



Effects of longitudinal pavement edgeline condition on driver lane deviation

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ABSTRACT

Single vehicle crashes, particularly those classified as run-off-the-road, are very common on two-lane rural highways. One method to potentially reduce such crashes is to provide additional driver information in the form of wider longitudinal edgeline pavement markings. However, since these markings deteriorate over time, the primary objective of this research was to study the effects of longitudinal edgeline pavement markings with varying deterioration levels and widths and to assess a driver's ability to maintain lane position. The University of Idaho's driving simulator was used to examine these effects by incorporating different marking deterioration percentages and roadway geometries on a two-lane rural highway environment. Two different pavement marking widths (4 and 6 inch) and four different deterioration levels (0%, 25%, 50%, and 75%) were assessed in daytime and nighttime conditions as part of this study. The results determined that while wider 6-in longitudinal edgeline pavement markings compared with standard four inch edgeline markings did not cause any significant changes in driver lane deviation during the day, statistically significant differences were observed in nighttime driving conditions. Drivers consistently maintained a lane position that slightly favored the edgeline side throughout the study and increasingly shifted away from the centerline as edgeline deterioration worsened.

1. Introduction

The inability of the driver to maintain appropriate lane position represents one of the largest causes of single vehicle crashes with drivers failing to maintain lane position contributing to 22% of all single vehicle crashes in the State of Idaho (Idaho Transportation Department (ITD, 2016). If additional driver cues in the form of wider longitudinal edgeline pavement markings can help drivers to maintain lane position and thereby reduce the likelihood of single vehicle crashes then a change to current operational practices would deserve consideration.

For this study, two different edgeline widths (4 and 6 inch) were implemented in a roadway simulation track environment to determine how these width variations impacted driver performance. In addition, it was recognized that these markings deteriorate over time due to weather, vehicle tire tracking, and snow removal operations. For these reasons, different edgeline deterioration percentages (0%, 25%, 50%, and 75%) were also applied to each width and evaluated under different types of roadway geometry (straight and curved horizontal segments).

1.1. Literature review

Many studies have been carried out to investigate the safety impacts of using wider pavement markings on crashes, vehicle lane position, operating speed, and driver behavior, but none have focused on explaining the effect of edgeline pavement marking width and deterioration on vehicle lateral position. Previous research efforts associated with the key elements of this study are broadly described in the following topic areas: pavement marking application, safety impacts and evaluation of wider edgelines, and marking retro-reflectivity (visibility) and service life (durability).

1.1.1. Industry practices

Wider edgeline markings are very common in the Eastern United States and twenty-two of the twenty-six states located east of the Mississippi River currently use wider markings; west of the Mississippi River only seven of the twenty-four states use them (Gates et al., 2002). Based on survey data collected from different state agencies, the main reason for implementing wider markings was visibility improvement (identified by 57% of respondents) followed by as a countermeasure for older drivers (19%) and crash reduction (14%) (Gates et al., 2002).

Based on the documented safety effects of wider edgelines on rural

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two-lane highways, individual states such as Michigan and Kansas increased their edgeline width from four to six inches while Illinois increased from four to five inches. Each state performed different statistical analyses based on obtained crash data (before and after implementing wider edgelines). These states concluded that wider edgelines reduced vehicle crashes with the highest crash reduction percentage in the fatal plus injury category (Kansas: 36.5%, Michigan: 15.4%, and Illinois: 37.7%) (Park et al., 2012).

1.1.2. Benefit/Cost

Crash data have been used to analyze the costs associated with fatal and injury crashes, and the benefits from the wider edgelines were quantified while taking into account the assumed service life of standard edgeline and installation costs. Specific crash benefits were obtained by calculating the difference between estimated and observed crashes and then multiplying this result by a fatality and injury cost value. In one example, the installation cost of a four inch waterborne edgeline width was \$0.10 per foot, while the installation cost of a six inch waterborne edgeline width was \$0.15 per foot, resulting in a cost difference of \$528 per mile. However, the results showed that there was a noticeable benefit to cost ratio improvement for fatal crashes; for every \$1 invested in the installation of a six inch edgeline an estimated benefit of \$55.20 in crash costs was realized (Carlson and Wagner, 2012).

1.1.3. Marking retro-reflectivity

Retro-reflectivity of edgelines are related to their service life. As the deterioration of the edgeline increases, retro-reflectivity decreases, indicating that the marking needs to be refurbished or replaced (Lee and Oh, 2005).

There are many factors that affect the deterioration of an edgeline's retro-reflectivity including: climate or environment, plowing and snow removal (in select states), vehicle loading, edgeline material type, and edgeline placement. All of these factors affect how often the edgelines should be maintained in order to provide appropriate roadway visibility. The Michigan DOT restripes 85% of their roadways on a yearly basis due to snow plowing activities that occur during a large portion of the year (Avelar and Carlson, 2014). A comparative test between glass bead and pavement marker materials in nineteen states showed that the service life for a two-lane rural highway edgeline with driver speeds of forty-five miles per hour (mph) or greater is in the range of three to five years (Migletz et al., 2001), with epoxy material (five years) lasting longer than typical profiled thermoplastic (three years).

1.1.4. Lateral position effects

Several studies have focused on explaining the effect of edgeline pavement markings on vehicle lateral position. An early behavioral study studied the impact of 4 inch edgelines on driver behavior and found that vehicle operators tended to shift toward the roadway centerline when no interference between vehicles was assumed (Sun and Tekell, 2005). The tendency and change in magnitude of a motorist to move toward or away from an edgeline pavement marking depended on many factors such as lane width, operating speed, time of day, frequency of heavy vehicles, the condition of the pavement, roadway alignment (curvature), edge drop-off, and traffic volume of the opposite direction (Tsyganov et al., 2005). During normal operations, drivers often employed a curve-flattening strategy to overcome centrifugal force. For this reason, drivers tended to be closer to the centerline of the road while driving through left-hand curves and closer to the edgeline when driving through right-hand curves (Chrysler et al., 2009).

1.1.5. Other impacts

Wider edgelines helped drivers under sober and alcohol-impaired conditions to better identify the roadway delineation on two-lane rural highways. One such study examined the lateral lane position in order to analyze driver performance and the results showed that an eight inch

wide edgeline was found to provide benefits when compared with a standard width (4 inch), while no reduction in variability occurred with the 6 inch edgeline (Hamerslag et al., 1981).

A separate study was conducted to determine if the use of edgelines and wider edgelines benefitted drivers under normal and impaired conditions. As part of the participants' driving tasks they encountered curves, obstacles, and road signs. The roadway simulation session was composed of different edgelines widths (none, 4 inch, and 8 inch), spot treatments, and curves. An analysis of variance (ANOVA) was conducted showing that under sober conditions the wider edgelines (8 inch) were associated with greater lateral lane position error than the standard edgeline (4 inch); however, neither edgeline was significantly different from the no edgeline condition. Participants with a high BAC level (0.12%) had greater lateral lane position error when there were no edgelines, with the error decreasing as the edgelines widened (Ranney and Gawron, 1986).

Although this research study did not examine the effects of driver sobriety, the results and methodology from these other studies served as helpful references when designing this particular study and assessing specific results.

2. Methodology

2.1. Background

A sample of forty-eight licensed participants were tested in a driver simulation environment that replicated a two-lane rural highway in the State of Idaho. Each participant was required to drive for about five minutes before the actual experiment commenced to become familiar with the responsiveness of the driving simulator. This initial drive segment helped the participants become accustomed to the sensitivity of the gas pedal, brake pedal, and steering wheel to help mitigate for data anomalies due to the driver's lack of familiarity.

All participants conducted at least two sessions, driving for about 45–50 min during each session. Each participant was exposed to a 42½ mile roadway simulation track in either daytime or nighttime conditions; within the 42½ miles, 40 miles were driven at speeds close to 60 mph (posted speed limit). One extra mile was placed at the beginning of the track in order for participants to reach the desired travel speed. An extra half mile was placed halfway along the track to accommodate a participant rest period. A final extra mile was placed at the end of the track so that participants could gradually come to a stop when completing the experimental drive.

2.2. Scenario development

Every scenario was composed of multiple tiles that displayed the appropriate roadway geometries and surrounding daytime or nighttime environment. The roadway geometry was composed of a paved roadway consisting of straight and horizontal curved segments (gentle and sharp curves), edgelines, gravel shoulder, and varying edgeline widths and deterioration percentages.

According to the Highway Capacity Manual (HCM, 2010), the base conditions of a two lane highway requires lane widths greater than or equal to twelve feet, shoulder widths up to six feet, zero no-passing zones, all passenger cars in the traffic stream, level terrain, and no impediments to through traffic (HCM, 2010, 2011). Based on these conditions, each scenario for this study was composed of: twelve foot lane widths, ten foot shoulders (eight foot gravel shoulder and two foot paved shoulder), zero no-passing zones, level terrain, and no impediments to through traffic. The surrounding daytime environment was composed of trees, mountain hills, and house/building structures. Adjustments were performed on the roadway geometry, and specifically to the edgeline width and its deterioration level. According to the Manual on Uniform Traffic Control Devices (MUTCD), the nominal (standard) edgeline is four inches wide (MUTCD, 2009 Edition, 2012). For this

study, scenarios with four and six inch edgeline widths were developed based on discussions with Idaho Transportation Department staff, and any changes to the width were made on the shoulder side of the roadway. In other words, the lane width between the centerline and the travel side of the edgeline was maintained at a constant twelve feet for the duration of the study.

The 3 ds MAX Design program (by Autodesk) was used to make the edgeline width and edgeline deterioration percentage adjustments (for every single tile) for all study scenarios. The Tile Mosaic Tool (TMT) was used to join multiple tiles together to create the appropriate roadway simulation track for all scenarios. The Interactive Scenario Authoring Tool (ISAT) was used to import all scenarios and add vehicles, speed limit signs, information signs, and triggers (data collection points) to each roadway simulation track. The ISAT was created for the National Advanced Driving Simulator (NADS), which was developed by the National Highway Traffic Safety Administration (Fisher et al., 2011).

2.2.1. Simulated traffic

According to the Idaho Transportation Department (ITD), typical Annual Average Daily Traffic (AADT) values for two-lane rural highways in this state ranged from 500 to 10,000 vehicles per day (Idaho Transportation Department (ITD, 2016)). In order to obtain an appropriate AADT value for the scenarios in this study, a sampling of thirty ITD traffic survey and analysis monitoring stations were reviewed. Based on these findings, an AADT of 3200 vehicles per day was calculated and used as a representative value for all study scenarios.

To obtain the Directional Design Hourly Volume (DDHV) in the oncoming lane, the previous AADT value was used along with a K-value of 0.10 (proportion of AADT occurring in the peak hour) and a D-value of 0.5 (proportion of peak hour traffic in the peak direction). A K-value of 0.10 is recommended by the HCM, 2010 for a rural highway (HCM, 2010, 2011) while a D-value of 0.5 assumed that the traffic volume experienced in both directions consisted of the same number of vehicles in each lane per hour. A DDHV of 160 vehicles was calculated for the oncoming lane (typical two-lane rural highway traffic volume per hour on one lane) and this DDHV value was implemented for all of the scenarios in this study.

2.2.2. Vehicle, speed limit and information sign, and trigger placement

According to the HCM, 2010, the State of Idaho has a default value of 12% heavy vehicles on two-lane highway (HCM, 2010, 2011). Using this information, a set of regular vehicles (SUVs, sedans, pickups, and vans), two police vehicles, and 12% heavy vehicles (semi-trucks and dump trucks) were placed in the oncoming lane.

All of these vehicles were placed using the ISAT for all eight scenarios (described later) in order to create the appropriate roadway simulation tracks with realistic traffic volumes and these oncoming vehicles had an approach speed of 60 mph to match the posted speed limit. The experimental vehicle (subject vehicle) was placed near the start of the simulation roadway track. The subject vehicle was accompanied by a vehicle following at a distance of about 1320 feet (one quarter of a mile) and by another vehicle in front at the same distance. These distances were held constant throughout the experiment so the participant was not able to pass the vehicle in front or be passed by the vehicle behind it.

Two speed limit signs of 60 mph were present along the simulation track, with one at the beginning and another at about halfway of the roadway simulation track in all scenarios. Informational signs included curve warning signs that provided directional information about the ensuing curve.

All participants were required to complete one session for each edgeline width. There were eight logs (triggers that create epochs) for each edgeline deterioration percentage and since each width scenario was composed of four different edgeline deterioration percentages, thirty-two logs (epochs) were generated from each roadway simulation

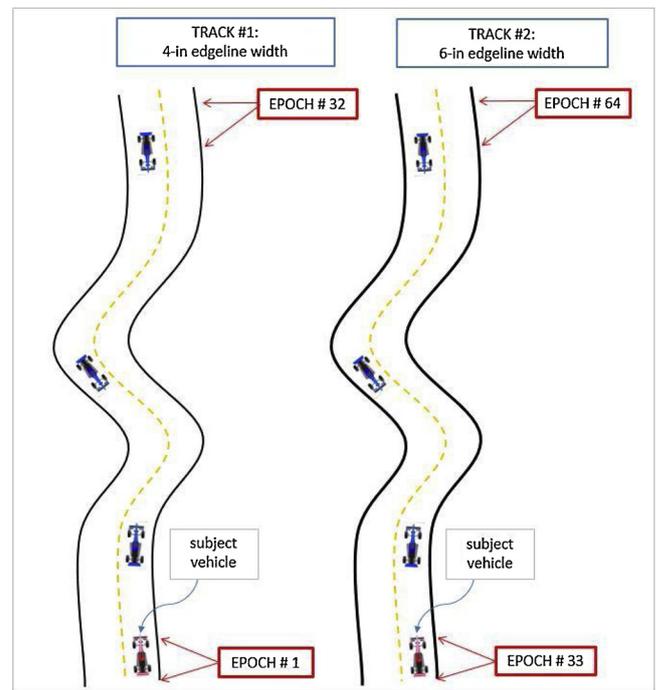


Fig. 1. Graphic description of epochs among scenario tracks.

track: four logs representing the straight segments, two logs representing the gentle curved segments (turning left and right), and two logs representing the sharp curved segments.

Fig. 1 shows a graphical representation of the number of epochs within each edgeline width scenario. Each participant drove through 64 defined triggers during their two sessions so 64 data points were collected for each of the 48 participants, resulting in a cumulative total of 3072 possible data collection points. Each of these pre-determined trigger locations were sited within the limits of each geometry type.

2.2.3. Description of scenarios created

A total of eight scenarios were created and consisted of four scenarios for each of the two edgeline widths. Each scenario had a specific edgeline deterioration percentage ordering. Fig. 2 shows the representative difference between the four and six inch edgeline widths, while Fig. 3 shows the difference between the 0%, 25%, 50%, and 75% edgeline deterioration percentages applied on the six inch edgeline width. From a simulation standpoint, the white pixels of the edgeline were increasingly replaced with an appropriate proportion of grey pixels to represent the correspondingly higher percentages of marking deterioration. The same design was applied to the four inch width but is not separately shown.

2.3. Driving simulator experiment description

The University of Idaho's driver simulator lab was used along with the NADS MiniSim program to display the simulations and to collect and record the data. A 2001 Chevrolet S10 pick-up truck cabin was used by participants to drive all of the scenarios. Forty-eight participants from the local community with unrestricted valid driver's licenses were recruited through online and bulletin board postings and participated in this research.

2.3.1. Procedure

Each participant's goal was to keep the vehicle centered in the lane and to travel at an appropriate speed, just as in everyday driving. All participants were instructed that they would be completing a 40 mile drive on a rural highway for each session and to imagine themselves

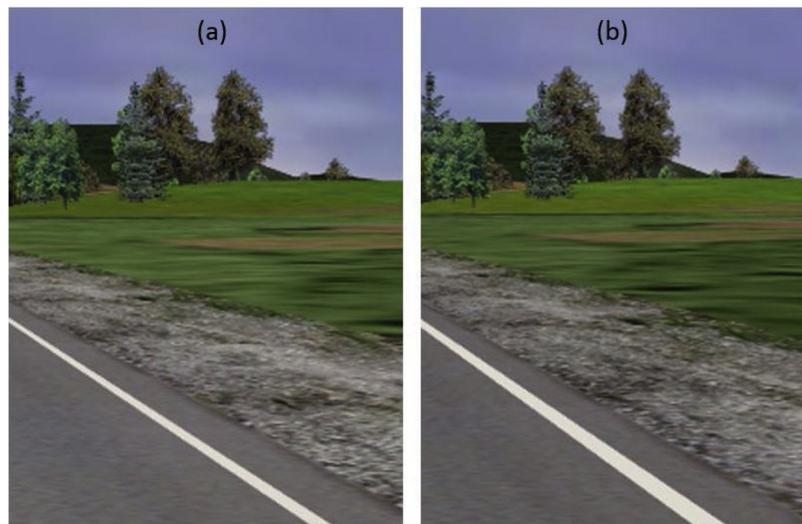


Fig. 2. Driver simulation graphic of edgeline widths: (a) 4 inch and (b) 6 inch.

returning from a weekend camping trip in rural Idaho.

2.3.2. Participants' session distribution

Every participant was assigned and completed sessions that consisted of a unique ordering of two different edgeline widths (4 and 6 inch); in other words, some participants experienced the 6 inch width during their first session and the 4 inch width in their second session while others experienced these conditions in the opposite order. Furthermore, each width was composed of four uniquely ordered edgeline deterioration percentages to minimize bias effects so some participants would have experienced a segment with a pristine edgeline (to reflect a freshly painted marking with no deterioration) while others would have experienced a faded edgeline (to simulate a marking subject to wear and tear and with noticeable deterioration).

2.4. Data collection

Before a participant began the experiment, the simulator vehicle was reset and centered on the travel lane with no lane deviation. When the vehicle moved toward the center of the roadway, a negative lane deviation value was generated. When the vehicle moved towards the edgeline, a positive lane deviation value was generated. These lane deviation values were measured in feet. Accelerator pedal position and steering wheel angle data were also collected but their results did not factor into the final lane deviation results of this study.

3. Data analysis and results

3.1. Participant information

Although forty-eight participants were initially selected for this study, preliminary analysis was only conducted using data from a reduced set of forty-four participants. This was due to the fact that some technical issues were encountered when converting the data format for three daytime participants and one nighttime participant; a fifth participant was identified as an outlier so this participant's data were manually removed from the analysis process.

Final data analysis was performed on the results from forty-three participants; there were twenty-eight male participants, and fifteen female participants. With regard to age, thirty-one participants were between eighteen and thirty years old, eight participants were between thirty-one and forty-nine years old, and four participants were between fifty and seventy years old. The youngest participant was a nineteen year old female, while the oldest participant was a sixty-nine year old male ($M = 29.5$ years, $SD = 12.8$ years). The average years of driving experience among the participants was 13.4 years ($SD = 12.7$ years).

3.2. Lane position

The lateral position of the vehicle within the travel lane depended on driver maneuvering to keep the vehicle in a stable position between

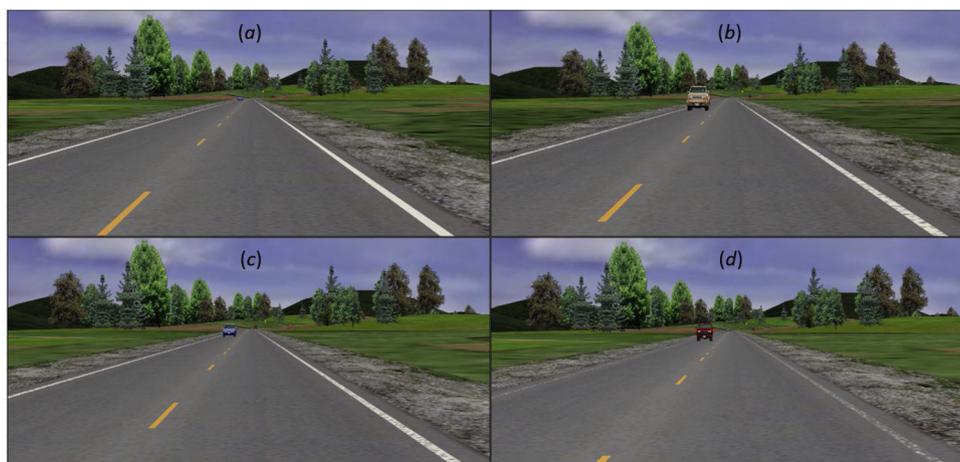


Fig. 3. Driver simulation graphic of edgeline deterioration percentages (only 6 inch shown): (a) 0%, (b) 25%, (c) 50%, and (d) 75%.

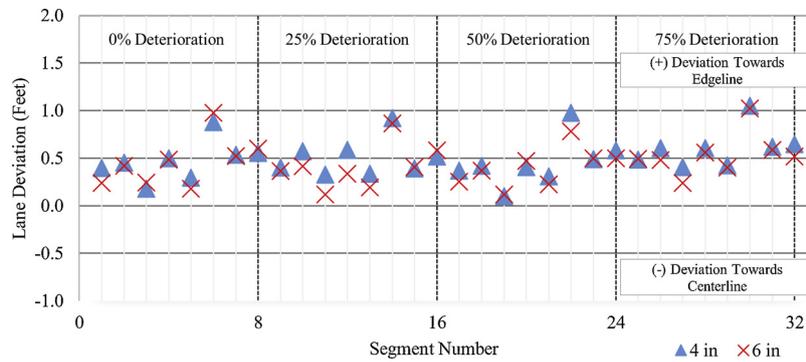


Fig. 4. Effects of pavement marking deterioration and width on driver lane deviation.

Table 1
Data collection points for specific geometry types.

Geometry Type	Data Collection Points
Straight Segments	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, and 31
Gentle Curved Segment (Turning Left)	6, 14, 22, and 30
Gentle Curved Segment (Turning Right)	4, 12, 20, and 28
Sharp Curved Segments	2, 8, 10, 16, 18, 24, 26, and 32

Table 2
Effect of edgeline width, deterioration percentage, and roadway geometry on vehicle lane deviation (all drivers).

Variable	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio	P-value $Pr(> F)$
Width (Edgeline)	1	1.29	1.287	2.7891	0.09502.
Deterioration (Edgeline)	3	10.17	3.391	7.3521	6.61e-05***
Roadway Geometry	3	97.76	32.588	70.6448	< 2.2e-16***
Width : Deterioration	3	0.74	0.246	0.5328	0.65982
Width : Roadway Geometry	3	0.53	0.175	0.3802	0.76732
Deterioration : Roadway Geometry	9	1.3	0.145	0.3134	0.97092
Width : Deterioration : Roadway Geometry	9	0.76	0.084	0.182	0.99597
Residual	2752	1269.49	0.461		

(Note: significance level, $Pr(> F)$: 0 '****' 0.001 '***' 0.01 '**' 0.05 '.' 0.1 '^' 1).

Table 3
Effect of edgeline width, deterioration percentage, and roadway geometry on vehicle lane deviation (nighttime drivers only).

Variable	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio	P-value $Pr(> F)$
Width (Edgeline)	1	2.23	2.2318	5.5232	0.0189*
Deterioration (Edgeline)	3	4.00	1.3349	3.3035	0.01961*
Roadway Geometry	3	51.25	17.0824	42.2747	< 2E-16 ***
Width : Deterioration	3	0.37	0.1244	0.3078	0.81974
Width : Roadway Geometry	3	0.04	0.0127	0.0314	0.99254
Deterioration : Roadway Geometry	9	0.45	0.0495	0.1224	0.99916
Width : Deterioration : Roadway Geometry	9	0.93	0.1033	0.2557	0.98567
Residual	1472	594.81	0.4041		

(Note: significance level, $Pr(> F)$: 0 '****' 0.001 '***' 0.01 '**' 0.05 '.' 0.1 '^' 1).

the centerline and edgeline pavement markings. In this research, the lateral position of the vehicle was analyzed based on lane deviation and measured off of the centerline of the right lane per SAE International recommended practice (SAE International, 2015).

As an example, the average participant performance based on lane deviation for the 4 and 6 inch edgeline width using the four deterioration scenarios (0%, 25%, 50%, and 75%) during nighttime conditions is plotted in Fig. 4. The y-axis represents the lane deviation of the vehicle in feet (zero refers to no lateral movement where the vehicle would be in the center of the lane), while the negative and positive values indicate the vehicle's deviation towards the centerline and edgeline, respectively. The x-axis was divided into four sections based on the pavement marking degradation percentage (0%, 25%, 50%, and 75%) and each symbol represented a different pavement marking width

(4 and 6 in.). Each section, as described earlier, consisted of eight data collection points that represented a differing roadway geometry option (see Table 1). For example, points 6, 14, 22, and 30 represented the lane deviation of each participant when traveling along the same gentler, left-hand curve segment section. Based on the visual analysis of Fig. 4, it can be concluded that all drivers tended to move toward the edgeline of the right lane at night and increasingly shifted away from the centerline as edgeline deterioration worsened; this could be a factor in run-off-the-road crashes. For all pavement marking degradation levels, a left-turn through the gentle curve segments caused the highest positive values on the lane deviation axis; in other words, drivers deviated the most toward the edgeline under this roadway geometric condition versus all of the other roadway geometry options. Similar results were observed for drivers who experienced daytime conditions.

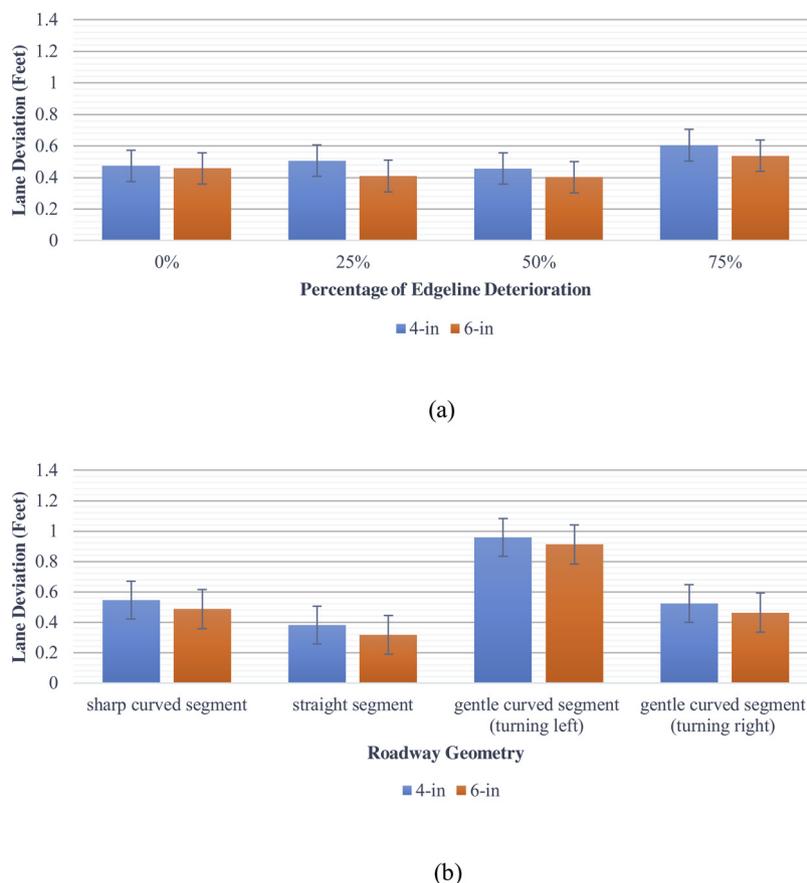


Fig. 5. Lane deviation: (a) impact of edgeline deterioration and (b) impact of different roadway geometries.

A three-way analysis of variance (ANOVA) was conducted to understand and statistically describe the effect of edgeline width, deterioration percentage, and roadway geometry on vehicle lane deviation. Table 2 summarizes the results when data from all participants were included. In addition, due to the value placed on pavement markings for drivers at night, Table 3 isolates the results for this particular segment of the driver population drivers (i.e., only those who experienced nighttime conditions). As shown in Tables 2 and 3 the three-way ANOVA revealed significant differences only with the edgeline deterioration percentage ($F(3, 2752) = 7.35, p = 6.6e-05$ and $F(3, 1472) = 3.30, p = 0.02$) and roadway geometry ($F(3, 2752) = 70.64, p < 2.2e-16$ and $F(3, 1472) = 42.27, p < 2E-16$) on lane deviation at the 0.05 significance level (type I error). This implied that the lateral position (i.e., lane deviation) of the vehicle was impacted independently by edgeline deterioration and by roadway geometry; both variables were also statistically significant when daytime drivers were isolated. However, when nighttime drivers were examined separately, marking width was added to the list of variables with statistically significant results ($F(1, 1472) = 5.52, p = 0.02$). For all cases the simultaneous interactions between edgeline width and deterioration percentage, width and roadway geometry, and edgeline width and deterioration percentages and roadway geometry did not have a significant impact on lane deviation.

Fig. 5(a) describes the cumulative impacts that edgeline deterioration percentage had on lane deviation. As the percentage of edgeline deterioration increased, lane deviation increased as well. When participants experienced 0% edgeline deterioration the corresponding lane deviation ranged from 0.46 to 0.47 feet (14.0 to 14.3 cm) while at a 75% edgeline deterioration the lane deviation increased to between 0.54 and 0.61 feet (16.5 to 18.6 cm). This higher edgeline deterioration percentage did have an impact on lane deviation and was statistically reliable. Fig. 5(b) shows a graphical representation of the impact of

edgeline widths on lane deviation at specific roadway geometries. It can be observed that when the participants drove along the gentle curved segment (turning left) they experienced a higher lane deviation of 0.91 to 0.96 feet (27.7 to 29.3 cm) as compared to the other roadway geometries that had lane deviations from 0.32 to 0.54 feet (9.8 to 16.5 cm). Since the lane deviation values were universally positive, the results from this study implied that participants moved toward the edgeline for all roadway geometry types.

3.2.1. Comparison between edgeline widths and deterioration levels based on lane deviation

One additional goal of this study was to determine if a driver would maintain similar lane position when encountering either a wider edgeline width with a higher deterioration percentage or a narrower edgeline width with less deterioration (such as a comparison between a six inch edgeline with 75% deterioration and a four inch edgeline with 50% deterioration). For this reason, an ANOVA with a single factor was conducted to compare specific edgeline widths (4 and 6 inch) at different deterioration percentages. The results obtained were based on a 95% confidence interval.

Most of the comparisons performed showed that the means between differing conditions were statistically insignificant, which indicated that they resulted in the same lane deviation, regardless of edgeline width or deterioration. The only exceptions were the comparisons between a six inch edgeline with 75% deterioration and a four inch edgeline with either 0% or 50% deterioration (p -value = 0.036 and 0.057 respectively). These cases implied that driver lane deviation behavior when encountering a six inch edgeline with 50% or less deterioration was similar to the behavior exhibited when encountering a four inch edgeline with no deterioration. However, these results also implied that drivers reacted similarly when encountering either a six inch edgeline with 75% deterioration or a four inch edgeline with 25%

deterioration, so these findings were determined to be inconclusive at this time.

4. Conclusions

The primary objective of this research was to study the effects of longitudinal edgeline pavement marking width with varying deterioration levels and to assess the driver's ability to maintain lane position. The study results determined that longitudinal edgeline pavement marking width alone does not affect lane deviation but there is a correlation between deterioration levels and increased lane deviation from the centerline across different roadway geometry types. For this study, drivers consistently maintained a lane position that slightly favored the edgeline side and increasingly shifted away from the centerline as edgeline deterioration worsened.

The study examined the relationship between driver lane deviation and varying combinations of edgeline pavement marking widths and deterioration levels, and the simulated environment encountered by all participants represented daytime and nighttime driving conditions. During real-world conditions with visible light, external factors such as signage, trees, and the presence of guardrail may impact driver behavior, though these elements were not simulated as part of this research. However, for these reasons, testing during nighttime conditions when such cues are not visible and when pavement markings are more heavily relied upon was included. This study recognizes that a logical next step would be to develop a study that replicates a high-crash, real-world segment in a simulation environment. Admittedly, real-world characteristics such as wind, sunlight, and other visual objects (i.e., a cliff or guardrail) can affect driver behavior in ways that cannot be measured in a simulation environment.

Edgeline deterioration is an expected event that occurs due to weathering, plowing, and wearing from recurrent vehicle tire loading. The results of this study have shown that there are subtle differences in driver behavior that occur at different deterioration levels and different widths. For public agencies who are responsible for the operations of these facilities, proper maintenance and upkeep of edgeline markings, regardless of width, suggests that vehicle operators, under normal driving conditions, will be most likely to maintain lane position when visibility of these markings is highest. The results for this study can be applied toward future studies that examine the expected safety performance of alternative pavement marking practices and to determine

an appropriate cost-benefit ratio for using wider pavement markings.

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