Accident Analysis and Prevention 111 (2018) 161–172

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

# Analysis of passenger-car crash injury severity in different work zone configurations

Mohamed Osman[a], Rajesh Paleti[b], Sabyasachee Mishra[a,c,*]

[a] Department of Civil Engineering, University of Memphis,3815 Central Avenue, Memphis, TN 38152 United States
[b] Department of Civil & Environmental Engineering, Old Dominion University, 135 Kaufman Hall, Norfolk, VA 23529, United States
[c] Intermodal Freight Transportation Institute, University of Memphis, Memphis, TN 38152, United States

ARTICLE INFO

*Keywords:*
Passenger car
Work zone safety
Injury severity
Mixed generalized ordered response probit
Heterogeneity

ABSTRACT

Work zone safety remains a priority to the Federal Highway Administration, State Highway Departments, highway engineers, and the traveling public. Work zones create a hospitable environment for crashes; an issue that gained tremendous share of attention in recent years. Therefore, every effort should be sought out to reduce the injury severity of crashes in work zones. In this paper we attempt to investigate factors contributing to the injury severity of passenger-car crashes in different work zone configurations. Considering the discrete ordinal nature of injury severity categories, a Mixed Generalized Ordered Response Probit (MGORP) modeling framework was developed. The model estimation was undertaken by compiling a database consisting of 10 years of crashes that involved at least one passenger car, and occurred in a work zone. Revealing the underlying factors contributing to injury severity levels for different work zone configurations will allow for distinguishing mitigation methods for higher severity outcomes that best suit each of the depicted work zone layouts. This can be accomplished through the implementation of specific safety measures based on the specific configuration of a work zone as a potential crash location. Elasticity analysis suggests that partial control of access, roadways classified as rural, crashes during evening times, crashes during weekends, and curved roadways are key factors that increase the likelihood of severe outcomes. Also, the effects of several covariates were found to vary across the different work zone configurations.

## 1. Introduction

Work zone safety remains a priority to the Federal Highway Administration (FHWA), Departments of Transportation (DOTs), highway engineers, and the traveling public. The presence of heavy machinery, barriers, traffic control devices, and generally the alteration of the roadway layout in a work zone creates an intimidating environment to the traveling motorists.

According to FHWA facts and statistics, 67,523 crashes were nationally reported to have occurred in work zones in 2013 (FHWA, 2016). Compared to 2012, the frequency of work zone crashes in 2013 was reduced, however higher severity levels were reported (FHWA, 2016). In 2013 alone, approximately 47,758 non-fatal injuries were reported in work zones (FHWA, 2016). In the same year, there were 527 fatal crashes in work zones resulting in 579 fatalities (FHWA, 2017). The number of work zone fatalities in 2013 equates to one work zone fatality every 15 h. On average, 85% of fatalities in work zones were drivers or occupants of passenger cars (FHWA, 2016).

The development of a temporary traffic control plan (TTC) for work zones typically depict the type of work zone configuration that is suitable for the specific proposed work activity to be accomplished. A TTC plan serves as an application that ultimately shapes the layout and type of work zone to be formed. Nationally, FHWA mandates such applications through the Manual on Uniform Traffic Control Devices (MUTCD) to specify the minimum TTC requirements needed for the different work zone configurations ("Manual on Uniform Traffic Control Devices (MUTCD)," 2009). Although there are numerous detailed typical TTC applications published by the MUTCD, the State of Minnesota (MN) has adopted a special work zone crash reporting technique allowing the summarization of the different TTC applications into five major types based on the specific work zone configuration where a crash has occurred. The Highway Safety Information System (HSIS) maintains the MN crash database under contract with the FHWA. HSIS presents the MN work zone crashes to have occurred in one of five categories: (1) Lane Closure, (2) Lane Shift/Crossover, (3) Shoulder or Median, (4) Intermittent/Mobile, or (5) Other. For illustration purposes and inspired by the 2009 edition of the MUTCD, Fig. 1 demonstrates generic versions of each of the work zone configurations; categories (1) through

* Corresponding author at: Department of Civil Engineering, University of Memphis,3815 Central Avenue, Memphis, TN 38152 United States.
*E-mail addresses:* mosman@memphis.edu (M. Osman), rpaleti@odu.edu (R. Paleti), smishra3@memphis.edu (S. Mishra).

https://doi.org/10.1016/j.aap.2017.11.026
Received 28 May 2017; Received in revised form 14 November 2017; Accepted 20 November 2017
0001-4575/ 

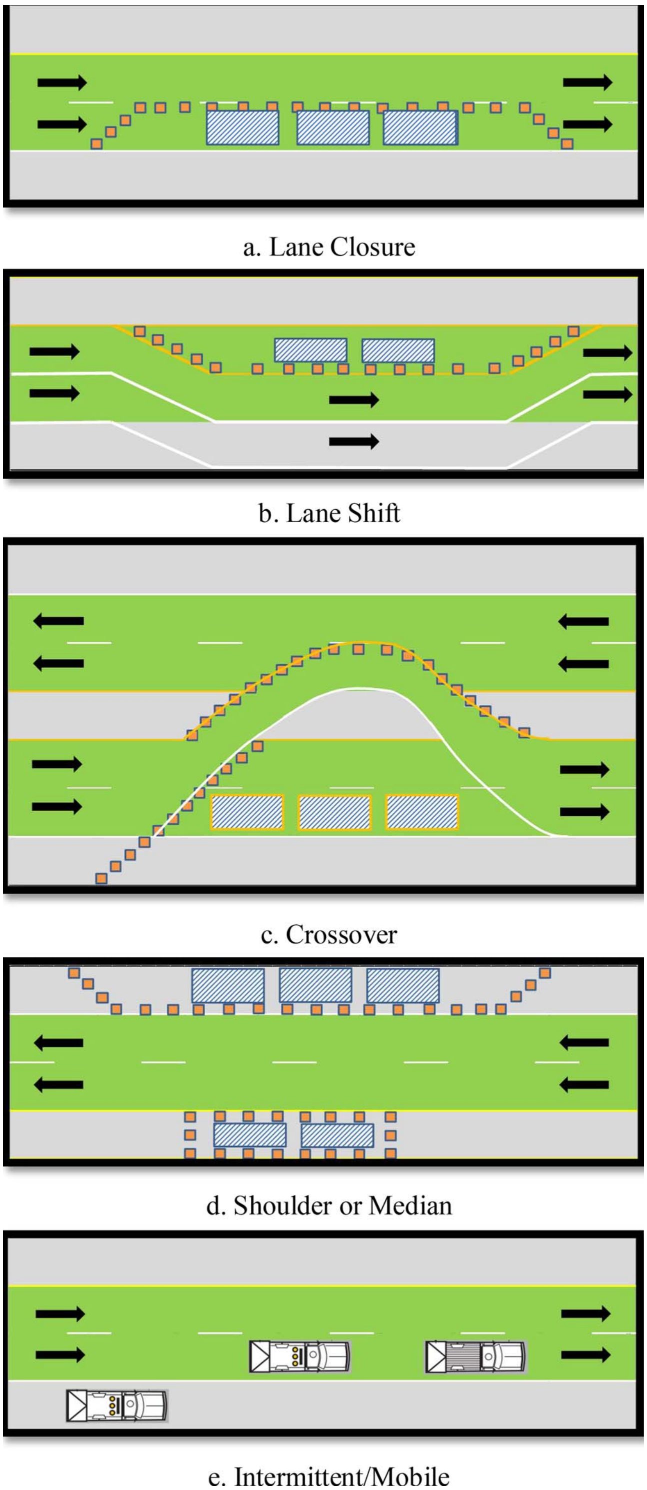


**Fig. 1.** Work zone configurations (adopted from: MUTCD, 2009).

(4) of such TTC layouts are shown (Fig. 1(a) though (d)), except for the "Other" category. Fig. 1(a) corresponds to a one lane closed on a mainline where traffic from the closed lane merges with other open lanes. Fig. 1(b) corresponds to a lane shift where both lanes remain open and shifted around the activity area. Fig. 1(c) corresponds to a lane crossover configuration where one direction of traffic is completely closed and traffic crosses the median to utilize roadway from opposing traffic. Fig. 1(d) corresponds to activities in the shoulder or median while mainline traffic stays unaffected. Fig. 1(e) corresponds to an intermittent or mobile activity which typically moves along the same direction of travel at a slower speed.

Each of these work zone configurations may vary in size and location depending on the nature of the work activity taking place. Earlier studies on work zone safety focused on different aspects including crash risk factors, severity, type, location, rate, and time frame. Due to the broad nature of these past studies, this study will mainly focus on studies related to work zone crash severity and risk factors. Within the work zone crash severity literature, some studies mainly focused on fatal crashes (Arditi et al., 2007; Daniel et al., 2000; Schrock et al., 2004), other studies discussed on both fatal and injury crashes (Elghamrawy et al., 2010; Li and Bai, 2008a), and some conducted injury severity analyses (Akepati and Dissanayake, 2011; Khattak and Targa, 2004; Khattak et al., 2002; Li and Bai, 2009; Qi et al., 2013; Wang et al., 2010). There have been inconsistencies in the literature regarding whether work zone crashes are more severe relative to those occurring in non-work zone areas. Some studies indicated that work zone crashes were in fact more severe (Bédard et al., 2002; Garber and Zhao, 2002; Meng et al., 2010; Pigman and Agent, 1990; Ullman et al., 2006), while others disagreed (FHWA, 2016; Hargroves and Martin, 1980; Nemeth and Migletz, 1978; Nemeth and Rathi, 1983; Rouphail et al., 1988).

According to the work zone safety literature, there have not been any studies that undertook analysis at the level of the specific work zone configuration where a crash has occurred. Most of work zone safety research to date accounts only for the work zone as an entire roadway segment that is under some type of TTC due to road work. Additionally, the potential effects of the different work zone configurations, especially within the context of injury severity analysis, on the severity of crashes were never comprehensively analyzed in the literature. Depending on the nature of the TTC plan pertaining to a specific work zone configuration, the determinants and the magnitude of impact of factors that influence injury severity of crashes that occur in work zones can vary across different work zone configurations. The objective of current study is to develop an analytical model of crash injury severity within each of the work zone configurations previously identified. In doing so, injury severity of the most injured passenger-car occupant within a specific work zone configuration is investigated by exploring the interactions between the identified five work zone configurations and different risk factors. Unobserved heterogeneous effects of the different risk factors are examined and identified through the modeling structure utilized. Understanding the different characteristics contributing to the injury severity of passenger-car most-injured occupant in the different work zone configurations will serve as a great advantage enabling practitioners, designers, and DOT officials to mitigate the severity of those individuals; generally involved in a work zone crash or particularly within a specific work zone configuration. As stated in the 2009 edition of the MUTCD ("Manual on Uniform Traffic Control Devices (MUTCD)," 2009), TTC applications were designed as minimum solutions for the depicted configurations and therefore, work zone designers and DOTs can make informed decision when upgrading TTC plans from those minimums to best suit their needs by possessing advanced knowledge of what factors may or may not affect the injury severity levels of motorists based on the work zone configuration it is.

The remainder of this paper is structured as follows. The next section presents the methodology adopted in this paper. The data section discusses the dataset utilized and the final estimation sample assembly process. The study analysis section presents a detailed overview of the estimation results, statistical measures of fit, elasticity effects, variables strength, and recommendations. Finally, the conclusion section provides a summary of this research along with major findings, limitations, and future scope of research.

## 2. Methodology

Several different modeling methods have been used to analyze crash severity data. Typically these methods can be grouped into two