

# Investigating the Human Factors Involved in Severe Crashes in Highway Work Zones

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## ABSTRACT

Highway work zones create an inevitable disruption in regular traffic flows and result in traffic crashes with injuries or fatalities. In many of these crashes, driver errors have been reported as the most significant causal factors. Understanding the role of human factors in these work zone crashes and then lowering the probability that they will cause crashes is critical for improving safety in highway work zones.

In this study, the role of human factors in severe work zone crashes involving fatalities or injuries was investigated. The objectives of the research were as follows: (1) to explore the influence of human factors on the occurrences and characteristics of fatal and injury work zone crashes and (2) to investigate the effectiveness of work zone temporary traffic control (TTC) devices in preventing human errors from causing severe crashes in work zones. The severe crashes that occurred in Kansas highway work zones during 1992 and 2004 were studied in detail. Statistical techniques such as Pearson chi-square, likelihood ratio chi-square, and logistic regression were utilized in the investigation. Through the systematic study, the researchers discovered the major impacts of several common driver errors on severe work zone crashes; the researchers also evaluated the effectiveness of some TTC methods in reducing these driver errors in highway work zones. The results of this study can provide knowledge that can facilitate the development of effective countermeasures for eliminating risky driver errors, ultimately in order to improve safety level in work zones.

**Key words:** human factors—Kansas—safety—traffic control effectiveness—work zone

## **INTRODUCTION**

Work zones on the national highway system result in safety concerns for the traveling public. Crash investigations have shown that highway work zones not only increase crashes rates (Garber and Zhao 2002; AASHTO 1987; Ullman and Krammes 1990), but also significantly increase the number of severe crashes (Garber and Zhao 2002; Ullman and Krammes 1990; Pigman and Agent 1990; Nemeth and Migletz 1978; AASHTO 1987). According to crash statistics, 1,068 people were killed in work zones in 2004, adding to about 49,620 more work zone-related injuries (FHWA 2006). The direct cost of highway work zone crashes, estimated based on the crash data from 1995 to 1997, was as high as \$6.2 billion per year, an average cost of \$3,687 per crash (Mohan and Gautam 2002). The recent Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) included a number of provisions addressing highway work zone safety and other work zone-related issues (FHWA 2005). Eliminating work zone crashes, especially severe crashes involving injuries and fatalities, has been a high-priority task for traffic engineers.

Traffic crashes result from human-machine interactions, and human factors play a critical role in the occurrence of crashes. Among all human factors, driver errors have been found to be the major causes of traffic crashes. Studies have shown that 45% to 75% of traffic crashes in the United States were in part caused by driver errors (Wierwille et al. 2002). In Arizona, for example, driver error is estimated to have caused about half of all traffic crashes (Hutabarat, Lam, and Lawrence 2004). In highway work zones, human errors are the major contributing factor as well. Among the various human errors, studies suggest that following too closely, inattentive driving, and misjudging traffic conditions were the most common causes of work zone crashes (Mohan and Gautam 2002; Pigman and Agent 1990).

In Kansas, too, previous crash analyses showed that driver errors were the dominant contributing factors to the severe crashes in highway work zones (Bai and Li 2006; Bai and Li 2007). Understanding driver errors is thus a key step towards work zone safety improvement in Kansas.

In this study, the human factors that have been associated with the severe crashes involving injuries and fatalities in Kansas highway work zones were analyzed. The primary objectives of the study were (1) to investigate the major human factors, especially driver errors, that resulted in severe crashes in Kansas highway work zones and (2) to understand the impacts of human errors on highway work zone safety. The crash data in Kansas highway work zones between 1992 and 2004 were analyzed through various statistical methods, including frequency analyses, chi-square tests, and logistic regression. The results of this in-depth study will help determine the role of human factors in the occurrence of crashes and will provide knowledge for traffic engineers and researchers to develop safety countermeasures that are effective in preventing major driver errors from causing severe crashes in work zones.

## **DATA COLLECTION**

Data for fatal and injury crashes in Kansas highway construction zones between 1992 and 2004 were collected from the Kansas Department of Transportation (KDOT) database. The original data was formatted such that a single crash was frequently described in multiple data rows and crash information was recorded using text. The original data were recompiled to facilitate the computer aided data analyses using SAS software. First, at-fault drivers were identified and their characteristics, along with other crash information, were collected into spreadsheets in which a crash was described in only one data row. Then, for the cases with missing or unclear information, the original accident reports, including detailed crash descriptions in text and sketches, were examined to ensure the data accuracy. The collected crash information contained 3 categories and 17 variables, as listed in Table 1. The observations of these crash variables were assigned unique integers so that the spreadsheet contained only numerical data.

During the study period, Kansas work zones had 157 fatal crashes and 4,443 injury crashes. It would have been extremely time consuming and not statistically meaningful to compile and analyze the entire fatal and injury datasets. Instead, the 157 fatal crashes and a sample of 460 injury crashes were used to save data collection time while maintaining reasonable accuracy in the results of the analysis. In addition to these fatal and injury crashes, a dataset that contained 655 recent crashes in 2003 and 2004, including 29 fatal crashes and 626 injury crashes, was also prepared for more advanced statistical studies of driver errors using chi-square tests and logistic regression.

**Table 1. Data categories and variables**

No.	Category	Variable
1	Crash variables	Age
		Gender
		Crash time
		Light condition
		Speed limit
		Area information
		No. of cars in collision
		Vehicle type
2	Driver errors	Inattentive driving
		Too fast for condition/exceeded speed limit
		Disregarded traffic signs, signals, or markings
		Followed too closely
3	Traffic control methods	Flagger/officer
		Stop sign/signal
		Flasher
		No passing zone
		Center/edge lines

The sample size for injury crashes was determined based on the method introduced by Thompson (2002). Considering that the data would be used for frequency analysis of characteristics, as reflected through the proportions of the different crashes marked by different variable observations, the sample size was determined so that the proportions could be estimated accurately. Based on normal approximation, to obtain a proportion estimator  $\hat{p}$  with a probability of at least  $1 - \alpha$  that was no farther than  $d$  (error) from the true population proportion  $p$ , a corresponding sample size would need to be chosen such that

$$P(|\hat{p} - p| > d) < \alpha \quad (1)$$

According to Thompson (2002), when there is no estimate of  $p$  available and the population size  $N$  is large, the following equation can be used to determine the minimum sample size  $n_{min}$ :

$$n_{min} = \frac{1}{(N-1)/Nn_0 + 1/N} \approx \frac{1}{1/n_0 + 1/N} \quad (2)$$

where

$$n_0 = \frac{z_{\alpha/2}^2 p(1-p)}{d^2} = \frac{0.25 z_{\alpha/2}^2}{d^2} \quad (3)$$

and  $z_{\alpha/2}$  is the upper  $\alpha/2$  point of the standard normal distribution.

For multiproportional estimations, Thompson (2002) showed that  $n_0$  was equal to 510 when  $\alpha = d = 0.05$  and when the population size  $N$  was large. Given the population of 4,443 injury crashes in this study, the minimum sample size needed for frequency analysis at 95% confidence level (an error  $d$  less than 5%) was determined using the above equation as follows:

$$n_{\min} \approx \frac{1}{1/n_0 + 1/N} = \frac{1}{1/510 + 1/4443} = 457 \quad (4)$$

The result was rounded to 460.

## HUMAN FACTORS IN HIGHWAY WORK ZONES

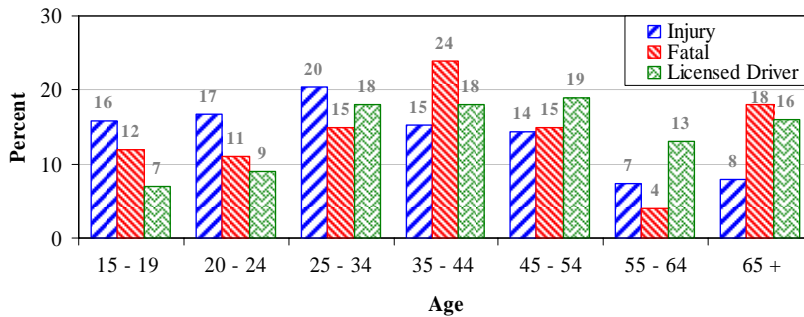
The human factors involved in severe work zone crashes were examined systematically based on Kansas work zone crash data. The results of an overview of the human factors, such as at-fault driver age and gender as well as driver errors associated with severe work zone crashes, were first presented. The four most frequent driver errors causing work zone crashes were then addressed in detail. These included “inattentive driving,” “too fast for condition/ exceeded speed limit,” “disregarded traffic signs, signals, or markings,” and “followed too closely.” The investigation of these driver errors involved various statistical methods such as chi-square tests and logistic regression.

### Overview

Based on the injury and fatal crash data in Kansas highway work zones between 1992 and 2004, male drivers were responsible for most of the crashes in highway work zones. Frequency analyses showed that male drivers caused 75% of the fatal crashes and 66% of the injury crashes. Note that male drivers only constituted about 50% of the total licensed drivers in Kansas, according to 2004 statistics (FHWA 2004).

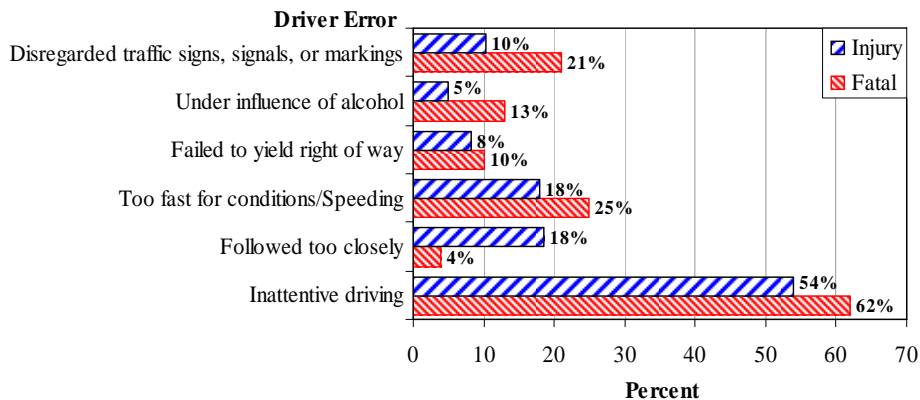
Figure 1 illustrates the percentages of the at-fault drivers in the fatal and injury work zone crashes by age. The age distributions of the Kansas licensed drivers (FHWA 2004) are also included in the figure. Among all age groups, drivers younger than 25 years of age caused the largest proportion of the severe crashes involving fatalities or injuries, followed by drivers aged between 25 and 34 years. In addition, the percentage of the severe crashes caused by young drivers under 25 years of age was significantly higher than their percentage in the total licensed drivers.

When comparing the percent frequencies of fatal crashes to injury crashes, drivers between 15 and 34 years of age caused a higher percentage of injury crashes than fatal crashes. However, drivers aged 35 to 44 years caused the highest percentage (24%) of fatal crashes among all the age groups. This percentage was 9% higher than the injury crashes caused by the same age group and 6% higher than their percentage in the total Kansas licensed driver population. Senior drivers (65 or older) were found to be responsible for a larger proportion of fatal crashes than for injury crashes (18% vs. 8%) in work zones.



**Figure 1. Fatal and injury crash frequencies and Kansas licensed drivers by age (in percent)**

Studies have showed that pedestrian factors, environmental factors, and vehicle factors are not significant causes of severe work zone crashes; human errors, on the contrary, contribute to most of the crashes involving fatalities and injuries in work zones (Bai and Li 2006; Bai and Li 2007). Based on the Kansas work zone crash data, “inattentive driving” contributed to more than half of the severe crashes, followed by “too fast for conditions/exceeded speed limit,” “followed too closely,” and “disregarded traffic signs, signals, or markings.” In addition, as exhibited in Figure 2, some driver errors such as “too fast for condition/ exceeded speed limit,” “disregarded traffic signs, signals, or markings,” and “under influence of alcohol” resulted in notably higher percentages of fatal crashes than injury crashes. Therefore, these driver errors could be factors leading to crashes of higher severity in highway work zones. On the other hand, “followed too closely” caused 14% more injury crashes than fatal crashes (18% vs. 4%).



**Figure 2. Fatal and injury crash percent frequencies by driver error**

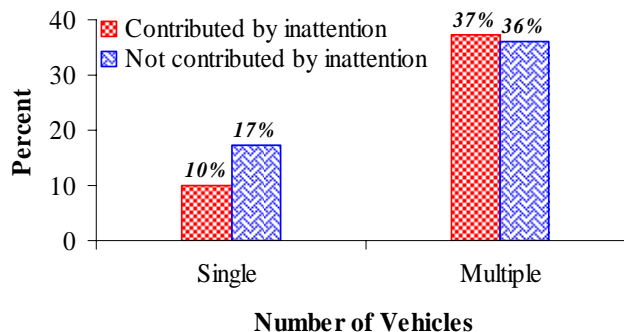
### Examination of the Most Common Driver Errors in Work Zones

The previous crash overview has indicated that “inattentive driving,” “too fast for condition/exceeded speed limit,” “disregarded traffic signs, signals, or markings,” and “followed too closely” were the most frequent driver errors associated with severe traffic crashes in highway work zones. Further in-depth studies of these major driver errors were conducted to identify their impacts on severe work zone crashes and the temporary traffic control (TTC) methods that may be effective in eliminating the errors. In these studies, chi-square tests were first utilized to determine the interactions of these driver errors with other crash variables; multivariate frequency analyses were then applied to determine the safety impacts of the driver errors together with the interrelated variables. The crash variables that were inputted into the chi-square tests included at-fault driver age and gender, crash time, light condition, speed limit, area information, number of vehicles in collision, and vehicle type. In addition, the effectiveness of the TTC

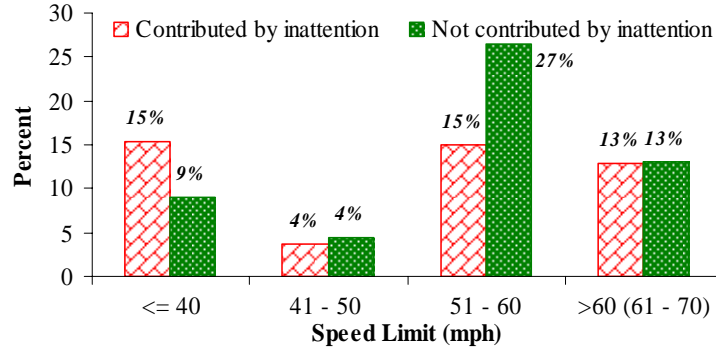
methods (including flagger/officer, stop sign/signal, flasher, no passing zone, and center/edge lines) in preventing these driver errors from causing severe crashes in work zones were evaluated using logistic regression techniques. The severe crashes involving fatalities or injuries that occurred during 2003 and 2004 in Kansas highway work zones were used in these analyses. The results would enable a better understanding of the driver errors and provide knowledge that may lead to safety improvements in highway work zones.

### *Inattentive Driving*

As used in this study, the term “inattentive driving” refers to such driver errors included in the standard State of Kansas motor vehicle accident report as “inattention,” “fell asleep,” “other distraction in or on vehicle,” “distraction-cell phone,” or “distraction-other electronic devices.” Inattentive driving was found to be the most frequent driver error leading to severe crashes in highway work zones. Statistical tests including Pearson chi-square test and likelihood ratio chi-square test indicated that inattentive driving was significantly associated (at a 0.05 level of significance) with the number of vehicles involved in crashes, the speed limit, and area information. Figure 3 shows the distributions of severe work zone crashes, with and without inattentive driving as a contributing factor, over the number of crash vehicles. As seen in the figure, inattentive driving contributed to more than half of the severe work zone crashes involving multiple vehicles, while only about one-third of the single-vehicle crashes had inattentive driving as a causal factor. An explanation might be that inattentive driving could increase the probability of having multiple-vehicle crashes in work zones. Crash frequencies by speed limit and by contribution of inattentive driving showed, as illustrated in Figure 4, that inattentive driving caused larger proportions of severe crashes in work zones with lower speed limits (e.g., work zones with speed limits lower than 41 mph) than in high-speed work zones. In addition, the results of the analysis also suggested that inattentive driving contributed to a larger proportion (88% vs. 83%) of the severe crashes in rural work zones than in urban work zones.



**Figure 3. Crash distribution over number of vehicle and involvement of “inattentive driving”**



**Figure 4. Crash distribution over speed limit and involvement of “inattentive driving”**

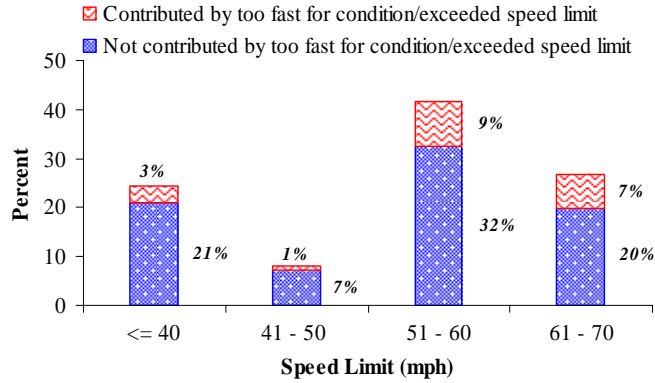
Using a logistic regression technique, the researchers evaluated the effectiveness of several TTC methods commonly used in work zones to prevent “inattentive driving” from causing severe crashes. These TTC methods included flagger/officer, stop sign/signal, flasher, no passing zone, and center/edge lines. Among these traffic controls, statistical analyses showed that a flagger/officer was effective in reducing inattentive driving in work zones. By denoting  $Y = 1$  as the occurrence of a severe crash caused by inattentive driving and  $X$  as the presence of flagger control ( $X = 1$  as present and  $X = 0$  as not present), the following logistic regression model was fitted at a 0.1 level of significance:

$$\text{logit}\{Y = 1|X\} = 0.34 - 0.51X \quad (5)$$

The odds ratio between a severe crash caused by inattentive driving with and without flagger control was estimated as 0.60. Therefore, using a flagger could reduce the odds that “inattentive driving” would cause severe crashes by 40% in highway work zones.

#### *Too Fast for Condition/Exceeded Speed Limit*

“Too fast for condition/exceeded speed limit” was another common driver error that contributed to a large proportion of the severe crashes involving fatalities or injuries in highway work zones. Chi-square tests indicated that this driver error was statistically related to crash time, speed limit, and area information. Hence, crash frequencies were analyzed for the combinations between the driver error “too fast for condition/exceeded speed limit” and these variables. The frequencies of the severe crashes in work zones in terms of speed limit and involvement of the driver error “too fast for condition/exceeded speed limit” were shown in Figure 5. This driver error contributed to much larger proportions of the crashes in work zones with high speed limits (51 mph to 70 mph), which may indicate that speeding in high-speed work zones was more likely to cause severe crashes than in low-speed work zones. In addition, frequency analysis results indicated that the driver error “too fast for condition/exceeded speed limit” contributed to a larger proportion (21% vs. 7%) of the crashes in rural work zones than in urban work zones. Based on the analysis of crash time, a much smaller proportion of the crashes during morning peak hours (6:00 a.m. to 10:00 a.m.) were contributed by this driver error.



**Figure 5. Crash distribution by speed limit and involvement of “too fast for condition/exceeded speed limit”**

When studying the effectiveness of TTC methods in preventing severe crashes in work zones caused by “too fast for condition/exceeded speed limit,” two traffic control methods, including flagger/officer and pavement center/edge lines, were discovered to have positive impacts on preventing speeding from causing severe crashes in work zones at the 0.10 level of significance. In modeling the effectiveness of using a flagger/officer, the logistic regression model was estimated as follows:

$$\text{logit}\{Y = 1|X\} = -1.01 - 0.46X \quad (6)$$

where  $Y = 1$  represents the occurrence of a severe work zone crash caused by the driver error “too fast for condition/ exceeded speed limit” and  $X$  denotes the presence of flagger control. According to this model, the odds ratio of a severe crash caused by “too fast for condition/ exceeded speed limit” with vs. without flagger control was 0.63. In another words, using a flagger to direct traffic in a work zone lowered the odds of having a severe crash caused by this driver error by 37%.

Results of logistic regression analysis suggested that having center/edge lines on work zone pavement was also effective in reducing the probability of severe crashes caused by “too fast for condition/exceeded speed limit.” The statistical model for the effectiveness of this TTC method is as follows:

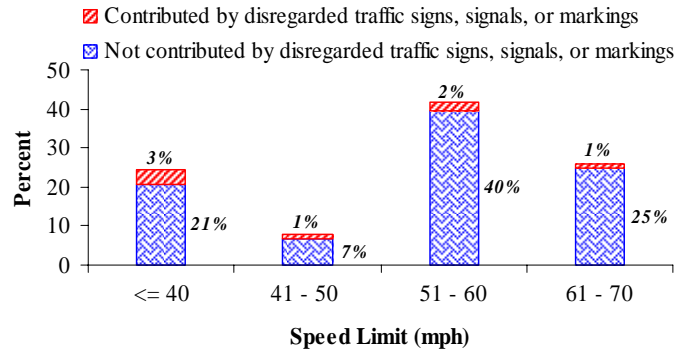
$$\text{logit}\{Y = 1|X\} = -1.61 - 0.35X \quad (7)$$

where  $Y = 1$  is the occurrence of a severe work zone crash caused by the driver error “too fast for condition/exceeded speed limit” and  $X$  is the presence of pavement center/edge lines. The odds ratio of a severe crash caused by this driver error with vs. without center/edge lines was estimated as 0.71. Therefore, having pavement center/edge lines in work zones would reduce the odds of a severe crash caused by this driver error by 29%.

#### *Disregarded Traffic Signs, Signals, or Markings*

According to the Pearson and likelihood ratio chi-square tests, the probabilities that the driver error “disregarded traffic signs, signals, or markings” would cause severe crashes in work zones were different with different speed limits. As seen in Figure 6, although the percentage of crashes caused by this driver error were all small in various speed zones, the proportions of crashes caused by this driver error in low-speed zones (speed limits lower than 51 mph) were considerably larger than in work zones with speed limits higher than 50 mph. For example, 12.5% of the crashes (3% out of 24%) in work zones with speed

limits lower than 41 mph were caused by “disregarded traffic signs, signals, or markings,” while the corresponding percentage in 61 to 70 mph zones was less than 4% (1% out of 26%).



**Figure 6. Crash frequencies by speed limit and involvement of “disregarded traffic signs, signals, or markings”**

To evaluate the effectiveness of TTC methods in reducing the driver error “disregarded traffic signs, signals, or markings,” logistic regression models were fitted by letting  $Y = 1$  denote the occurrence of a work zone crash and  $X$  denote the presence of the TTC method under evaluation ( $X = 1$  as present and  $X = 0$  as not present). At the 0.10 level of significance, the flagger/officer and no passing zone controls were found effective in preventing the driver error from causing severe crashes in work zones. For the flagger/officer traffic control, the logistic regression model is as follows:

$$\text{logit}\{Y = 1|X\} = -1.78 - 0.77X \quad (8)$$

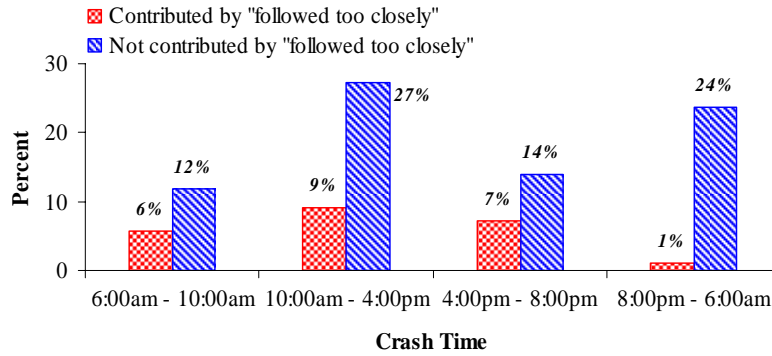
The odds ratio of a severe work zone crash caused by the driver error “disregarded traffic signs, signals, or markings” when a flagger/officer control was/was not present was estimated at 0.46. For the no passing zone control, the regression model was developed as follows:

$$\text{logit}\{Y = 1|X\} = -2.20 - 0.35X \quad (9)$$

The odds ratio of a severe work zone crash caused by this driver error when a no passing zone control was/was not present was 0.71. Based on these results, the flagger/officer and no passing zone controls could reduce the odds of this driving error causing a severe work zone crash by 54% and 29%, respectively.

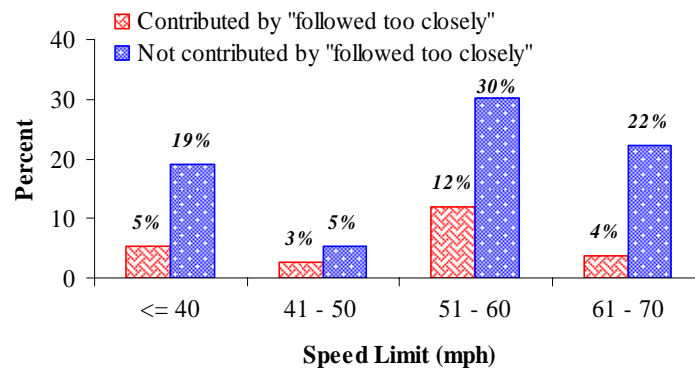
#### *Followed Too Closely*

Pearson and likelihood ratio chi-square tests showed that the driver error “followed too closely” was statistically related to crash variables such as crash time, light condition, vehicle type, speed limit, and area information. Crash frequency analyses in terms of crash time and presence of the driver error “followed too closely” showed that the proportion of the crashes caused by “followed too closely” in daytime work zone crashes was considerably higher than in nighttime crashes (8:00 pm to 6:00 am), as shown in Figure 7. This fact confirms that “followed too closely” was more likely to occur during the daytime, when traffic volume was high. Correspondingly, a much larger proportion of the crashes in good light conditions than in poor light conditions were contributed to by “followed too closely.”



**Figure 7. Crash frequencies by crash time and involvement of “followed too closely” driver error**

In regard to vehicle type, a much larger proportion of the crashes involving only light duty vehicles than the crashes involving heavier trucks was attributed to the driver error “followed too closely.” Regarding the relationship between speed limit and “followed too closely,” as shown in Figure 8, a relatively small proportion of the crashes in high-speed zones (e.g., work zones with speed limits between 61 and 70 mph) were associated with this driver error. This could be a result of the relatively low traffic density on high-speed roads. Similarly, analyses also showed that a considerably larger proportion of urban work zone crashes than rural work zone crashes were attributed to the “followed too closely” driver error.



**Figure 8. Crash frequencies by speed limit and involvement of “followed too closely” driver error**

Based on logistic regression analyses, traffic controls were identified that could affect the probability that “followed too closely” would cause severe crashes. The researchers found that pavement center/edge lines were effective in preventing this driver error from causing severe crashes in highway work zones. The regression model developed for evaluating the effectiveness of center/edge lines is as follows:

$$\text{logit}\{Y = 1|X\} = -1.30 - 0.20X \quad (10)$$

where  $Y = 1$  is the occurrence of a severe crash caused by “followed too closely” and  $X$  is the presence of the pavement center/edge lines ( $X = 1$  for present and  $X = 0$  for not present). The odds ratio of a severe crash caused by “followed too closely” when pavement center/edge lines were/were not present was estimated at 0.81. This indicates that having center/edge lines in work zones may reduce the odds of severe crashes caused by “followed too closely” by 19%.

The stop sign/signal control, on the other hand, was found to be countereffective in preventing the “followed too closely” driver error. The logistic regression model for stop sign/signal control ( $X$  represents the presence of stop sign/signal) was fitted as follows:

$$\text{logit}\{Y = 1/X\} = - 2.38 + 1.26X \quad (11)$$

The odds ratio of a severe crash caused by the driver error “followed too closely” when stop sign/signal control was/was not present was estimated at 3.53. Therefore, statistically speaking, work zones having stop sign/signal control may have roughly 3.5 times the chances of experiencing a severe crash caused by the “followed too closely” driver error than work zones without stop signs/signals. Therefore, the installation of stop signs/signals in work zones should be carefully planned, and supplemental traffic control devices should be used to avoid crashes caused by the “followed too closely” driver error.

## CONCLUSIONS AND RECOMMENDATIONS

Work zone safety has been a focus of research for many years, and improving safety in highway work zones is a high-priority task for traffic engineers. Because a significant proportion of work zone crashes are attributed to driver errors, preventing driver errors from causing severe crashes in work zones is a top-priority objective. Based on the severe crashes involving injuries or fatalities in Kansas highway work zones from 1992 to 2004, the human factors, including at-fault driver characteristics and the driver errors frequently leading to severe crashes, were systematically examined. The effectiveness of several TTC methods in preventing driver errors from causing crashes in work zones was also evaluated using the logistic regression method. This knowledge regarding the role of human factors in work zone crashes will lead to a better understanding of the influence of human factors and will enable the development of safety improvements in work zones.

Study results showed that most of the work zone crashes involving fatalities or injuries were caused by male drivers. Drivers younger than 25 years of age frequently caused severe crashes in work zones. In terms of fatal crashes only, the drivers between 35 and 44 years of age and senior drivers older than 64 years had the highest crash frequencies. In addition, driver errors were the most common causal factors of the severe crashes in work zones, and “inattentive driving” was the most prominent, followed by “too fast for conditions/ exceeded speed limit,” “followed too closely,” and “disregarded traffic signs, signals, or markings.” The authors did not find statistical relationships between the age and gender of at-fault drivers and these driver errors. Further examinations of the most common driver errors showed the following:

1. “Inattentive driving” caused proportionally more multivehicle crashes than single-vehicle crashes in work zones, and this error is most likely to cause severe crashes in work zones with speed limits no higher than 40 mph. A traffic control study showed that using a flagger/officer to direct traffic in a work zone could effectively reduce the odds of severe crashes caused by “inattentive driving.”
2. “Too fast for condition/exceeded speed limit” tended to cause proportionally more severe crashes in high-speed (51 to 70 mph) work zones and rural work zones. In addition, using flagger/officer controls or having center/edge lines in work zones may considerably lower the odds of severe crashes caused by this driver error.
3. “Disregarded traffic signs, signals, or markings” caused a larger proportion of severe crashes in work zones with speed limits lower than 51 mph than in work zones with higher speed limits. Logistic regression analyses indicated that flagger/officer controls and no passing zone controls in work zones could effectively prevent this driver error from resulting in severe crashes involving fatalities or injuries.

4. The “followed too closely” driver error caused larger proportions of severe crashes during daytime hours and in work zones with speed limits between 41 and 60 mph. Based on the crash data, the authors found that work zone center/edge lines may lower the odds of severe crashes caused by this driver error by 19%. On the contrary, having stop signs/signals in work zones would dramatically increase the odds of a severe crash caused by this driver error.

Based on these results, potential safety improvements in work zones are recommended. First, to reduce inattentive driving, more effective warning methods need to be developed in work zones to alert the inattentive drivers of the upcoming work zone conditions. Such approaches may include the installation of temporary rumble strips or other raised pavement markings that can effectively alert vehicle passengers by physical vibration. Second, the high frequency of speeding-caused crashes indicates a need for the development of more effective and more strictly enforced speed control strategies in highway work zones. Third, traffic control strategies should be developed to effectively control and enforce safe headways between consecutive vehicles, especially when the platoon contains heavy vehicles. Finally, and importantly, public education programs should be launched to raise the awareness of highway work zone hazards, especially for the young drivers who have the highest probability of causing severe crashes in work zones.

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