An Empirical Assessment on the Effects of Geometry and Non-Geometry Factors in Work-Zone Crashes with Unobserved Heterogeneity

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Abstract

Work zones are uniquely configured and managed by special traffic signs, standard channelizing devices, appropriate barriers, and pavement markings. Unexpected driving conditions through different work-zone configurations may potentially cause risks for drivers. Using data from Florida for 2012 to 2017, driver injury severities in single-vehicle work-zone crashes were studied using random parameters logit models that allow for possible heterogeneity in the means and variances of parameter estimates. The available data include a wide variety of factors known to influence driver injury severity, including data related to the crash characteristics, vehicle characteristics, roadway attributes, prevailing traffic volume, driver characteristics, and spatial and temporal characteristics. The estimated models produced significantly different parameters for work-zone crashes due to geometry-related and non-geometry-related factors, suggesting a complex interaction. In several key instances, the marginal effects of individual parameter estimates show marked differences between these two scenarios. The model estimation findings add to the growing body of literature that suggests that geometric restrictions inside work zones pose a different set of risk factors in work-zone crashes from non-geometry-related factors. The notion of geometric restrictions, apart from normal driving conditions, could have profound effects on the safety performance of geometric configurations of work zones as well as various training opportunities for crash scene investigators to identify accurate contributing factors.

Keywords: Work-zone crashes; Contributing Factors; Injury severity; Mixed logit model with heterogeneity in means and variances.

1. Introduction

In Florida, the number of work-zone crashes has increased steadily since 2014 even though the number of work zones has not changed significantly. There were 8,494 crashes in work zones in 2017, while there were only 5,409 crashes in 2014. This equates to one work-zone crash almost every hour in 2017, as opposed to one crash in every 1.6 hours in 2014. Single-vehicle crashes in work zones comprise about 20% of all crashes in Florida according to crash ststiatics. They are of particular interest because they reflect how the fundamentals of work-zone design impact potential driver errors [1]. Moreover, with increasing emphasis on the maintenance and reconstruction of existing highways and infrastructure, as well as the growing need to build new roadway facilities, work-zone safety is a growing priority for both workers and motorists.

Work-zone safety in general, and specifically injury severities in work-zone crashes, has been the subject of a number of research studies [1-7]. These studies have provided valuable insights into the factors that determine work-zone injury severity. However, the geometric configuration of work zones has not been addressed as a contributing factor in work-zone crash severity models [2] despite general agreement that it plays a role. For example, in Florida geometry was identified as a contributing factor in about 25% of total work-zone crashes from 2012 to 2017. The proportion of severe (fatal and incapacitating injury), moderate (non-incapaciating and possible injury), and no injury (property damage only) crashes for geometry-related and non-geometry-related factors in single-vehicle work-zone crashes account for 8%, 31%, and 61% and 10%, 31%, and 59% of total work-zone crashes, respectively in Florida from 2012 to 2017.

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Past research has studied work zones from different perspectives. For example, some studies on work-zone crash severity have mainly focused on fatal crashes [8-10], other studies have discussed both fatal and injury crashes [7, 11], and some have conducted injury severity analyses [6, 12-16]. Other studies have focused on whether work-zone crashes involving heavy vehicles are more severe compared to non-work-zone areas [17]. Some indicated that work-zone crashes were in fact more severe [5, 18-21], while others disagreed [22-26]. However, none of the studies has conducted research on work-zone geometry as a contributing factor. In some work-zone crashes, investigators identify work-zone geometry as a contributing factor but not in others. This raises the question of whether all work-zone crashes should be attributed to geometry that originates from the temporary traffic control plan or not. Although most crashes can be attributed to human factors, road geometry and work-zone activity, specifically traffic signs, marking, and channelization with barrels, affect drivers' speed adpatation and lane keeping, as well as overall risk perception. This analysis investigates the potential differences in contributing factors where geometry was identified as a factor in a work-zone crash versus those cases where it was not. In addition, this study is intended to provide more insights into how work-zone geometry may affect driver injury severity in work-zone-related crashes in Florida.

2. Analysis and Results

Table 1 shows the marginal effects estimated for geometry and non-geometry related mixed logit models with heterogenity in means and variances for the analysis period: 2012-17. The following subsections explain with more details:

2.1. Spatial Characteristics

District 7 (Hillsborough, Pinellas, Pasco, Citrus, and Hernando counties) was found to experience an increase in severe injury crashes, with average marginal effects of 0.006 and 0.009 in geometry-related and non-geometry-related factors, respectively. A similar result was found in [1]. District 6 (Miami-Dade and Monroe counties) had less likelihood of severe and minor injury crashes in both scenarios. District 5 (Brevard, Flagler, Lake, Marion, Orange, Osceola, Seminole, Sumter, and Volusia counties) had more likelihood of severe and minor injury crashes, with an average marginal effect of 0.004 in the non-geometry-related factors model.

2.2. Vehicle Characteristics

Passenger cars and pickup trucks were found to be statistically significant in the geometry-related factors model. Passenger cars were found to decrease the likelihood of severe and minor injury crashes, with average marginal effects of 0.01 and 0.02, and increase no injury crashes with average marginal effects of 0.03 in work-zone crashes in both scenarios. Moreover, pickup trucks were found to increase the likelihood of severe injury but decrease minor injury crashes in work zones in both scenarios.

2.3. Environmental Characteristics

Rainy weather was likely to increase minor and no injury crashes, with average marginal effects of 0.005 and 0.001, respectively, in the geometry-related factors model. A similar result was found in a study by [1]. This indicates that drivers are cautious about driving through work zones in rainy or inclement weather conditions [2]. Daylight was likely to increase no injury crashes as drivers are more alert and remain vigilant within the driving environment of the work zone.

2.4. Geometric Characteristics

Lane closures in work zones increased the likelihood of severe injury crashes and reduced the likelihood of minor injury crashes in the non-geometry-related factors model. On the contrary, shoulder- and median-related work increases the likelihood of severe injury crashes, with average marginal effects of 0.017 and 0.013 for geometry-related and non-geometry-related models, respectively. This is because work on the shoulder or median continues in parallel with operational traffic on all lanes, which clearly indicates that drivers are not fully aware of work being in progress while speeding through the work zones [2]. Also, drivers may be anxious since there is no room for corrections in case of any mistake. A large shoulder width of 6 to 10 ft increases the likelihood of a severe or minor injury crash by the marginal effects of 0.005 and 0.007, respectively, for the geometry-related factors model. A similar result was found in [1]. A transition area inside the work zone increases the likelihood of minor and no injury crashes for work-zone geometry-related crashes.

2.5. Crash Characteristics

A harmful event (i.e., the first injury or damage-producing event) on the right shoulder increases the likelihood of severe and minor injury crashes by 0.011 in the non-geometry-related model. However, a harmful event on the right shoulder increases the likelihood of severe injury crashes with an average marginal effect of 0.010 in the geometry-related model. Harmful events, such as hitting roadside fixed objects, increase the likelihood of severe and minor injury crashes with an average marginal effect of 0.005 in the non-geometry-related model. These harmful events occurred on the right shoulder, median, and off-road locations.

2.6. Traffic Characteristics

Truck volume less than 10% of total traffic volume increases the likelihood of minor injury crashes, with average marginal effects of 0.026 and 0.016 for the geometry-related and non-geometry-related models, respectively. A similar result was found in [1].

2.7. Driver Characteristics

Driver age below 30 years was found to increase minor injury crashes, with an average marginal effect of 0.018 for non-geometry-related work-zone crashes. This age group might be associated with risky driving behaviors, such as speeding or distraction. Negligent or careless driving behavior is likely to increase minor injury crashes, with an average marginal effect of 0.027 and 0.016 for the geometry-related and non-geometry-related models, respectively. A similar result was found in [1].

Table 1: Comparison of marginal effects for geometry and non-geometry-related factor in work-zone crashes

	No Injury		Minor Injury		Severe Injury	
Variable	Geometry	Non-Geometry	Geometry	Non-Geometry	Geometry	Non-Geometry
Spatial characteristics						
District 5 indicator (1 if crash occured in District 5, 0 otherwise)	–	-0.0080	–	0.0041	–	0.0040
District 6 indicator (1 if crash occured in District 6, 0 otherwise)	0.0110	0.0062	-0.0085	-0.0041	-0.0025	-0.0020
District 7 indicator (1 if crash occured in District 7, 0 otherwise)	-0.0058	-0.0081	-0.0008	-0.0010	0.0066	0.0091
Vehicular characteristics						
Passenger car indicator (1 if passenger car involved in crash, 0 otherwise)	0.0324	0.0372	-0.0216	-0.0226	-0.0108	-0.0146
Pickup truck indicator (1 if pickup truck involved in crash, 0 otherwise)	0.0067	0.0054	-0.0075	-0.0063	0.0008	0.0008
Environmental characteristics						
Rain indicator (1 if it was rainy at the time of crash, 0 otherwise)	–	0.0051	–	0.0006	–	-0.0057
Daylight indicator (1 if crash occurred in the daylight, 0 otherwise)	0.0255	–	-0.0159	–	-0.0097	–
Geometric characteristics						
Large shoulder width indicator (1 if crash occurred at right shoulder width between 6 to 10 ft, 0 otherwise)	-0.0122	–	0.0069	–	0.0053	–
Lane closure work-zone indicator (1 if crash occurred at lane closure, 0 otherwise)	–	0.0073	–	-0.0079	–	0.0006
Work on shoulder-median work indicator (1 if crash occurred while work on shoulder or median, 0 otherwise)	-0.0152	-0.0117	-0.0020	-0.0015	0.0172	0.0132
Transition area indicator (1 if crash occurred in the work zone's transition area, 0 otherwise)	0.0024	–	0.0003	–	-0.0027	–
Crash charcteristics						
Harmful event off-road indicator (1 if the harmful event occurred off road, 0 otherwise)	–	-0.0098	–	0.0046	–	0.0052
Harmful event on right shoulder indicator (1 if harmful event occured at the right shoulder, 0 otherwise)	-0.0076	-0.0224	-0.0011	0.0107	0.0087	0.0118
Traffic characteristics						
Low truck volume indicator (1 if truck volume below 10% of all traffic at the time of crash, otherwise)	-0.0243	-0.0143	0.0265	0.0159	-0.0021	-0.0015
Driver characteristics						
Young driver indicator (1 if driver's age below 30 years involved in crash, 0 otherwise)	–	-0.0168	–	0.0184	–	-0.0016
Negligent driver indicator (1 if negligent driving involved in crash, 0 otherwise)	-0.0246	-0.0146	0.0268	0.0162	-0.0022	-0.0016
Other factors						
No worker presence indicator (1 if no worker was present at the time of crash, 0 otherwise)	-0.0367	–	0.0398	–	-0.0031	–

3. Discussion

Using single-vehicle crash data in work zones in Florida from 2012 to 2017, this study used a random parameter logit model (with heterogeneity in mean and variance) to explore the differences between injury severities of the drivers for work-zone crashes due to geometry-related and non-geometry-related factors. Three injury levels were considered—severe (combining fatal and incapacitating), minor (combing non-incapacitating and possible injury), and no injury. The model results encompass factors such as spatial characteristics vehicle characteristics, environmental characteristics, geometric characteristics, crash characteristics, traffic characteristics, and driver characteristics. All of these factors are interrelated in a complex nature with human factors aspects, particularly, driver behaviors and characteristics related to work-zone crashes specific to geometric and non-geometric attributes.

Although there are some consistencies between geometry-related and non-geometry-related factors (of the 17 variables found to be statistically significant in at least one, 12 of these were found to be statistically significant in both), likelihood ratio tests show that the estimated parameters were different for geometry-related and non-geometry-related factors for driver injuries in Florida work-zone crashes over the 2012-2017 analysis period.

The model results indicate that heterogeneity in mean being the traffic volume below 40,000 vehicles per day were significant in work-zone geometry-related crashes, but this has become insignificant, when first harmful event on right shoulder became significant in work-zone non-geometry-related crashes. Moreover, heterogeneity in variance with truck volume of 10% to 20% of traffic volume in work-zone geometry-related crashes became insignificant and no longer significant in work-zone non-geometry-related crashes; whereas, roadside fixed object as harmful event became significant in work-zone non-geometry-related crashes.

4. Conclusions

The differences in the magnitude and factors associated with geometry- and non-geometry-related work-zone crashes are particularly important as the effects of crash, traffic, geometry, temporal, spatial, vehicle, and driver characteristics varied between these two scenarios. Complex interrelationship exist in geographical regions (District 6 and District 7), work-zone characteristics (shoulder and median work), vehicle characteristics (passenger car and pickup truck), negligent/careless driving, and low truck volume (truck volume below 10% of total traffic). However, there are other characteristics related to driver age (below 30 years), environmental attributes (rain), harmful event location (right shoulder, roadside) and work-zone type (lane closure) that are specific to non-geometry-related work-zone crashes. Similarly, there are other characteristics related to work zone location (transition area), large shoulder (6 to 10 feet), environmental attributes (daylight), and worker absence that are specific to geometry-related work-zone crashes. For future work, the model results indicate a need for temporal instability analysis dealing with data split for factors, geometry-related versus non-geometry-related, and different work zone types. This is because work-zone-related crashes warrant substantial attention in the near future for Florida and nationally despite the inherent uncertainty pointed out in the model estimation. The model results based on a data-driven and advanced econometric framework on different injury levels clearly provide insights for safety professionals, policymakers, and law enforcement agencies, particularly those dealing with work-zone management and data management regarding the identification of appropriate factor(s) in work-zone crashes. The findings of this study contribute a new dimension to existing work-zone safety management practice for stakeholders with newer technology in-vehicle or smart work zone application (27) where safety in work zones is recognized as an important emphasis area in Florida's Strategic Highway Safety Plan.

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