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# Evaluating the effect of vegetation and clear zone width on driver behavior using a driving simulator

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ABSTRACT

Roadside vegetation provides a myriad of environmental and psychological benefits to drivers. While research has shown that natural landscapes cause less stress and frustration to the driver among other benefits, the same vegetation may potentially increase the severity of run-off-the-road crashes. The aim of this study was to evaluate the extent to which clear zone width and roadside vegetation density influence operating speeds and lateral positioning to determine whether the roadside environment has any effect on drivers' attention to their speed. A within subject driving simulator experiment tested six combinations of clear zone widths and roadside vegetation densities. Participants' driving performance was measured throughout the virtual drive. Along tangents and curves to the left, participants slowed down and drove closer to the centerline when trees were near the edge of the road. Similar to the results reported in Calvi (2015), no statistically significant differences in operating speeds were observed with change in vegetation density. The analysis of drivers' eye movements indicated that the roadside configuration did not affect participants' attention to their operating speed, however, the number of glances was highly correlated to the time spent in the virtual drive. The results provide evidence to suggest that, while the increased roadside vegetation density does not necessarily result in reduced driver speeds or deviated lateral positioning, the manipulation of the roadside clear zone width does provide tangible benefits to safe driver behavior. These research findings should be considered in the design of roadside elements, accounting for overstated benefits to roadside vegetation.

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## 1. Introduction

Natural environments within the roadway network have been found to have many positive implications on the activity of driving, such as reduced stress, decreased road rage and alleviated depression (Cackowski & Nasar, 2003; Naderi, 2007; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998). While trees provide numerous psychological and environmental benefits, significant risk is known to be imposed on drivers when trees are placed in close proximity to the traveled way. Fixed-object crashes involving trees in particular, are among the most severe crashes, given that 46% of collisions with

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trees are fatal (Dixon & Wolf, 2007). An even greater risk is posed by mature trees with a trunk diameter greater than 50 cm (20 in.), as larger trees are associated with higher driver fatality rates than smaller trees (Zeigler, 1986).

A primary cause for this high fatality rate is the presence of trees along high-speed rural roads. Due to the high cost of removal, trees are often present near the edge of the roadway thus increasing the likelihood of a fixed object collision in the event of a run-off-the-road (ROR) crash. Additionally, the presence of trees near the roadway affect drivers' visual scan pattern, leading to the driver's inability to detect potential hazards such as wildlife, pedestrians or smaller vehicles. As described by the American Association of State Highway and Transportation Officials (AASHTO), the clear zone is a design element on both local and collector roads and is intended to provide a recovery area for errant vehicles. It should be a minimum of 2.1 m and 3 m (7 and 10 ft) on roads with and without a curb, respectively (AASHTO, 2011a). The Roadside Design Guide recommends clear zone widths based on speeds, traffic volumes, roadway geometry and curb heights. It also stipulates that side slopes steeper than 1V:3H are not considered traversable and are not considered part of the clear zone (AASHTO, 2011b).

Previous studies have examined to some extent, the effect that clear zone width and vegetation density have on vehicle speeds and lane position. In 2014, a study by Fitzpatrick, Harrington, Knodler, and Romoser (2014) utilized a computer-based static evaluation in addition to field observations to investigate the effect that clear zone width and vegetation density had on driver speeds and lane positioning. They found from the 100 drivers who each watched 13 videos of different clear zone configurations that drivers would select lower speeds on the roadways with small clear zones. In field observations, this was confirmed, and additionally, video data revealed that motorists drove closer to the edge of the road in large clear zones (Fitzpatrick et al., 2014). The researchers acknowledged that a field or driving simulator study would be needed to further validate the relationship of roadside configurations to vehicle speed. More recently, (Calvi, 2015) conducted such a simulator study with 40 participants and two clear zone widths and three roadside tree spacings. Calvi found that drivers reduced their speeds by 8.4 km/h ($p < 0.01$) and moved 0.09 m closer toward the center of the lane ($p < 0.01$) when trees were close to the road. The spacing of trees did not affect driver speeds, but did influence lane positioning as drivers moved away from the edge of the road as tree spacing decreased. He concluded that further studies were warranted to investigate different roadside tree configurations, road alignment geometries and vegetation types (Calvi, 2015).

Other studies have been conducted that have focused upon roadside vegetation without consideration of the clear zone. A comparison of suburban and urban streets via a driving simulator demonstrated a mean speed reduction of 4.86 kph (3.02 mph) when trees were placed adjacent to the curbside in a suburban landscape (Naderi, Kweon, & Maghelal, 2006). Additionally, suburban roadways were perceived to be the safest by participants in a follow-up survey and the presence of trees aided drivers with sensing the edge of the road. A driving simulator study conducted in 2010 demonstrated no change in lateral position when trees were close to the edge of the road with and without guard rails (Bella & Tulini, 2010). These data indicate that drivers did not view trees as hazardous due to the lack of a perception of danger within a virtual drive, leading the researchers to conclude that a field study would be needed for validation. However, as a means of validating speed selection in the simulator environment, a study comparing driving simulator versus field data speeds on identical routes with a common set of drivers showed that drivers did not perceive speeds differently in the field versus in a driving simulator (Hurwitz & Knodler, 2007; Hurwitz, Knodler, & Dulaski, 2005).

### *1.1. Objectives and hypotheses*

The objective of the current effort is twofold: (i) to determine if clear zone width and roadside vegetation density has any influence on operating speeds and lateral positioning; and (ii) to determine whether roadside environment has any effect on drivers' attention to their speed (as measured by drivers' eye movements).

Based on previous literature, the current study had three a priori hypotheses:

**Hypothesis 1.** We hypothesize that participants will select lower speeds and move away from the edge of the roadway when the clear zone is smaller.

**Hypothesis 2.** Based on the findings from (Calvi, 2015), we hypothesize that vegetation density will not affect operating speeds but it may, however, influence lateral positioning.

**Hypothesis 3.** Finally, we hypothesize that participants will glance at their speedometers less frequently in a small clear zone, as the close presence of trees could heighten their attention toward staying on the road.

## 2. Methods

A within subject experimental design was developed based upon existing literature to further examine the effect of roadside vegetation (clear zone width and vegetation density) placement on roadway safety. The following section outlines the research tasks that were employed to address the objectives of this study.