana. Each location had orange markings in one direction with typical markings used on the opposite direction of travel. The Sellersburg site was located on I-65 near exit 9, with orange markings on the northbound side. The Lebanon site was located on I-65 near exit 141 with orange marking on the northbound side. A map showing the location of the sites can be found in Appendix B.

6.2 Color and Retroreflectivity

Multiple visits to each test site were conducted to evaluate the daytime/nighttime color and retroreflectivity of the orange pavement markings. All testing devices were current on calibration and standard testing procedures were followed for data collection. Colors were measured shortly after installations and again after exposure to traffic and the elements using a HunterLab mini-scan EZ, portable color spectrophotometer which can be seen in Figure 6.1. Color was near the recommended color spectrum on all tested sites.

Figure 6.1 Mini-scan EZ calibration testing.

Figure 6.2 and Figure 6.3 display the color spectrum test for the Sellersburg and Lebanon sites. An additional site located on the Indiana Toll Road was tested to provide insight when moving from a tape product to a paint product. The results for the Toll Road location can be found in Appendix C. Markings were also evaluated for retroreflectivity for the purpose of visibility in low lighting conditions. An LTL-X Retro-reflectometer was used for testing, which can be seen in Figure 6.4.

Based on past research a minimum retroreflective level of 50 mcd/m^2/lux is recommended to provide adequate visibility to drivers. The INDOT retroreflectivity minimum level for newly install marking on construction contracts is 300 mcd/m^2/lux, with a minimum maintained level of 100 mcd/m^2/lux for roads posted at 70 mph or greater and a minimum maintained level of 50 mcd/m^2/lux for roadways posted at less than 70 mph. Both test sites were above the minimum level at installation. The results of the retroreflective testing are in the following sections broken down by product type.

6.2.1 Tapes

The first test site was located at Sellersburg Indiana, the work zone was located on I-65 between exits 7 and 9 in Sellersburg and had the temporary orange markings installed in the place of the white edge line and lane line in April of 2022. The type of material used at this site was fluorescent orange removable tape. At installation the tapes color and retroreflectivity were found to be acceptable. After nearly 3 months of exposure to traffic and the elements, the tape faded from fluorescent orange to a peach color and saw a significant decrease in retroreflectivity.

At installation retroreflective readings averaged 960 mcd/m^2/lux, after 25 days of exposure the averaged reading reduced to 543 mcd/m^2/lux and by 2 months of exposure average readings decreased to 382 mcd/m^2/lux a reduction of 578 mcd/m^2/lux from the initial reading at installation. A graph of the decay rate can be seen in Figure 6.5. It was also determined that due to the bead package used on the tape, the markings appeared white at night. As can be seen from the graph the tape evaluated can be used for short term projects and still maintain the minimum INDOT retroreflectivity value of 100 mcd/m^2/lux for roads posted at 70 mph or 50 mcd/m^2/lux for roads posted at less than 70 mph. Based on the finding of the retroreflectivity testing the recommendation would be to limit the use of tapes to projects that will be completed in less than 99 days. The tested tape was also found to wear quickly with exposed to crossover traffic in an area with curvature further decreasing retroreflectivity. One location with heavy trucks exposure into the construction site found levels to be as low as 194 mcd/m^2/lux in a short section used to access the work zone. Figure 6.6 provides an example of fading with the single strip having 2 months of exposure and the double strip having 2 weeks. A visible difference in color is apparent. The Sellersburg marking

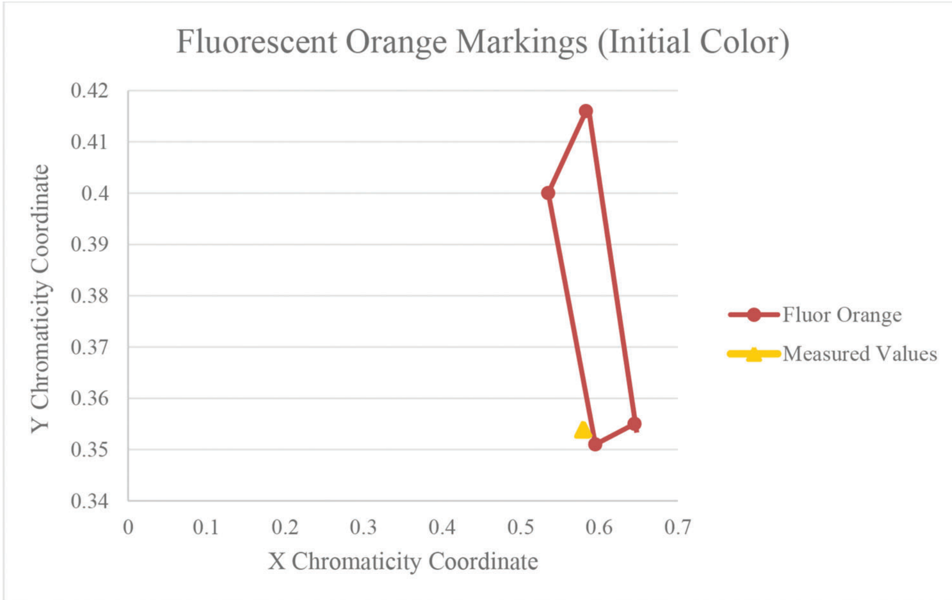

Figure 6.2 Sellersburg color test.

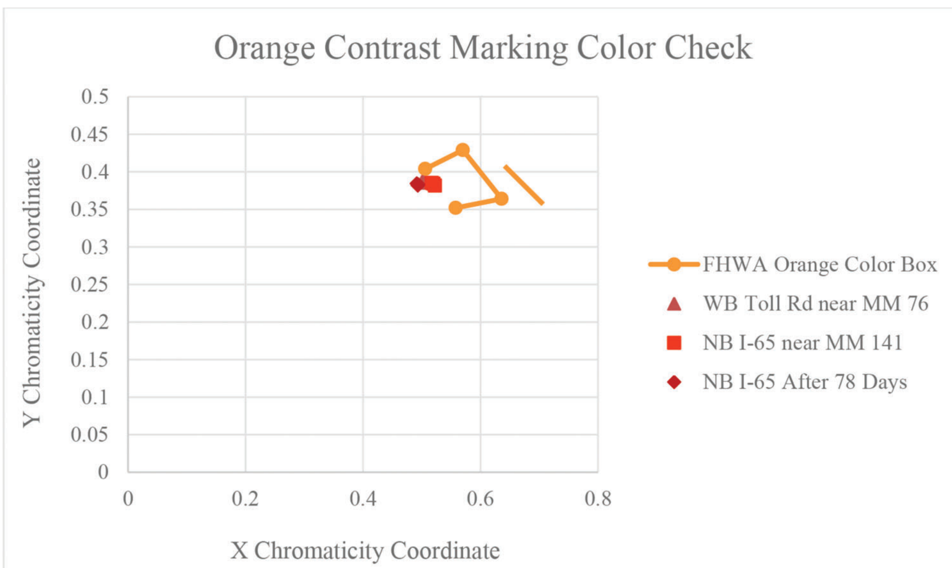

Figure 6.3 Lebanon color test.

consisted of a solid orange strip for the center and right edge line, with a yellow left edge line. Figure 6.7 provides a visualization of the marking configuration used at the Sellersburg site.

6.2.2 Paints and Bead Packages

After the durability concerns with the orange tape product and after visiting the Indiana Toll Road to inspect a paint product being used, the next test site on INDOT roadways decided to evaluate a paint product with an improved bead package. An orange paint paired with an orange bead package was selected to the Lebanon site. Complementary orange contrast markings were installed on August 9th on a northbound section of I-65 near mile marker 141.4 in Lebanon, Indiana in August of 2022. The bead package used was Orange Visimax beads from Potters Industries, which provide orange color at night, an improvement from the Sellersburg location and the orange traffic paint was from PPG. Orange markings were used as a conspicuity enhancement to delineate the gore area near the exit to US 52. Retroreflectivity levels were measures at installation and at two other points during the project duration. The retroreflective levels of the paint were found to be much lower than the tape product, with the initial reading average of 249 mcd/m^2/lux. At 21 days the

Figure 6.4 Retro-reflectometer.

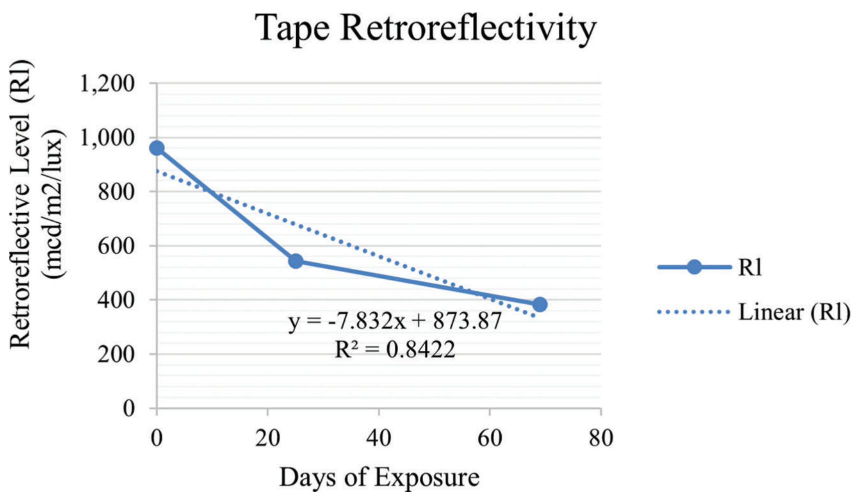

Figure 6.5 Tape decay rates.

Figure 6.6 Tape fading.

level slightly dropped to 241 mcd/m^2/lux, and at 77 days the level had decayed to 98 mcd/m^2/lux. The estimated number of day to reach the minimum of 50 mcd/m^2/lux for roadways posted below 70 mph was found to be 103 days. Figure 6.8 provides a graph of the decay rate with a formula and correlation coefficient. Figures 6.9 and 6.10 provide a visualization of the marking design used at the Lebanon site.

6.3 Safety Benefits

6.3.1 Speed Effect

The speed effect was tested at the Lebanon site where the northbound lanes had orange complementary marking and the southbound lanes had a white center and right edge line with a yellow left edge line.

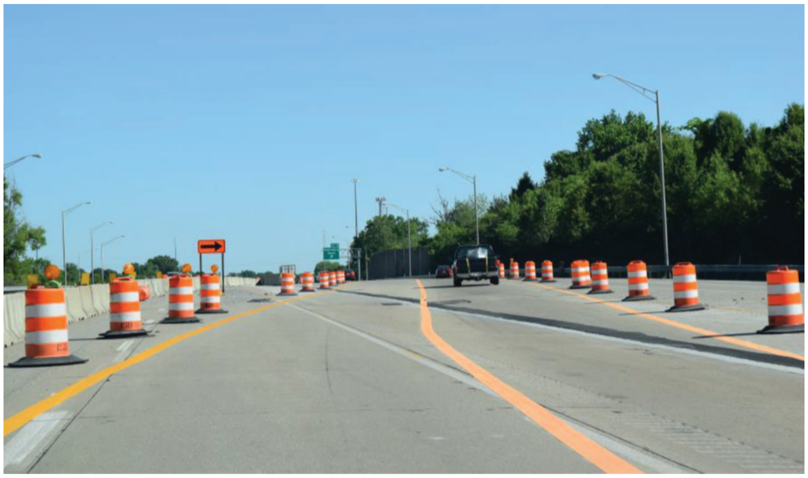

Figure 6.7 Sellersburg marking configuration.

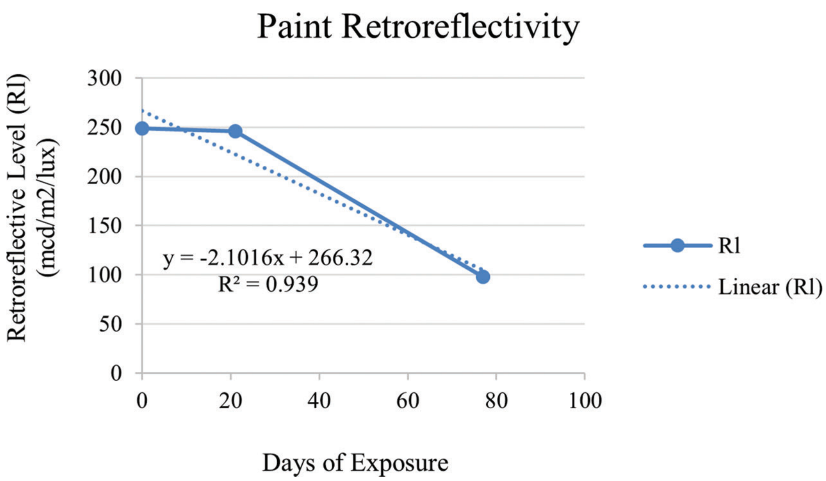

Figure 6.8 Orange paint decay rate.

Figure 6.9 Complementary orange marking.

Figure 6.10 Lead/lag and complementary orange marking.

To examine the speed effect of orange marking a random sample of 200 speeds were collected with a handheld radar gun between the hours of 4 pm and 6 pm on a weekday. The work zone was posted at 55 mph, average speeds were found to be 63 mph for the southbound lanes with typical markings and 59 mph for the northbound lanes, with orange markings. Results suggest a 4-mph reduction in work zones with the use of orange marking. A table of the collected speeds can be found in Appendix D.

6.3.2 Lane Positioning

Vehicle lane positioning within the lane were also evaluated using an observational approach. Video recordings were collected during the pm peak hours at each orange marking test site, and a comparable section for reference. The purpose was to determine if drivers in orange pavement marking sections behaved differently than drivers in typically striped sections with white and yellow markings. Drivers were placed into three groups—left, center, and right within each lane. Three researchers independently reviewed each video and placed each vehicle in the appropriate group (left, center, right). An average between the researchers was taken to ensure correct classification, Table 6.1 depicts a summary of the results. The results of the base section with similar design characteristics can also be found in the table to provide a better understanding of typical lane positioning. The left lane on the Sellersburg and Lebanon sections had no shoulder, with a concrete barrier approximately 2 feet from the edge line. At the Sellersburg site over half the drivers kept to the center of the left lane with 27% keeping left and 22% staying to the right. At Lebanon 41% of drivers kept to the center of the left lane with 27% left and 32% right. At a base section 74% of drivers kept to the left of the left lane, with only 24% centering in the lane and 2% keeping to the right.

Drivers in the right lane at Sellersburg had similar behaviors with 49% centering in the lane, 32% to the left and 19% to the right. At Lebanon drivers in the right lane tended to keep left shying away from the barrels that protected the exit barrier. The base section had similar results to the Sellersburg segment with 59% keeping to the center of the lane, 23% left, and 18% keeping right.

The exit lane at Lebanon was also evaluated it was found that 70% of the drivers kept as far right as possible away from the barrier, with only 25% centered in the lane and 5% keeping left.

From the results of left lane positioning, it appears that drivers in orange marking sections may tend to be centered in their lanes more frequently than drivers on typical striped sections of roadways. Barrier placement near the lane may also have an impact on driver's lane position choice. The right lane positioning maybe influenced by exits near or within the area of study, causing drivers to keep left of the barriers in the gore area, which is evident in at the Lebanon site. Overall drivers were keeping away from roadside fixed objects when possible and staying centers in sections with continuous traffic barrier.

6.3.3 Lane Choice

Driver lane choice was evaluated with vehicles placed in one of four groups—left lane, right lane, straddlers (vehicles taking up part of both lanes), and lane changers. Both Sellersburg and Lebanon sites were evaluated using video recordings during the peak pm hours using an observational method. Table 6.2 displays the results, left lane volumes were slightly higher than the right lane at both locations, it is believed that this is due to familiar drivers avoiding the right lane due to vehicles slowing to exit within the study area. No straddlers were observed indicated drivers had a good understanding of lane markings and could make a definite lane choice within the work zone. A small percentage of drivers changed lanes in the work zone, it is believed this to be an effect of heavy traffic volumes in the pm peak.

6.3.4 Crash Reductions

The safety benefit evaluation of the orange pavement markings again followed the HSM quantitative approach using prediction models to estimate the number of expected crashes and compared to the observed crashes to determine the safety benefits in terms of a CMF. The same equations presented in section five were used to quantify the safety benefit of the orange pavement markings.

It is important to note that the approach taken is typically used for larger data sets. Limitations in the study approach for orange markings include short duration of construction projects, limited crash data for analysis, short segment length and limited locations for use in the analysis. The approach used was to compare the northbound (orange marking) versus the south-bound (white and yellow stripping) at Sellersburg and

TABLE 6.2
Lane Choice

Sellersburg Lane Volume (%)		**Lebanon Lane Volume (%)**	
Left	55.51	Left	64.38
Right	44.46	Right	35.40
Straddlers	0.00	Straddlers	0.00
Lane Changers	0.03	Lane Changers	0.23

TABLE 6.1
Lane Positioning at Test Sites

	Left Lane of Highway			**Right Lane of Highway**			**Exit Lane of Highway**		
	Left (%)	**Center (%)**	**Right (%)**	**Left (%)**	**Center (%)**	**Right (%)**	**Left (%)**	**Center (%)**	**Right (%)**
Sellersburg	27	51	22	33	49	19	–	–	–
Lebanon	27	41	32	62	32	6	5	25	70
Base Section	74	24	2	23	59	18	–	–	–

TABLE 6.3
Development of CMFs Orange Marking

Site	Condition	AADT	Length	CMF	CMF Average
Sellersburg	Orange White/Yellow	64464	0.75	0.21	0.26
Lebanon	Before After	56267	0.5	0.30	

TABLE 6.4
Survey Results

Questions	Responses			
What was the weather condition when you drove through the work zone?	Clear 87.50%	Cloudy 10.00%	Raining 0.00%	Foggy 2.50%
Questions	**Responses**			
What time of day did you drive through the work zone?	Daytime 85.37%	Nighttime 4.88%	Dawn 9.76%	Dusk 0.00%

Questions	Responses	
	Yes	No
Did you notice the orange pavement markings in the work zone?	87.80%	12.20%
Did the orange markings make you more aware of the work zone?	80.49%	19.51%
Do you feel orange markings are more visible than white parkings?	81.40%	18.60%
Do you feel orange markings are more visible than yellow parkings?	82.22%	17.78%

comparing before and after period at the Lebanon site. Results provide some insight into the possible effects of orange pavement markings related to roadway departure crashes; however, it should be noted that with few sites in the analysis the results of further studies may vary. Table 6.3 provides the site-specific details and the results of the CMF development for the orange pavement marking test sites, with the average CMF estimated to be 0.26, indicating a 74% reduction in lane departure crashes when orange pavement markings are used in a work zone.

6.4 Survey of Roadway Users

To gain an understanding of public acceptance of the experimental orange pavement marking use in work-zone within Indiana a survey was conducted. Indiana road users were given the chance to complete a web-based survey that was made available at the rest area north of the Lebanon work zone, 70 participants volunteered to complete the survey during survey period.

Results indicate Indiana road users are accepting orange pavement markings in work zones. Road users were more aware of work zones with 88% indicating they noticed the orange marking and 80% indicating they were more aware they were traveling through a work zone. Roadway users also indicated that orange marking are more visible than the white (81%) or yellow (82%). A summary of the results can be seen in Table 6.4. Survey questions, the survey flyer, and the internal review board (IRB) approval can be found in Appendix E.

6.5 Lane Departure Systems Testing

Lane departure technology is becoming standard on many vehicles, which has the potential to significantly reduce roadway departure crashes with the continued expansion of this technology. This study also evaluated the detection rates of lane departure warning/lane keeping systems currently available on vehicles due to concerns about orange marking detection. The method used was to test a sample of available vehicles with lane departure warning/lane keeping systems on high-speed roadways (common interstate or freeways). The systems were individually evaluated for their ability to detect marking categories consisting of different colors and levels of visibility, dependent on wear.

TABLE 6.5
Detection Rates of Marking Colors

Marking	Detection Rate (%)	Response
Yellow Solid	100	Detection at or before line
White Solid	100	Detection at or before line
White Dashed	100	Delayed detection caused by wear to marking
Orange Solid	100	Detection at or before line
Orange Dashed	100	Detection at or before line
Ghost Marking	0	No detection even when grooving had remnants of marking

Each vehicle was tested on sections of the roadway at speeds between 55 mph and 70 mph. The approach taken was to test each marking color and type a minimum of 50 times, observing the response of the lane departure warning/lane keeping systems. All markings tested were found to have a 100% detection for solid lines on pavement edges. Dashed white lines were observed to have a lower detection time caused by wear of marking on certain sections, the delayed response allowed the vehicle to cross the dashed line by 6 to 12 inches before an alert was issued on the worn sections. However, detection rates were still at 100% when dashed lines were in good condition or greater than 20%. Experimental orange marking present in work zones were evaluated as part of this project due to address concerns of experimental marking detection. Orange markings have limited use in the United States, no previous studies were found that evaluated lane departure warning/lane keeping systems ability to detect markings.

Observations found that orange marking detection rates were equivalent to other colors at 100% for both solid and dashed orange markings. One marking type that has caused some concern and is commonly located in work zones is the ghost marking. Ghost marking is a condition where a marking has been removed by grinding, leaving a partially painted marking, or causing a markings like presence stemming from the difference in pavement color between the freshly ground and the exposed pavement surrounding it. Ghost markings were also evaluated in several work zones using each test vehicle. No ghost marking were detected by any system used during the study. It is important to note that the location of the ghost marking was predominantly center of lane or diagonally crossing the lane of travel and it is possible that ghost markings closely paralleling work zone striping may have a varying effect. Table 6.5 depicts a summary of the detection rates and responses of the sample of vehicles tested.

6.6 Discussion of Results

The evaluation of orange pavement markings in work zones provided new knowledge that can be used to further the national level experiment on orange pavement markings being coordinated by the FHWA. The study identified retro reflectivity decay rates on the tested products and the preferred bead package for optimal nighttime visibility. Safety benefits were also identified in the study including speed effect, lane positioning, lane choice and crash reduction impacts in the form of a CMF. Public opinion was obtained through a web-based survey and found Indiana roadway users are accepting orange markings in work zones. Detection of orange pavement markings were found to have similar detection rates as other lane markings. The results provide insight into the ongoing national level research.

7. SUMMARY AND CONCLUSION

This study evaluated contrast pavement markings on concrete sections and experimental orange markings in work zones. The overall goal was to establish the safety benefits of each pavement marking type.

The contrast markings were evaluated on two concrete sections of interstate in the Indianapolis area, I-65 south of the I-465 interchange and I-70 near the Indianapolis International Airport. Findings suggest that a reduction in lane departure crashes can be expected with the use of contrasted markings on concrete sections of roadway. A similar result was found to that of the nationally developed CMF.

Orange markings in work zones was evaluated at two locations on INDOT controlled roadways. Multiple aspects of orange pavement markings were investigated including service life, color fastness, retroreflectivity, speed effects, lane keeping, safety benefits, public opinion, and detection by autonomous vehicles. The color at installation was found to me at or near the recommended color spectrum level for orange markings. The decay rates of tested products were identified related to retroreflectivity, with recommended limits on days of use established. A reduction in speed was found when compared to base section of 4 mph, suggesting improved driver compliance to work zone speed limits. Lane keeping was also investigated to establish if an effect of lane centering or lane choice could be found with orange pavement marking use. It was observed that drivers in straight sections of roadway with orange markings kept to the center of their lanes more than drivers in sections with white markings. The effect could result in fewer lane departure crashes. Public opinion was found to be very high related to using orange markings in work zones. Overall, more than

88% of participating road users approved of the use of orange pavement markings on Indiana roadways, providing key feedback to future expanded use in Indiana and other states. Autonomous vehicle systems were evaluated due to the concern of detection with experimental pavement markings. Overall detection of orange markings were found to be equal to existing pavement markings approved for use on roadways. Ghost markings, another marking of concern were also evaluated and found to not be detected by the sample of vehicles tested.

Overall, the project results provide new information related to contrast and orange pavement markings which can be used in the safer design of roadways in Indiana.

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APPENDICES

Appendix A. Contrast Pavement Marking Locations and Crash History

Appendix B. Orange Marking Locations

Appendix C. Marking Color

Appendix D. Speed Data

Appendix E. IRB Approval for Deploying Online Survey to Roadway Users

APPENDIX A. CONTRAST PAVEMENT MARKING LOCATIONS AND CRASH HISTORY

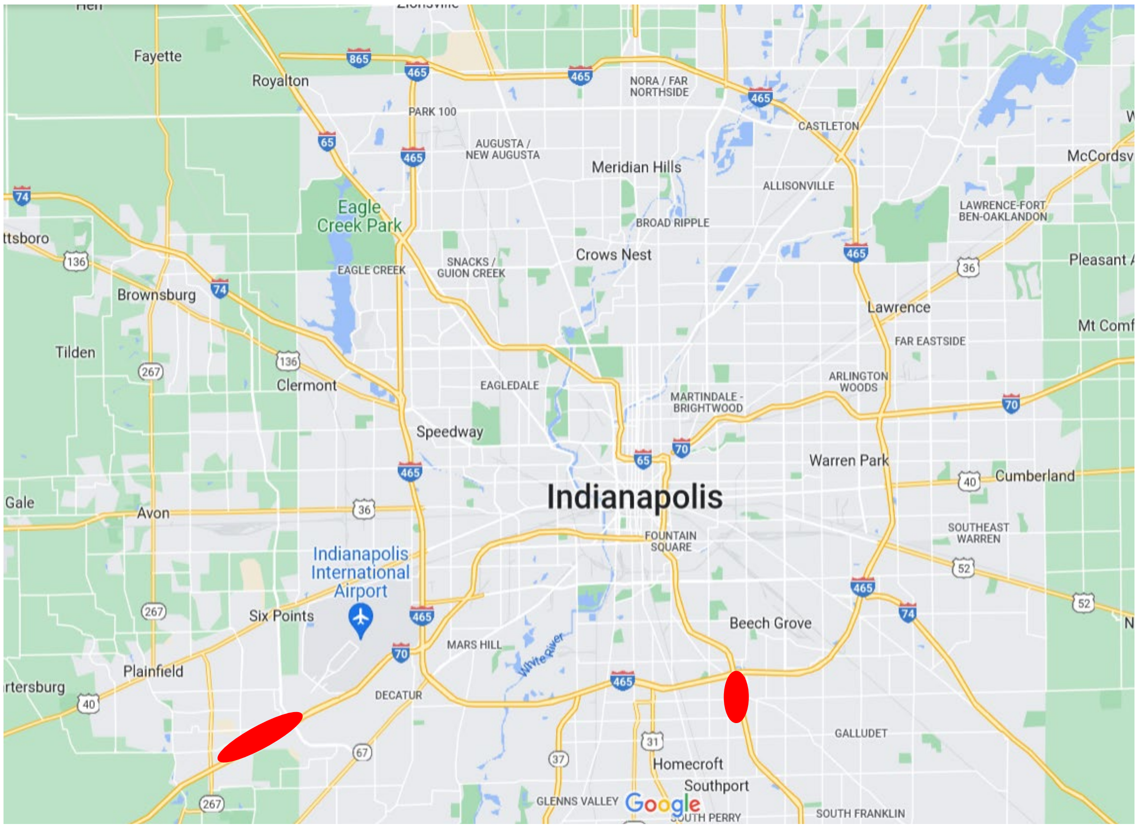
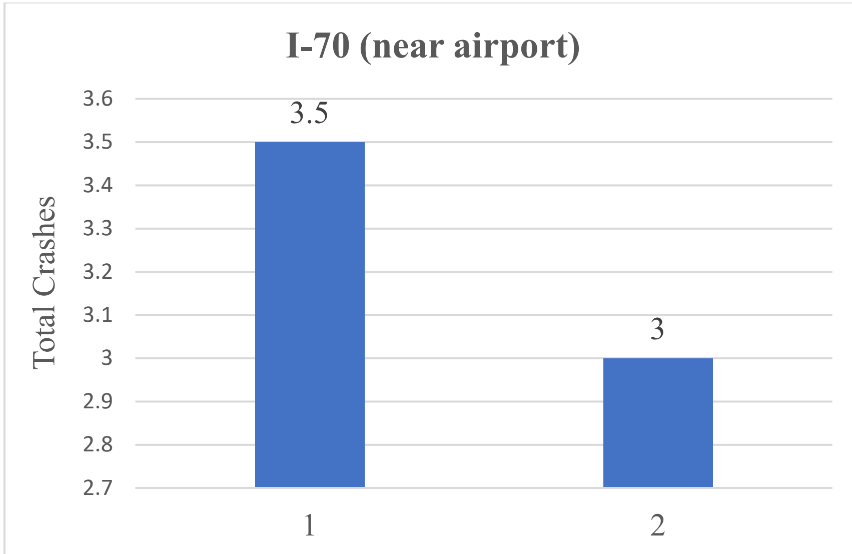
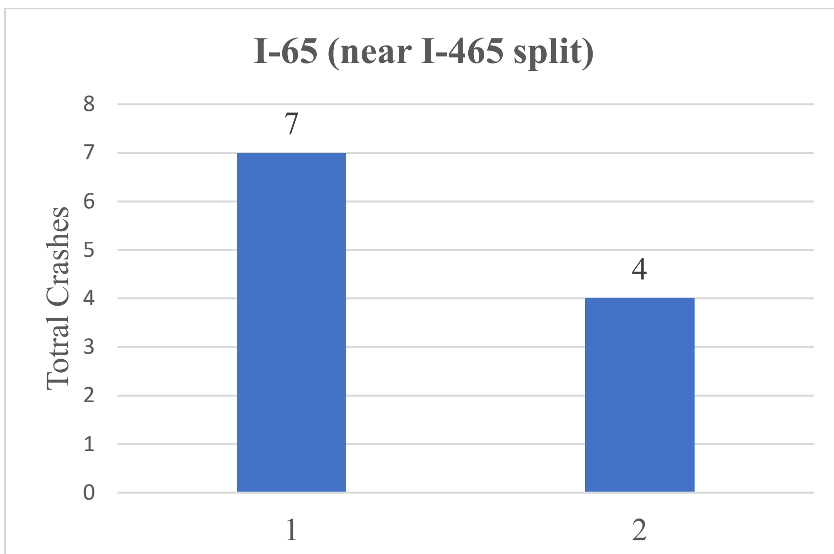


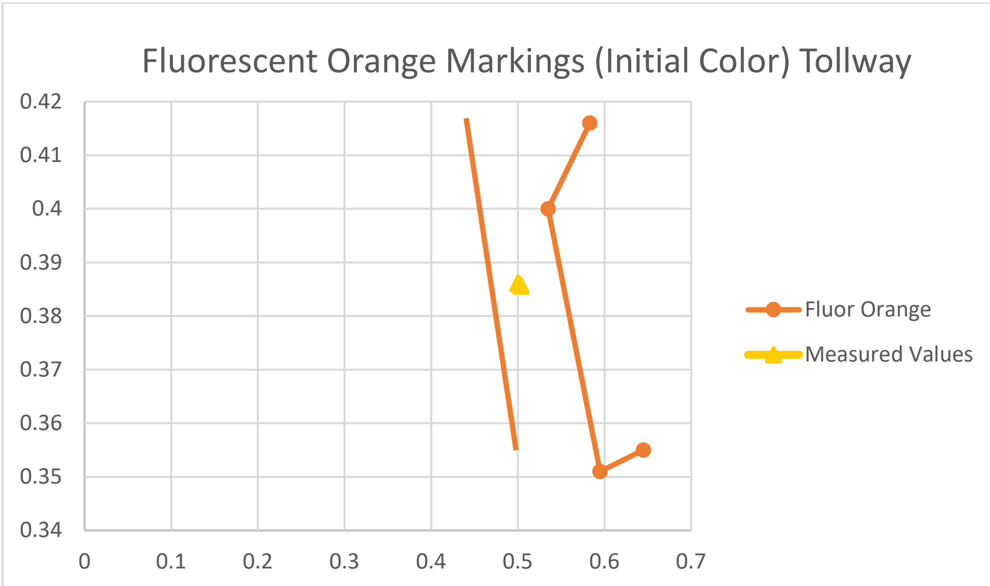
Figure A.1 I-65 and I-465 interchange.


I-70 (near airport)
Total Crashes
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
3.5
3
1
2


I-65 (near I-465 split)
Totral Crashes
8
7
6
5
4
3
2
1
0
7
4
1
2

APPENDIX B. ORANGE MARKING LOCATIONS

APPENDIX C. MARKING COLOR



APPENDIX D. SPEED DATA

Sample	Control	Orange Strip
1	55	55
2	64	61
3	55	62
4	68	56
5	63	57
6	64	65
7	63	60
8	70	64
9	55	63
10	61	52
11	66	60
12	58	54
13	69	50
14	69	53
15	66	54
16	69	63
17	56	64
18	56	55
19	63	50
20	56	58
21	70	57
22	70	54
23	61	55
24	65	66
25	66	57
26	65	67
27	70	54
28	63	65
29	55	59
30	66	57
31	62	57
32	67	62
33	57	55
34	63	57
35	70	58
36	67	58
37	60	67
38	59	54
39	56	56

40	59	64
41	57	51
42	66	60
43	58	51
44	67	63
45	59	52
46	60	66
47	64	59
48	56	62
49	68	67
50	69	66
51	61	55
52	56	54
53	60	64
54	65	63
55	65	59
56	66	63
57	58	61
58	59	64
59	56	66
60	66	56
61	64	53
62	67	51
63	57	52
64	60	56
65	64	66
66	63	57
67	66	68
68	59	53
69	64	60
70	67	58
71	60	61
72	58	53
73	67	62
74	69	60
75	55	64
76	70	57
77	56	54
78	58	62
79	57	54
80	65	58
81	68	56

82	58	55
83	69	66
84	62	68
85	65	60
86	60	56
87	64	68
88	66	67
89	66	62
90	63	54
91	70	64
92	63	66
93	65	62
94	56	60
95	58	52
96	68	67
97	66	68
98	68	50
99	69	54
100	56	60
101	67	52
102	59	62
103	69	57
104	66	59
105	55	55
106	65	62
107	60	68
108	64	62
109	67	53
110	65	54
111	70	57
112	65	65
113	65	66
114	61	64
115	67	60
116	59	56
117	57	63
118	60	62
119	59	50
120	67	56
121	65	63
122	56	54
123	68	65

124	67	54
125	68	53
126	63	55
127	61	55
128	67	68
129	66	67
130	62	51
131	56	59
132	62	58
133	56	62
134	70	64
135	61	52
136	65	64
137	64	56
138	62	53
139	56	63
140	58	56
141	68	53
142	69	51
143	57	53
144	66	60
145	70	52
146	59	54
147	66	68
148	59	66
149	66	59
150	70	65
151	64	60
152	63	62
153	65	65
154	64	56
155	59	58
156	59	68
157	58	67
158	69	50
159	55	59
160	60	58
161	65	68
162	61	59
163	57	64
164	64	59
165	66	54

166	61	65
167	60	51
168	63	51
169	62	55
170	63	51
171	68	62
172	63	62
173	68	67
174	60	50
175	69	59
176	56	53
177	59	59
178	66	66
179	62	56
180	60	53
181	63	67
182	55	51
183	69	62
184	57	52
185	58	58
186	60	55
187	65	60
188	59	58
189	61	59
190	57	56
191	58	65
192	61	64
193	64	62
194	66	55
195	62	51
196	70	61
197	58	50
198	64	61
199	59	51
200	60	60
Average	62.72	58.86

APPENDIX E. IRB APPROVAL FOR DEPLOYING ONLINE SURVEY TO ROADWAY USERS

Indiana State University
More. From day one.

Institutional Review Board

Terre Haute, Indiana 47809
812-237-3088
Fax 812-237-3092

DATE:	November 6, 2022
TO:	Michael Williamson
FROM:	Indiana State University Institutional Review Board
STUDY TITLE:	[1973596-2] Survey of Drivers
SUBMISSION TYPE:	Amendment/Modification
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	November 6, 2022
REVIEW CATEGORY:	Exemption category #2

Thank you for your submission of Amendment/Modification materials for this research study. The Indiana State University Institutional Review Board has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations (45 CFR 46). You do not need to submit continuation requests or a completion report. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exempt categories, you will have to reapply to the IRB for review of your modified study.

Internet Research: If you are using an internet platform to collect data on human subjects, although your study is exempt from IRB review, ISU has specific policies about internet research that you should follow to the best of your ability and capability. Please review Section L. on Internet Research in the IRB Policy Manual.

Informed Consent: All ISU faculty, staff, and students conducting human subjects research within the "exempt" category are still ethically bound to follow the basic ethical principles of the Belmont Report: 1) respect for persons; 2) beneficence; and 3) justice. These three principles are best reflected in the practice of obtaining informed consent.

If you have any questions, please contact Ryan Donlan within IRBNet by clicking on the study title on the "My Projects" screen and the "Send Project Mail" button on the left side of the "New Project Message" screen. I wish you well in completing your study.

Default Question Block

You are being invited to participate in a research study. This study aims to find out public opinion on orange striping in work zones. The way you can help me answer the question is by answering the questions in this anonymous survey, which should take you about two minutes.

Some reasons you might want to participate in this research are provide valuable information to engineers for safer design of work zones. Some reasons you might not want to participate in this research are very slight risk of a breach of confidentiality.

The choice to participate or not is yours; participation is entirely voluntary. You also can choose to answer or not answer any question you like, and to exit the survey if you wish to stop participating. No one will know whether you participated or not. Participants cannot withdraw from the study once submitting their electronic survey.

You can choose not to respond to any of the questions or close the browser to discontinue your participation at any time. You must be 18 years of age or older to participate.

The survey asks questions about related to work zone striping. You have been asked to participate in this research because recently drove through a work zone.

Although every effort will be made to protect your answers, complete anonymity cannot be guaranteed over the Internet. Other potential risks of the study include a breach of confidentiality, where your data maybe accessed by an unauthorized outside.

It is unlikely that you will benefit directly by participating in this study, but the research results may benefit the broader society by providing safer work zones in Indiana.

If you have any questions, please contact Dr. Michael Williamson, 812-237-8416, michael.williamson@indstate.edu.

If you have any questions about your rights as a research subject or if you feel you have been placed at risk, you may contact the Indiana State University Institutional Review Board (IRB) by mail at Indiana State University, Office of Sponsored Programs, Terre Haute, IN 47809, by phone at (812) 237-3088 or by email at irb@indstate.edu.

By clicking "Yes" below you are offering consent to participate in this research.

Yes

No

What was the weather condition when you drove through the work zone?

Clear

Cloudy

Raining

Foggy

What time of day did you drive through the work zone?

Daytime

Nightime

Dawn

Dusk

Did you notice the orange pavement markings in the work zone?

Yes

No

Did the orange markings make you more aware of the work zone?

Yes

No

Do you feel orange markings are more visible than white markings?

Yes

No

Do you feel that orange markings are more visible than yellow markings?

Yes

No

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

Further information about JTRP and its current research program is available at http://www.purdue.edu/jtrp.

About This Report

An open access version of this publication is available online. See the URL in the citation below.

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