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Work Zone Safety Performance on Illinois State Routes

Prepared by
Kerrie Schattler
Sadit Maharjan
Audrey Hawkins
Krishnanand Maillacheruvu
Bradley University

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7. Authors Kerrie L. Schattler (https://orcid.org/0000-0003-4184-8318), Sadit Maharjan (https://orcid.org/0000-0001-9460-8276), Audrey Hawkins, Krishnanand Maillacheruvu (https://orcid.org/0000-0002-8995-2029)	**8. Performing Organization Report No.** ICT 20-002 UILU-ENG-2020-2002
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16. Abstract

The Illinois Department of Transportation (IDOT) faces challenges in understanding the causes of increased work zone crashes. Although direct safety metrics of work zone (WZ) crashes are useful, they do not completely reflect work zone safety performance. A research project was commissioned to examine the correlation between WZ exposure and crashes and fatalities/injuries, which included three main objectives. The first objective was to more clearly quantify and report yearly trends on WZ crashes with an emphasis on fatal and injury crashes with respect to WZ exposure variables. Data were recorded for WZ traffic crashes from 2013 to 2017, WZ characteristics for IDOT roads, and roadway characteristics. Work zone safety performance measures were determined for the following: WZ total crashes, WZ fatal (K) and A-injury crashes, WZ fatal/injury (K, A, B, C) crashes, WZ fatalities/injuries, number of IDOT work zones, WZ miles, WZ days, and WZ day-miles. Crash rates were calculated for the four crash types and four WZ exposure variables. Annual trend analyses were conducted for 16 crash rates, which provided additional insights in WZ safety trends in Illinois. The second objective was to conduct an in-depth analysis of site-specific WZ sites and characteristics in Illinois to develop prediction tools. Data for 384 sites were used in a model calibration and validation study, using statewide databases. Safety performance functions (SPFs) for predicting total and fatal/injury WZ crashes were developed and supplemented by an Excel tool to assess WZ safety, and crash modification factors (CMFs) for WZ length and duration were derived. The third objective was to identify gaps in existing WZ data in Illinois and make recommendations on data needs. Several issues with the WZ data currently collected by IDOT were identified. FHWA's Work Zone Data Initiative manuals provide recommended practices for collecting and managing uniform WZ activity data across jurisdictional and organizational boundaries. These manuals were used as the basis for recommending WZ data collection improvements in Illinois. This report discusses data collection procedures, issues, and assumptions made to overcome them, as well as the annual work zone crash rates with recommended exposure variables. The SPF and CMF development process and resulting SPF models are presented, along with how they can be applied to improve work zone safety. Finally, this report presents data needs and recommendations for collecting and maintaining work zone data with higher levels of accuracy that also support the FHWA work zone data initiatives. Overall, this research will aid in assessing safety aspects of work zones, which will enable IDOT to make progress towards achieving zero WZ fatalities.

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Members of the Technical Review Panel (TRP) were the following:

- Juan Pava (TRP Chair), IDOT
- Kyle Armstrong, IDOT
- Mark Blankenship, IDOT
- Mike Copp, IDOT
- Anna Ghidina, IDOT
- Paul Gurklys, IDOT
- Dean Mentjes, FHWA
- Marshall Metcalf, IDOT
- Carlos Munoz, IDOT
- Susan Stitt, IDOT
- Megan Swanson, IDOT
- Kyle Videgar, IDOT

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EXECUTIVE SUMMARY

The Illinois Department of Transportation (IDOT) faces challenges in understanding the causes for increased work zone crashes. Although direct safety metrics such as the number of work zone fatal and A-injury crashes are available, they do not completely reflect work zone safety performance. Three objectives were established for this research. The first objective is to more clearly quantify and report yearly trends on work zone crashes and injuries with an emphasis on fatal and A-injury crashes with respect to work zone exposure variables such as number of work zones, work zone length, and work zone duration. The second objective is to conduct an in-depth analysis of site-specific work zone sites and characteristics in Illinois to develop prediction tools such as safety performance functions (SPFs) and crash modification factors (CMFs) to assess work zone safety. The third objective is to identify gaps in existing work zone data in Illinois and make recommendations on data needs. Overall, this research will aid in assessing safety aspects of work zones, which will enable IDOT to make progress towards improving safety and reducing fatalities and serious injuries in work zones.

Work Zone Safety Performance Measures

The three performance measures that were used to quantify work zone safety in Illinois are (1) traffic crash frequencies, (2) exposure variables, and (3) crash rates.

Data from three main sources were obtained from IDOT to analyze work zone safety performance in Illinois from 2013 to 2017. They are the traffic crash, lane closure, and roadway network databases. The three databases were fused to obtain work zone information in terms of traffic crash frequencies and work zone exposure variables in Illinois. Annual work zone frequencies were obtained and trend analyses were conducted for all roads and IDOT roads for the following crash types: total work zone (WZ) crashes, WZ fatal (K) and A-injury crashes, WZ fatal/injury (K, A, B, C) crashes, and WZ fatalities/injuries.

WZ exposure variables were only available for IDOT roads. Thus, annual trends of work zone exposure variables were quantified for IDOT roads only from 2013 to 2017 for the following: number of IDOT work zones, WZ miles, WZ days, and WZ day-miles.

Crash rates were then calculated for the four work zone crash types and four exposure variables. Annual trend analyses were conducted for 16 crash rates for IDOT roads from 2013 to 2017, which revealed that WZ exposure variables and crash rates do provide additional insights into WZ safety performance and should continue to be collected in the future.

Site-Specific Work Zone Analysis

For the site-specific work zone analysis, data for 384 work zone sites were used in a model calibration and validation study, using multiple statewide databases. SPFs were developed to predict total work zone crashes (for all crash severities—K, A, B, C, and property damage only [PDO]) and work zone fatal/injury crashes (K-, A-, B-, and C-injury crashes).

Safety Performance Functions

Twelve data elements for each of the 384 work zone sites were queried from three IDOT sources: the traffic crash, lane closure, and road network databases. The 12 data elements included work zone crash, operational, and characteristic data, as well as non-work-zone crashes, geometry, and characteristics. The characteristics of the 384 work zone sites were compiled and analyzed using the IBM SPSS statistical analysis software. Assuming an underlying Poisson/negative binomial distribution, which is a common assumption in modeling traffic crashes per the *Highway Safety Manual*, SPF models were then developed to predict crashes using variables that were found to have a statistically significant influence on work zone total crashes and fatal/injury crashes.

Three statistically significant models were developed for total work zone crashes and one for work zone fatal/injury crashes. Statistically significant results for a work zone K-A crash model specifically could not be developed, and thus was not able to be included in this research.

The 384 work zone sites were initially divided into a calibration group or a validation group. The calibration data set included 256 randomly selected work zone sites. The four resulting variables of the 12 considered that were found to have a statistically significant impact on crashes were work zone duration (D), work zone length (L), annual average daily traffic (AADT), and the product of non-work-zone speed limit and work zone speed limit (NWZ SL x WZ SL).

The remaining 128 sites were used to develop validation models. Analyses were conducted to confirm the models developed with the calibration data set through comparisons with the validation models. Such analyses included analysis of cumulative residual (CURE) plots, goodness-of-fit statistical tests, and comparison of individual variable coefficients, standard errors, and p-values between the calibration and validation data sets.

The results of these analyses identified which of the three resulting total work zone crash SPF models was superior and that the fatal/injury work zone model was validated. Once the general form of the total and fatal/injury work zone models were validated, the two subsets were combined to develop the final values of the coefficients for the SPF variables in each model, using the pooled set consisting of all 384 sites. A statistical analysis of the observed and predicted work zone crashes was conducted. The results indicated a nonsignificant difference, which means that the models were accurately able to predict work zone total and fatal/injury crashes. All statistical analyses were conducted at 95% level of confidence. The recommended SPF models are as follows:

$$\mu_{Total} = e^{-7.049} \times D^{0.904} \times L^{0.317} \times AADT^{0.486} \times e^{-0.0004(NWZ\ SL \times WZ\ SL)}$$

$$\mu_{Fatal/Injury} = e^{-2.872} \times D^{0.812} \times L^{0.323} \times e^{-0.0005(NWZ\ SL \times WZ\ SL)}$$

A Monte Carlo simulation analysis was conducted to determine the relative impact of the variables in each of the total and fatal/injury work zone SPFs models. Both the total and fatal/injury work zone crash models revealed that the variables with the highest relative impact were NWZ SL x WZ SL, followed by work zone duration.

Excel Tool for SPF Calculations

An Excel tool was developed to facilitate the ease of the calculations for the SPFs and assess safety performance of work zones in Illinois. A user can analyze a single work zone, or up to three work zone alternatives at a time. The tool includes a tutorial worksheet, which explains the basic components of a work zone and descriptions of the color-coding schemes for data input, and a Work Zone Safety Performance—Analysis using the Work Zone SPFs worksheet. In the latter worksheet, a user would input data and the results would be generated for total and fatal/injury work zone crashes per WZ duration.

Crash Modification Factors

CMFs were extracted from the SPF coefficients for total WZ crashes for work zone length (0.317) and work zone duration (0.904), and for fatal/injury work zone crashes for length (0.323) and duration (0.812). The CMFs developed for IDOT work zones were compared with those developed in the past by other authors, which revealed similarities for duration. Differences in the CMF for WZ length were observed, which may be due to the minimum work zone length considered in the data samples.

Work Zone Data Needs

Several issues with the work zone data currently collected by IDOT were identified. FHWA's Work Zone Data Initiative manuals provide recommended practice for collecting and managing uniform work zone activity data across jurisdictional and organizational boundaries. These manuals were used as the basis for developing recommendations in a tiered priority list of work zone data improvement needs in Illinois.

The following is the suggested high-priority list for improving the quality of work zone data in Illinois.

Priority 1 Work Zone Variables

- For number of work zones: identifier, project ID, project event ID
- For work zone duration: actual start date/time, actual end date/time
- For work zone length: actual begin location, actual end location
- Other critical exposure variables:
    - AADT
    - Work zone average daily traffic
    - Speed limit of road under normal conditions
    - Work zone speed limit
    - Functional classification of road

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LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AADT	Annual average daily traffic
ADT	Average daily traffic
AIC	Akaike’s Information Criterion
ASCE	American Society of Civil Engineers
BIC	Bayesian Information Criterion
CMF	Crash modification factor
CMH	Cochran-Mantel-Haenszel
CN	Condition numbers
CSI	Crash severity index
CURE	Cumulative residual
DOT	Department of Transportation
FHWA	Federal Highway Administration
GIS	Geographic Information System
HSM	*Highway Safety Manual*
IDOT	Illinois Department of Transportation
LOC	Level of confidence
MAD	Mean absolute deviation
MASD	Mean absolute scaled deviation
MENB	Measurement error negative binomial
MPB	Mean predicted bias
MOT	Maintenance of traffic
NCHRP	National Cooperative Highway Research Program
NHWZSP	National Highway Work Zone Safety Program
NWZ SL × WZ SL	Product of non-work-zone and work zone speed limits
OPER 2410	Road restriction form used to create IDOT’s lane closure database
PDO	Property damage only
SPF	Safety performance function
TRP	Technical Review Panel
TTC	Temporary traffic control
VATraffic	Virginia Traffic Information Management System
VDOT	Virginia Department of Transportation
VMT	Vehicle miles traveled
WisLCS	Wisconsin Lane Closure System
WZ	Work zone
WZAD	Work zone activity data
WZDI	Work Zone Data Initiative

CHAPTER 1: INTRODUCTION

Historically, safety in work zones has been a major concern to transportation professionals, regulatory and law enforcement agencies, construction companies and their workers, maintenance crews, utility companies, and the motoring public at large. Over the past few years, work zone crashes have increased by 38% in the US from 67,887 in 2013 to 94,000 in 2017. Additionally, work zone fatal crashes in the US increased by 3%, while fatal crashes outside of work zones decreased by 1.5% from 2016 to 2017 (FHWA, 2019a, 2019b).

The Federal Highway Administration (FHWA) established the National Highway Work Zone Safety Program (NHWZSP) to enhance safety and operational efficiency of highway work zones for highway users (FHWA, 2019b). One of the four components of the NHWZSP is to "Improve Evaluation of Work Zones." Through safety evaluation and performance measure assessment, an agency can analyze crash trends, identify safety deficiencies, and develop countermeasures to alleviate work zone crashes and injuries. Work zone safety evaluation also helps to measure the benefits of current safety practices.

Current Federal Regulations (23 CFR 630 Subpart J) encourage states to collect and analyze both safety and mobility data to address work zone impacts at an agency level. Work zone evaluation involves developing performance measures, encouraging widespread use of measures, tracking measures over time, and using the findings to identify and make improvements. Performance measures can help agencies assess if and how their work zone safety policies, processes, and procedures are working well or should be improved (Ullman et al., 2013).

Historically, work zone mobility data has been widely tracked by agencies, and many tools are available to assist in quantifying and analyzing mobility data. However, research on assessing the safety performance of work zones is limited. Crash modification factors (CMFs) and safety prediction models for work zones are provided in the *Highway Safety Manual* (*HSM*) (Khattak et al., 2002; AASHTO, 2010) that account for the effects of project length and duration on crash frequency as compared with normal road operations. The crash data used to derive the CMFs in the *HSM* are from one state, California. Since the publication of the *HSM*, a few studies have been conducted to calibrate or update CMFs in Missouri, Indiana, and Michigan (Sun, et al., 2014; Venugopal & Tarko, 2000; Rista et al., 2017).

In 2014, as a part of the Smart Work Zone Deployment Initiative, researchers in Missouri calibrated the *HSM*'s work zone CMFs for duration and length for the Midwest region (Sun et al., 2014). Similar research was conducted in 2000 in Indiana to develop CMFs for work zone duration and length (Venugopal & Tarko, 2000). Research conducted in Michigan examined the safety impacts of temporary traffic-control strategies on freeways, including shoulder closures, lane closures, and lane shifts (Rista et al., 2017). The authors found that "crash rates increase more rapidly in work zones that are shorter in length or duration. Single-lane closures, multilane closures, and lane shifts were associated with an increase in crashes, whereas shoulder closures did not show a significant difference compared with similar, non-work-zone conditions" (Rista et al., 2017, p. 1). A comparison of the CMFs from this past research shows that CMFs for work zone length in miles varies from 0.58

in the Missouri study (Sun et al., 2014) to 0.82 in the Michigan study (Rista et al., 2017), while the CMFs for project duration in days varies from 0.90 in the Michigan study (Rista et al., 2017) to 1.11 in the California study (Khattak et al., 2002; AASHTO, 2010).

Many state departments of transportation, including the Illinois Department of Transportation (IDOT), face challenges in understanding the causes in increased work zone crashes. Although direct safety metrics such as the number of work zone fatal and A-injury crashes are available, they do not completely reflect work zone safety performance. Three objectives were established for this research. The first objective is to quantify and report statewide work zone safety performance measures and yearly trends for work zone crashes/injuries and exposure variables such as work zone length, duration, and number of work zones, using available data. The second objective is to conduct an in-depth analysis of site-specific work zone sites and characteristics in Illinois to develop prediction tools, such as SPFs and CMFs, to assess work zone safety. The third objective is to identify gaps in existing work zone data in Illinois and make recommendations on data needs.

This report contains the following chapters:

Chapter 2—Literature Review
Chapter 3—Study Purpose and Methodology
Chapter 4—Work Zone Safety Performance Measures
Chapter 5—Site-Specific Work Zone Analysis
Chapter 6—Methodology for Work Zone Safety
Chapter 7—Work Zone Data Needs
Chapter 8—Conclusions and Recommendations

CHAPTER 2: LITERATURE REVIEW

To assess the work zone safety performance on Illinois state routes, an in-depth literature review was conducted. This search was conducted through web-based queries and queries through specific search engines such as the Transportation Research Board Publication Index, the Transportation Research Information Services, the American Society of Civil Engineers' *Journal of Transportation Engineering*, the Institute of Transportation Engineers Library, and others. Various journals, papers, reports, and other documents were reviewed. A summary of the findings of these documents is divided into the following topics: work zone safety, work zone crash causation, and work zone risk factors.

2.1 WORK ZONE SAFETY

A study by Kweon et al. (2016) developed safety performance measures for work zones in Virginia. Previously, the Virginia Department of Transportation (VDOT) used the number of fatalities and serious injuries in work zone crashes as safety performance measures. However, this does not account for exposure measures such as length and duration. Therefore, the authors conducted a study to determine whether increases in work zone crashes were due to underlying safety issues or the increasing quantity of work zones.

To accomplish this, the VDOT crash database and the Virginia Traffic Information Management System (VaTraffic) were combined. Count measures were found using the crash database, while exposure measures were found using the VaTraffic database. A traffic-monitoring system and roadway inventory databases were also used to obtain additional information. Three of the four databases used (the crash database, traffic-monitoring system, and roadway inventory databases) are subsets of the VDOT Roadway Network System.

The analysis involved visual examinations, correlation analysis, and regression analysis. During the analysis, the research team faced three issues with their data. First, there were differences in how work zone events were coded. For example, in a multiday pavement-marking project, a separate work zone ID would sometimes be created for each day of the advancing project. This would create multiple work zone IDs for one project. However, sometimes just one work zone ID was assigned to an entire pavement-marking project. Because these could not be recorded using a consistent method, the work zone counts were affected in some regions.

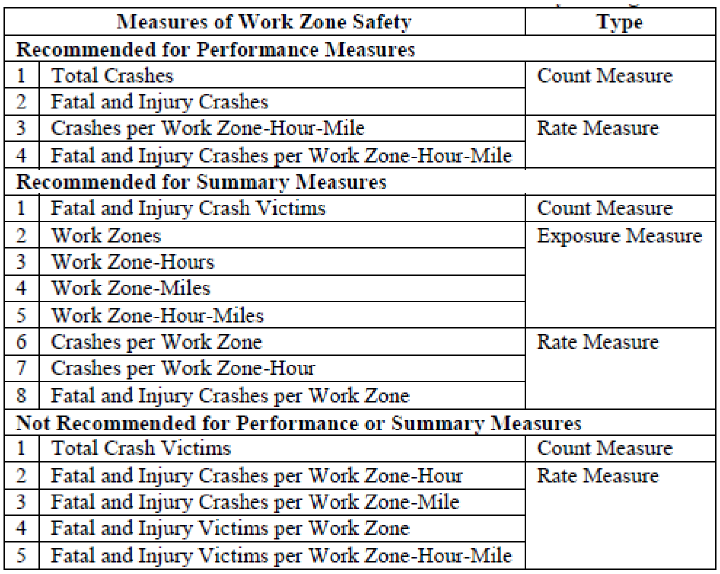
Second, some issues arose while matching traffic crashes to respective work zones. The crash and work zone were considered a match when "the location of the crash lies within the bounds of the work zone and the time of the crash is within the specified time period of the work zone" (Kweon et al., 2016, p. 10). However, the matching success rate was only 20% unless additional time-consuming algorithms were used. Therefore, the work zone crash and event data were not matched very well at a project level. However, the data could still be used for exposure and rate measure calculations at a district, region, and state level. The third data issue was that it was not possible to obtain the traffic volume data at a work zone. It is extremely difficult to record these volumes during a construction project. Therefore, they excluded any traffic volumes from their analysis.

Ultimately, the following count and exposure measures were used (Kweon et al., 2016):

- Count: total WZ crash count, total person count involved in WZ crashes, fatal and injury WZ crash count, and fatality and injury count involved in WZ crashes.
- Exposure: WZ count, WZ-miles, WZ-hours, and WZ-hour-miles.

Using these count and exposure measures, crash rates (crashes per work zone, crashes per WZ-hour, crashes per WZ-mile, etc.) were tested using a linearity condition through regression analysis for three road types (all roads, interstate highways, and non-interstate highways) and four temporal levels of crashes (annual, biannual, quarterly, and monthly).

The authors concluded that "four performance measures are appropriate for monitoring and evaluating the statewide safety performance of work zones and eight summary measures are appropriate for obtaining further insights and understanding with regard to statewide safety issues at work zones in Virginia" (Kweon et al., 2016, p. 27). Figure 2.1 shows the recommended performance and summary measures. The study concluded that the exposure measures are critical when evaluating the safety of a work zone and the exposure measures should reflect both duration and length for the best results.



Measures of Work Zone Safety		Type
Recommended for Performance Measures		
1	Total Crashes	Count Measure
2	Fatal and Injury Crashes	
3	Crashes per Work Zone-Hour-Mile	Rate Measure
4	Fatal and Injury Crashes per Work Zone-Hour-Mile	
Recommended for Summary Measures		
1	Fatal and Injury Crash Victims	Count Measure
2	Work Zones	Exposure Measure
3	Work Zone-Hours	
4	Work Zone-Miles	
5	Work Zone-Hour-Miles	
6	Crashes per Work Zone	Rate Measure
7	Crashes per Work Zone-Hour	
8	Fatal and Injury Crashes per Work Zone	
Not Recommended for Performance or Summary Measures		
1	Total Crash Victims	Count Measure
2	Fatal and Injury Crashes per Work Zone-Hour	Rate Measure
3	Fatal and Injury Crashes per Work Zone-Mile	
4	Fatal and Injury Victims per Work Zone	
5	Fatal and Injury Victims per Work Zone-Hour-Mile	

Figure 2.1. Recommended measures of work zone safety in Virginia (Source: Kweon et al., 2016).

Another study by Kweon et al. (2017) provides details of the process used in Virginia to fuse the crash and roadway databases to determine work zone crash rate measures. For the analysis, four data sources were used, which contained crash data, roadway inventory data, traffic volume data, and roadway activities data (Kweon et al., 2017).

The exposure measures obtained from the data were split into four temporal categories: yearly, biyearly, quarterly, and monthly. These were found for three road types: all roads, interstate highways, and non-interstate highways. This resulted in 192 regression models based on statewide data. Conclusions were made from the regression analyses that were found to be statistically significant. First, although the databases contained imperfect data, it was still possible to find exposure measures from them. Another conclusion was that interstate and non-interstate highways had significantly different safety performance measures. This implies that this data should always be analyzed separately. Next, rate measures involving three characteristics of work zones (total number, duration, and length) seem to be better than those involving two characteristics (Kweon et al., 2017).

A study by Cheng et al. (2012) analyzed work zones by integrating crash and lane-closure data so that more conclusions could be made on the overall safety of a given work zone. Another goal of this study was to develop a method of integrating crash and lane-closure data efficiently. The data sources used in this study were the Wisconsin Lane Closure System (WisLCS) and the Wisconsin crash database.

The matching of work zone crashes and line segments had to satisfy two requirements. First, the crash had to happen during the time of the work zone. Secondly, the crash had to happen in the impact area of the work zone. Figure 2.2 shows the diagram used for location matching. If the crash happened on the same route as the work zone, then it needed to be in between the start and end of the closure (with an additional 0.25-mi buffer zone upstream and downstream). If the crash happened on an intersecting road, then the road had to be between the start and end point of the zone. If the crash happened on a ramp, then the ramp beginning and end needed to be between the start and end of the work zone (Cheng et al., 2012).

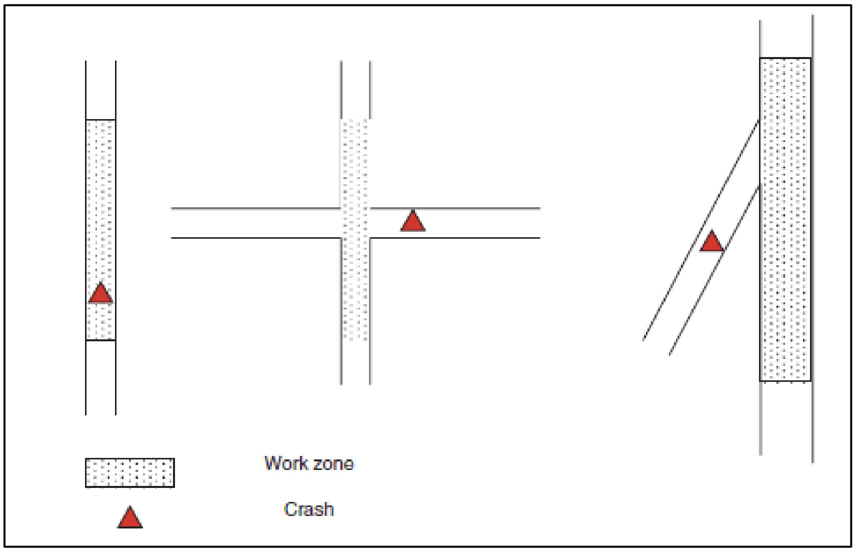


Figure 2.2. Locations of work zones and crashes (Source: Cheng et al., 2012).

Using this matching algorithm, 82.3% of the total crashes, or 1,262 crashes, were matched and analyzed. Of these matched crashes, most occurred inside the work zone. Of the remaining matched crashes, those occurring upstream of the work zone were four times as frequent as those occurring downstream. A total of 255 work zone coded crashes were not matched with a lane closure. The researchers determined that each was caused by one of three errors: crash mapping errors, local work zones, or report coding errors (Cheng et al., 2012).

Various attributes of crashes and lane closures (such as crash severity and crash rates) were compared to determine what combination of attributes may be the most unsafe. However, no actual model resulted for analyzing the likelihood of a crash based on given work zone information. The researchers did conclude that three possible actions could be taken to improve work zone data (Cheng et al., 2012, p. 24):

1. "An alternative way to identify work zone-related crashes that does not rely solely on the police crash report.
2. The ability to monitor work zone safety on a systematic level and within the lane closure approval process.
3. The ability to bring more detailed information about specific work zones to the analysis."

Although they were able to merge the lane closure and crash data fairly well, the authors believe that any one of these actions could bring about better work zone safety analyses (Cheng et al., 2012).

Another study by Cheng et al. (2015) provides details for the data integration process used to combine crash and real-time traffic and lane closure data for analysis. The sources that were integrated were statewide lane closure data, police crash reports, and ITS traffic detector data (Cheng et al., 2015). Additionally, the Wisconsin Lane Closure System, WisLCS, was analyzed individually during this study. All data systems used were available in the Wisconsin Transportation Portal. The process of data integration is outlined as three tasks: "(1) obtain the work zone length and actual duration, (2) find all crashes that occurred near or within work zones and all ITS detectors that are located upstream, within or downstream of those work zones, and (3) calculate the actual vehicle mile traveled (VMT) for work zones" (Cheng et al., 2015, p. 5).

First, to obtain the work zone lengths, the beginning highway mileage was subtracted from the end highway mileage. If the work zone was represented as a point instead of a segment, then a distance of 0.25 mi was assigned to it. The WisLCS also categorized their lane closures into four duration types: daily/nightly, weekly, continuous, and long term. These were accounted for while calculating duration; however, the primary method was subtracting the start date from the end date. Lastly, work zone VMT was calculated by multiplying the length of the work zone by the total volume of traffic that traveled through the work zone while it was active. This volume was obtained using volume, speed, and occupancy detectors.

From 2009 to 2012, there were 20,425 work zones with reliable traffic data and nearby detectors during work zone periods that were used in the authors' study. Of these, 1,564 work zones had at least one crash occur within them. In Wisconsin, a total of 4,273 work zone crashes occurred from 2009 and 2012, while 2,054 crashes occurred in the sample of 1,564 work zones. In the end, the researchers believe that they were able to create a "successful alignment of previously disparate data sources to a common linear referencing system" (Cheng et al., 2015, p. 16).

The authors then calculated work zone crash rates using actual VMT as the exposure variable and conducted a comprehensive review of statewide work zone safety. The authors concluded that: "(1) different work zone settings have different impacts on the crash rate and crash severity, and (2) planned work zones with shorter duration, and fewer lanes closed are generally safer than unplanned, longer and more lanes closed ones" (Cheng et al., 2015, p. 16).

Research conducted by Rista et al. (2017) compared different work zone traffic-control strategies. The lane-closure types included in this comparison are shoulder closures, lane closures, and lane shifts. The specific characteristics evaluated were segment length, duration, traffic volume AADT, and closure type. Data for this study was collected during two separate time periods: during the construction period and the same time period from the prior year (when no construction was taking place) (Rista et al., 2017).

The sources of the data included the Michigan DOT's lane closure reports, AADT estimates, and the Michigan state police traffic crash database. The data was analyzed using Poisson and negative binomial modeling. The results of the analysis showed significant increases in crashes from pre-work zone to work zone conditions for lane closures and lane shifts. This was especially true if a single-lane closure occurred on a four-lane highway, with two lanes in each direction. However, they concluded that there was no significant increase when the closure type was a closed shoulder (Rista et al., 2017).

The authors' research also examined the impacts of changes in traffic volumes, work zone length, and duration. The average effect of AADT was 1.10, indicating that increases in annual average traffic volumes results in increased crashes. The average effect of work zone length was 0.82, and the average effect of work zone duration was 0.90. The authors concluded that "crash risk is highest at short-duration work zones and tends to level off over time" (Rista et al., 2017, p. 91). In the analysis of Michigan's work zones, a number of shorter projects (with a minimum of three days) were analyzed. The authors also stated that drivers traveling through longer work zones in place over a longer duration may acclimatize themselves to a work zone over time and over longer distances (Rista et al., 2017).

The study by Ullman et al. (2008) compared the driver risk associated with nighttime versus daytime work zones. This research evaluated management practices that increase the safety and mobility of work zones and provided recommendations regarding work zone crash reporting to improve the available data. The main sources of data used in this study were the New York State DOT crash database and the work zone activity and crash databases for 64 projects located in California, North Carolina, Ohio, and Washington.

First, the authors concentrated on the New York State DOT database for road closure and crash information for work zones on freeways and expressways. They analyzed time of crash as occurring during the day or night, crash severity, contributing factors, and other crash and road closure characteristics. In this database, crashes occurring in work zones between 6 a.m. and 6 p.m. were coded as daytime crashes and those occurring between 6 p.m. and 6 a.m. were coded as nighttime crashes. The data were collected from 2000 to 2005 and over 3,400 crashes were included in the analysis. The crash data were then organized by daytime and nighttime crashes, and chi-square tests of independence were performed to determine if the differences in the distributions of daytime and nighttime work zone crashes were statistically significant. A summary of the authors' key findings include (1) "About half of daytime work zone traffic crashes and 60% of nighttime work zone crashes on New York State DOT freeways and expressways occur during traffic lane closures, (2) there appears to be little difference in traffic crash severity between daytime and nighttime work operations, and (3) rear-end collisions comprise a smaller proportion of work zone traffic crashes at night work zone operations than during daytime operations" (Ullman et al., 2008, p. 13).

For the second component of the study, after evaluating the data from the 64 projects in California, North Carolina, Ohio, and Washington, multiple conclusions about the differences between daytime and nighttime work zones were made. First, when the work was being performed at night and no temporary lane closures were used, severe crashes increased by 41.4% from non-work-zone conditions. In comparison, daytime work zones with the same conditions experienced a 17.4% increase from non-work-zone conditions. This is possibly due to poor lighting and glare during the night, more equipment and material being delivered in and out of the work area at night, and common issues that drivers have at night regardless of a work zone (Ullman et al., 2008). Also, there were statistically significant increases in property damage only (PDO) crashes at night when the work was inactive and there were no lane closures. This may be due to the same issues stated above. Another finding by the authors was that there was an increased cost of work zone crashes for daytime work compared to nighttime work, which means that the public is experiencing more safety risks driving through daytime construction (Ullman et al., 2008).

Another aspect mentioned by Ullman et al. (2008) involves strategies that can be used to improve the safety of work zones. Based on the AASHTO Strategic Highway Safety Plan and a comprehensive NCHRP publication on work zone safety, the following strategies were identified to increase safety:

- "Improve maintenance and construction practices to reduce work zone duration and to reduce the number of work zones that are required
- Utilize full-time roadway closure for construction operations
- Utilize time-related contract provisions to reduce construction duration
- Use nighttime road work
- Use demand management programs to reduce volumes through work zones
- Design future work zone capacity into new or reconstructed highways" (Ullman et al., 2008, p. 35).

2.2 WORK ZONE CRASH CAUSATION

A study by Akepati and Dissanayake (2011) was conducted to improve the understanding of work zone crash causes by analyzing crash data during a five-year period (2002 to 2006). The study was performed in states under the Smart Work Zone Deployment Initiative, including Iowa, Kansas, Missouri, Nebraska, and Wisconsin. A total of 44,004 crashes out of the 44,678 available in the database were able to be analyzed. Some issues arose with this data such as a lack of consistency among states and lack of available exposure measures. These issues narrowed the crash characteristics that were considered. Chi-square tests of independence were performed to determine whether a variety of variables (light condition, road condition, driver gender, etc.) had a significant impact on the crash severity. Of the 15 variables analyzed, the only one that was statistically insignificant was the impact of the road surface condition on work zone crash severity.

A few of the major findings from this study were that 50% of the work zone crashes occur in the activity area, whereas the safest area of a work zone was before the first warning sign. Also, the most predominant collision type was rear-end crashes. In addition to this, the highest percentage of work zone crashes occurred in those with a lane closure. The authors also suggested that crash report forms be reviewed to improve future analyses, as they contain more information on work zones. Some of the additions they recommended were crash location within work zone, length of work zone, and status of work zone being active or inactive (Akepati & Dissanayake, 2011).

The study by Clark and Fontaine (2015) analyzed crashes that were coded as work zone crashes per the police crash report form. The goal was to determine whether the crashes being coded as work zone crashes were actually related to a work zone. This was done by individually studying Virginia work zone crash data for two years. The specific steps used for analyzing crash reports is as follows:

- “Review crash report narratives to identify if the work zone influenced the likelihood or severity of a crash
- Identify the major factors that contributed to crashes influenced by the work zone and the chain of events that led to the crash, and
- Using this information, identify areas where DOTs should invest greater resources in work zone planning and safety” (Clark & Fontaine, 2015, p. 62).

For the sample, crash types that represented at least 10% of the total crashes were considered. This left 94.8% of the total 6,774 work zone crashes to be analyzed. These crashes occurred between 2011 and 2012. Information was compiled into three categories: total crashes, work zone-coded crashes, and work zone directly related crashes. The work zone directly related crashes were determined by examining police crash reports. Factors that caused the crash to fall into this category were:

- “A work zone vehicle or piece of equipment was struck,
- The crash narrative directly referred to a work zone feature,
- The crash narrative directly indicated that the work zone created changes in flow or speed
- The narrative indicated a specific driver response to the work zone” (Clark & Fontaine, 2015, p. 63).

After the analysis, 23% of the total 6,424 coded crashes were placed into the directly related work zone category. The traffic crashes were further analyzed and subcategorized by cause to determine how work zones influence crashes. Some examples include stopping or slowing because of the work zone, unauthorized work zone entry, and confusion because of work zone traffic control.

The authors concluded that many work zone crashes are caused because of driver behavior, which cannot be fixed by the DOT. However, some improvements that could be made include placing emphasis on improving traffic congestion on interstate work zones and improving traffic control so drivers know when to merge. The authors recommended improvements to the crash report forms for data purposes. This is because they had to manually analyze so much of the report to receive proper data for work zones crashes (Clark & Fontaine, 2015).

A study by Yang et al. (2013) identified work zone risk factors through the estimation of a crash frequency model using crashes and characteristics of 60 site-specific work zones in New Jersey. The authors proposed a measurement error (ME) model integrated with the negative binomial (NB) model, called the MENB, to overcome issues related to work zone length. Many work zone lengths change during the duration of the project and that variability could decrease the accuracy of the models developed. They obtained crash data from the New Jersey DOT database and the work zone length was determined "using the length from the work zone project file, and employing spatial-temporal diagrams of work zone crash data" (Yang et al., 2013, p. 193). Figure 2.3 shows a sample spatial-temporal diagram used in the Yang et al. study.

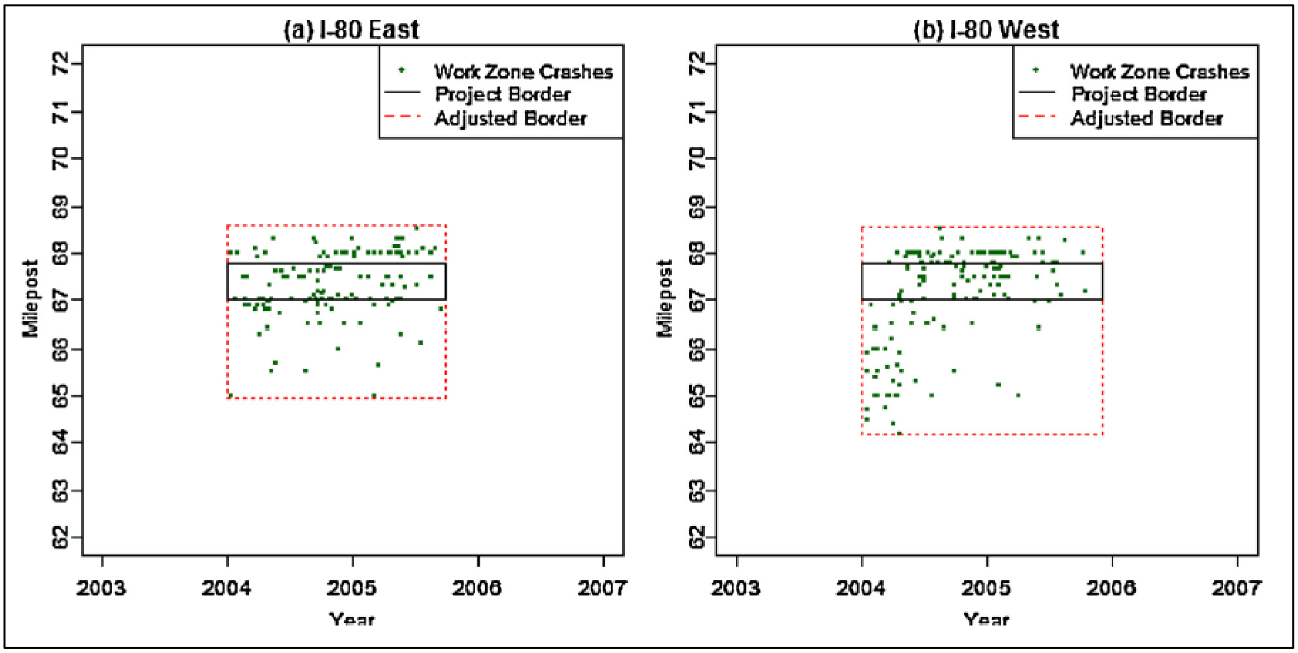


Figure 2.3. Sample spatial-temporal distribution of work zone crashes (Source: Yang et al., 2013).

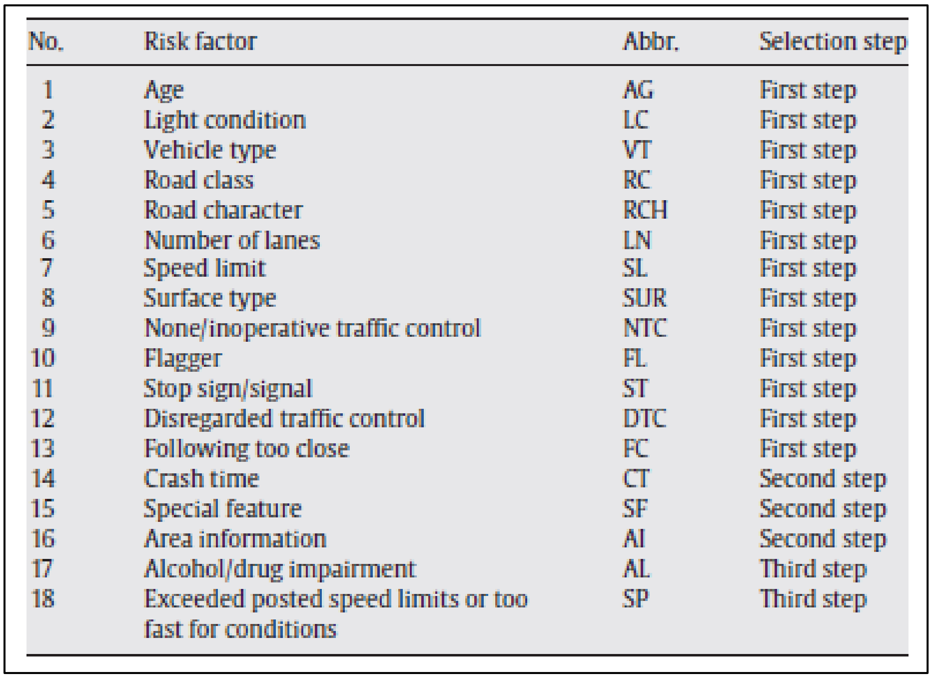
The work zone length obtained from the New Jersey DOT database was inaccurate and did not reflect the actual length during the road work. This is because lengths are recorded prior to the start of the project and changes could occur during the project, which are not reflected in the data. Also, the spatial-temporal method of determining the length of the work zone was inaccurate because it was based on crashes that occurred in the vicinity of the work zone. Because crashes are random, this estimation is not the best way of determining work zone length.

The authors used measurement errors in the modeling process to help reduce the variability imposed by work zone length. A model with a MENB was created for the analysis. Comparing the results of the model with and without the MENB showed that the MENB model achieved more accurate results.

The authors emphasize that although this model can be used to account for measurement errors and improve the overall results, it does not rectify the issue with low-quality data being collected. Therefore, engineers should still strive for more accurate data collection methods for work zone data (Yang et al., 2013).

2.3 WORK ZONE RISK FACTORS

The study by Li and Bai (2008) developed crash severity index (CSI) models to predict the likelihood of fatal crashes occurring in a given work zone. They identified risk factors of past work zones and then used the chi-square test and Cochran-Mantel-Haenszel (CMH) statistics to determine the significance. The crash data was obtained from the Kansas DOT and included 85 fatal and 604 injury crashes. The dates of the fatal crashes ranged from 1998 to 2004, while the dates of the injury crashes ranged from 2003 to 2004. The data collection process also included analyzing crash report forms to clarify unclear or missing information. Figure 2.4 shows the significant risk factors for the work zone crash data analyzed.



No.	Risk factor	Abbr.	Selection step
1	Age	AG	First step
2	Light condition	LC	First step
3	Vehicle type	VT	First step
4	Road class	RC	First step
5	Road character	RCH	First step
6	Number of lanes	LN	First step
7	Speed limit	SL	First step
8	Surface type	SUR	First step
9	None/inoperative traffic control	NTC	First step
10	Flagger	FL	First step
11	Stop sign/signal	ST	First step
12	Disregarded traffic control	DTC	First step
13	Following too close	FC	First step
14	Crash time	CT	Second step
15	Special feature	SF	Second step
16	Area information	AI	Second step
17	Alcohol/drug impairment	AL	Third step
18	Exceeded posted speed limits or too fast for conditions	SP	Third step

Figure 2.4. Selected work zone risk factors (Source: Li & Bai, 2008).

Using the CSI models, the authors were able to accurately predict most crash severity outcomes for given work zones and thus recommend the use of the CSI models when designing a work zone. This will help create countermeasures for high-risk work zones to prevent crashes from occurring. One issue with the model is that it does not accurately predict fatal crashes. This may be due to a much smaller sample of fatal crashes than severe injury crashes. The authors recommended further research on this topic to develop a model that can also accurately predict fatal work zone crashes (Li & Bai, 2008).

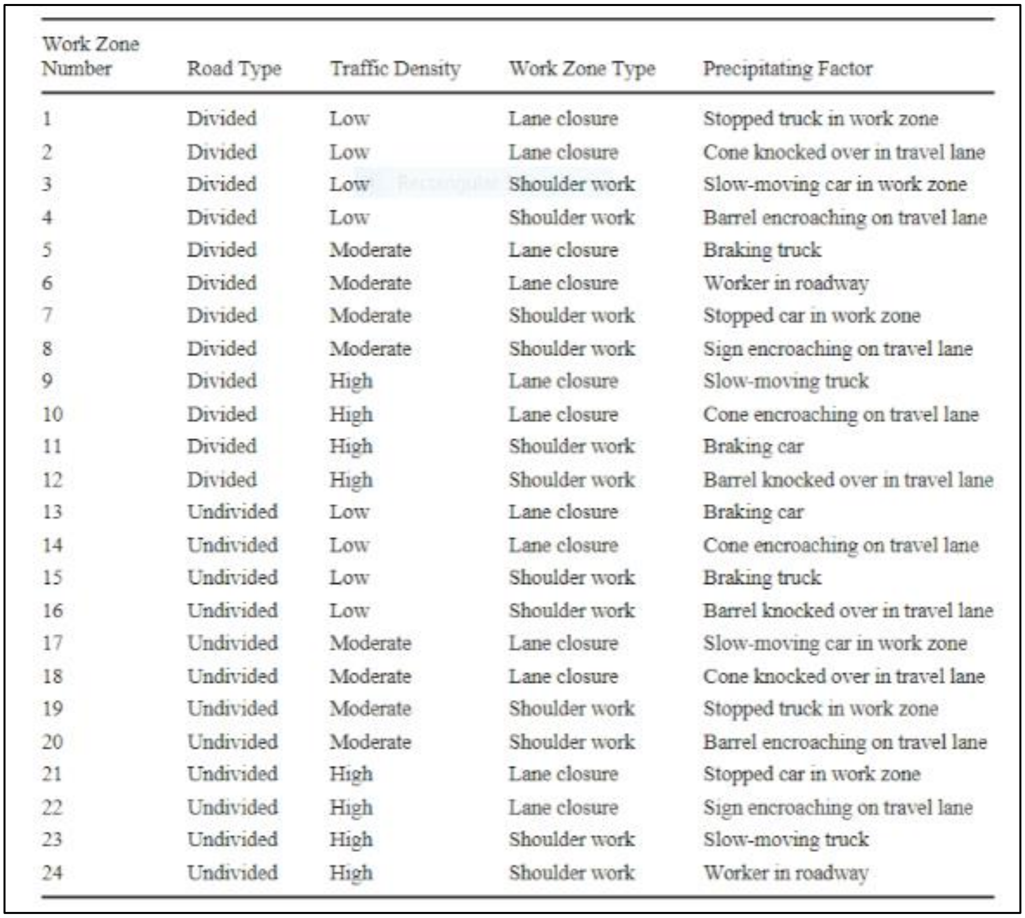
Another study by Li and Bai (2009) used the CSI models developed in their previous work to analyze work zone crashes to identify risk factors that could increase the probability of a fatality in a severe work zone crash. Severe and fatal crashes occurring between 1998 and 2004 and injury crashes occurring between 2003 and 2004 were considered in the study. The data analysis included chi-square testing, CMH statistics, and relevant historical data to identify significant risk factors involved in a fatal work zone crash. Additionally, a frequency analysis and logistic regression were used to analyze the impact of the specific risk factors.

In total, 85 fatal crashes (1998–2004) and 620 injury crashes (2003–2004) occurring on Kansas highway work zones were analyzed in the study. When unclear or missing information was present for crashes in this database, the police crash report forms were reviewed for clarification. Many significant risk factors were identified. First, people in the age ranges of 65+ and 35–44 were more likely to be in a fatal work zone crash. Also, fatal work zone crashes were more likely to occur in poor lighting conditions. This resulted in the recommendation of better illumination of work zones during the night to reduce confusion. Lastly, rural two-lane highways and urban highways with speed limits over 60 mph were more likely to have fatal work zone crashes. Overall, the study by Li and Bai was able to provide insights into what work zone characteristics could pose a significant risk for drivers.

The research conducted by McAvoy et al. (2011) used a driving simulator to determine the most hazardous primary and precipitating factors involved in a work zone crash. The primary factors that were evaluated included roadway type, traffic density, and work zone type. The precipitating factors were ones that could cause either driver behavior or roadway characteristics to change in a way that initiated a work zone crash. A driving simulator was used in the study to eliminate the subjectivity that is often present in crash data.

The driving simulator, a DS-600c Research Simulator, was located at Cleveland State University in Ohio. To obtain data, drivers were maneuvered through various work zone types and road condition scenarios in the simulated environment. Figure 2.5 outlines the various configurations that were tested as a part of this study.

The focus group consisted of 45 participants who lived in the Cleveland metropolitan area and used the freeways during their commute. Their ages ranged from 18 to 49 years, with 75.6% male and 24.4% female. The data from this simulation found that the most hazardous precipitating factors were a stopped work truck and a braking car. Also, the driving situation that was found to be most hazardous was a combination of divided roadways, low-density traffic conditions, and a lane closure. Drivers tended to have the most difficulty when there were many lane deviations because of a lane closure and there were moderate traffic conditions present. The researchers emphasized that although these findings are interesting, they are not real-life situations, so more research should be conducted to confirm the findings (McAvoy et al., 2011).



Work Zone Number	Road Type	Traffic Density	Work Zone Type	Precipitating Factor
1	Divided	Low	Lane closure	Stopped truck in work zone
2	Divided	Low	Lane closure	Cone knocked over in travel lane
3	Divided	Low	Shoulder work	Slow-moving car in work zone
4	Divided	Low	Shoulder work	Barrel encroaching on travel lane
5	Divided	Moderate	Lane closure	Braking truck
6	Divided	Moderate	Lane closure	Worker in roadway
7	Divided	Moderate	Shoulder work	Stopped car in work zone
8	Divided	Moderate	Shoulder work	Sign encroaching on travel lane
9	Divided	High	Lane closure	Slow-moving truck
10	Divided	High	Lane closure	Cone encroaching on travel lane
11	Divided	High	Shoulder work	Braking car
12	Divided	High	Shoulder work	Barrel knocked over in travel lane
13	Undivided	Low	Lane closure	Braking car
14	Undivided	Low	Lane closure	Cone encroaching on travel lane
15	Undivided	Low	Shoulder work	Braking truck
16	Undivided	Low	Shoulder work	Barrel knocked over in travel lane
17	Undivided	Moderate	Lane closure	Slow-moving car in work zone
18	Undivided	Moderate	Lane closure	Cone knocked over in travel lane
19	Undivided	Moderate	Shoulder work	Stopped truck in work zone
20	Undivided	Moderate	Shoulder work	Barrel encroaching on travel lane
21	Undivided	High	Lane closure	Stopped car in work zone
22	Undivided	High	Lane closure	Sign encroaching on travel lane
23	Undivided	High	Shoulder work	Slow-moving truck
24	Undivided	High	Shoulder work	Worker in roadway

Figure 2.5. Work zone scenarios (Source: McAvoy et al., 2011).

CHAPTER 3: STUDY PURPOSE AND METHODOLOGY

IDOT faces challenges in understanding the causes of increased work zone crashes. Although the direct safety metrics such as the number of work zone fatal and A-injury crashes are available, they do not completely reflect work zone safety performance. Three objectives were established for this research. The first objective is to more clearly quantify and report yearly trends on work zone crashes and injuries with an emphasis on fatal and A-injury crashes with respect to work zone exposure variables such as number of work zones, work zone length, and work zone duration. The second objective is to conduct an in-depth analysis of site-specific work zone sites and characteristics in Illinois to develop prediction tools, such as SPFs and CMFs, to assess work zone safety. The third objective is to identify gaps in existing work zone data in Illinois and make recommendations on data needs. The following sections provide an overview of the methodologies used for each objective.

3.1 WORK ZONE SAFETY PERFORMANCE MEASURES

The three performance measures that were used to quantify work zone safety in Illinois are traffic crash frequencies, exposure variables, and crash rate measures.

Data from three main sources were obtained from IDOT to analyze work zone safety performance in Illinois from 2013 to 2017. They are:

- Traffic crash database, in GIS (geographic information system) from 2013 to 2017.
- Lane closure databases (OPER 2410) for points and segments that document road restrictions on IDOT roads.
- Roadway network database, containing the base map and attributes of roads in Illinois.

The three databases were fused to obtain work zone information in terms of traffic crash frequencies and work zone exposure variables in Illinois. Annual work zone frequencies were obtained, and trend analyses were prepared for all roads and for IDOT roads for the following crash types:

1. Total work zone (WZ) crashes
2. WZ fatal (K) and A-injury crashes
3. WZ fatal and injury (K, A, B, C) crashes
4. WZ fatalities and injuries (number of persons injured or killed in work zone crashes)

Exposure variables were only available for IDOT roads. Thus, annual trends of work zone exposure variables were quantified for IDOT roads only for 2013 to 2017 for the following:

1. Number of work zones
2. WZ miles
3. WZ-days
4. WZ day-miles

Crash rates were then calculated for the four work zone crash types and four exposure variables. Annual trend analyses were then prepared for the following 16 crash rates for IDOT roads from 2013 to 2017:

1. WZ total crashes per work zone
2. Fatalities and injuries per work zone
3. Fatal and injury crashes per work zone
4. K-A WZ crashes per work zone
5. WZ total crashes per work zone-mile
6. Fatalities and injuries per work zone-mile
7. Fatal and injury crashes per work zone-mile
8. K-A WZ crashes per work zone-mile
9. WZ total crashes per work zone-day
10. Fatalities and injuries per work zone-day
11. Fatal and injury crashes per work zone-day
12. K-A WZ crashes per work zone-day
13. WZ total crashes per 100,000 work zone-day-miles
14. Fatalities and injuries per 100,000 work zone-day-miles
15. Fatal and injury crashes per 100,000 work zone-day-miles
16. K-A WZ crashes per 100,000 work zone-day-miles

3.2 SITE-SPECIFIC WORK ZONE ANALYSIS

For the site-specific work zone analysis, data for 384 work zone sites were used in a model calibration and validation study, using statewide databases. SPFs were developed assuming an underlying Poisson/negative binomial distribution to predict total work zone crashes (for all crash severities—K, A, B, C, and PDO) and work zone fatal/injury crashes (K-fatal, and A-, B-, and C-injury crashes).

3.2.1 Data Collection

Data for each of the 384 work zone sites were queried from the three IDOT sources: the traffic crash, lane closure, and road network databases. The following data were recorded:

1. IDOT district number and functional classification
2. Work zone duration (number of days)
3. Work zone length (miles)
4. AADT, vehicles per day
5. Number of lanes reduced
6. Speed limit, non-work-zone speed limit (miles per hour)
7. Work zone speed limit (miles per hour)
8. Work zone crashes and injuries—crash frequency by severity per work zone days (confirmed, likely, probable work zone crashes) for
    a. K-A work zone crashes
    b. Fatal/injury work zone crashes (K, A, B, C)
    c. Total work zone crashes (all severities—K, A, B, C, PDO)
9. Pre-construction crash frequency (same duration as respective work zone with no overlap)

10. Number of intersections/ramps in work zone
11. Type of road closure (lane reduction/closure, ramp closed, one-way traffic with flaggers, intermittent road work, one-way traffic with temporary signals, shoulder work, intersection restrictions, shoulder/bridge/road closed, etc.)
12. Work zone crash frequency per work zone days (workers not present and workers present)

The contract identification numbers of the work zones were used to access the maintenance of traffic (MOT) plans and additional data was extracted, such as type of road closure, work zone speed limit, and other information. Historic AADT values were obtained from IDOT's Traffic Count Database System and represent the non-work-zone traffic volumes in vehicles per day.

The lengths of the work zones were estimated from the lane closure database and were supposed to represent the length from the advance warning area to the termination area. However, work zone lengths were not consistently recorded per this definition among the districts in Illinois. To account for this inconsistency, a 0.25-mi buffer was applied upstream and downstream of the work zone segments and the crashes were queried over this distance.

The statewide traffic crash database consists of information from Illinois Traffic Crash Report SR 1050. In 2013, work zone fields were added to the SR 1050 crash report form, including: if a crash occurs in a work zone, the type of work zone (construction, maintenance, utility, or other), and whether workers were present at the time of the crash. The statewide traffic crash database was used to query crash data for the site-specific locations over the duration from 2013 to 2017. The crash report forms were also downloaded and analyzed for the 384 sites to correct coding errors common on these forms.

In addition to obtaining and analyzing traffic crash data for crashes occurring within the work zone, the pre-construction crash frequency was also collected and analyzed for the same duration (same months and days) but for the previous non-work-zone time period, with no overlap.

3.2.2 Detailed Work Zone Crash Analysis

An in-depth crash analysis was performed for all 384 work zone sites from 2013 to 2017 to reduce the effects of coding errors reported on the traffic crash report forms. The analysis of crashes did not rely on the recorded attribute of whether the crash occurred in a work zone, as it did not clearly indicate if the coded work zone crash was because of the presence of the work zone. Based on information from the crash report form narratives, crashes were aggregated into the four categories listed below as a part of a more detailed crash analysis. These categories were developed to provide additional flexibility and accuracy during the modeling process.

1. **Confirmed Work Zone Crash** was marked "as a work zone crash" by the reporting police officer, and there was evidence in the narrative that supported that the crash did in fact occur in a work zone. Such evidence reported in the narrative section of the crash report form included:

  - Stopping/slowing due to the work zone (queue, merging), flagger, advance warning sign
  - Changing lanes due to lane closure
  - Limited sight distance or confusion because of work zone traffic controls or activities
  - Vehicle entering or exiting a work zone
  - Avoiding crash with work zone device/barrier or with another vehicle
2. **Likely Work Zone Crash** was marked "as a work zone crash" on the crash report form but may not show evidence in the narrative section that associates the crash with the work zone. Although such crashes were reported to have occurred in the work zone area, they may have been influenced by additional factors such as driver health issues, cell phone usage, vehicle issues, distraction inside the vehicle, weather condition, animals, etc.
3. **Probable Work Zone Crash** was marked "not as a work zone crash" on the crash report form but had work zone-related evidence in the narratives, as listed above.
4. **Not a Work Zone Crash** was marked as "not a work zone crash" and did not have any evidence in the narrative that it occurred in a work zone, yet the crash matched with the length and duration query.

3.2.3 Safety Performance Function Modeling Process

The work zone crashes, work zone characteristics, site characteristics, traffic volumes, and operational features of the 384 work zone sites were compiled and analyzed using the IBM SPSS statistical analysis software. Assuming an underlying Poisson/negative binomial distribution, which is a common assumption in modeling traffic crashes per the *HSM* (AASHTO, 2010), SPF models were then developed to predict crashes using variables that were found to have a statistically significant influence on work zone crashes.

Three statistically significant models were developed for total work zone crashes and one for work zone fatal/injury crashes. Statistically significant results for a work zone K-A crash model specifically could not be developed, and thus was not able to be included in this research.

The 384 work zone sites were initially divided into a calibration group or a validation group. The calibration data set included 256 randomly selected work zone sites. The resulting variables of the 12 considered that were found to have a statistically significant impact on work zone crashes were:

- Work zone duration
- Work zone length
- AADT
- Product of non-work-zone speed limit and work zone speed limit

The remaining 128 sites were used to develop validation models. Analyses were conducted to confirm the models developed with the calibration data set through comparisons with the validation data sets and models. Such analyses include:

- Analysis of cumulative residual (CURE) plots
- Goodness-of-fit statistics
- Comparison of individual variable coefficients, standard errors, and p-values between the calibration and validation data sets.

The results of these analyses identified which of the three resulting total work zone crash SPF models was superior and that the fatal/injury work zone model was validated. Once the general form of the total and fatal/injury work zone models were validated, the two subsets were combined to develop the final values of the coefficients for the SPF variables in each model, using the pooled set consisting of all 384 sites. A statistical analysis of the observed and predicted work zone crashes was conducted, and the results were not significant, meaning that the models were accurately able to predict work zone crashes and injuries. All statistical analyses were conducted at 95% level of confidence.

To further explore the total and fatal/injury work zone SPFs, a Monte Carlo simulation analysis was performed to determine the relative impact of the variables in each model. Details are contained in chapter 5.

CMFs were extracted from the SPF coefficients for total crashes for work zone length and work zone duration. Comparisons of the CMFs developed for Illinois roads were compared with those developed by other authors.

Methodologies and examples on how to use the SPFs and CMFs developed as a part of this research are presented in chapter 6. An Excel tool was also developed to apply the SPFs using varying work zone lengths and durations. These methodologies and tools can be used by work zone planners when designing the MOT plans to identify which work zone layout and staging will result in fewer work zone crashes and injuries.

3.3 WORK ZONE DATA NEEDS

Several issues with the work zone data currently collected by IDOT were identified. Even at the inception of the research project, the Technical Review Panel (TRP) and IDOT engineers were aware of the work zone data quality issues. Thus, an additional objective was incorporated into this project to identify data needs and to provide recommendations on how work zone data may be collected in the future to improve its accuracy. The following tasks were performed to accomplish the work zone data need objective as a part of this research.

- Identify current IDOT data collection methods for work zone variables.
- Review FHWA’s Work Zone Data Initiative (WZDI), which developed a recommended practice for collecting and managing uniform work zone activity data across jurisdictional and organizational boundaries.
- Provide recommendations on how critical work zone variables should be collected and maintained by IDOT that are consistent with FHWA’s WZDI.

CHAPTER 4: WORK ZONE SAFETY PERFORMANCE MEASURES

Three performance measures were used to quantify work zone safety in Illinois: traffic crash frequencies, exposure variables, and traffic crash rates. Traffic crash frequencies provide a direct count measure of work zone safety in Illinois. Exposure variables provide information of the change in characteristics of work zone such as duration and length. Crash rates provide a combination of the count and exposure measures and the safety impact per unit exposure.

4.1 DATA COLLECTION

Data from three main sources were obtained from IDOT to analyze work zone safety performance in Illinois from 2013 to 2017. They are:

- *Traffic crash database* in GIS from 2013 to 2017, containing data from the SR1050 traffic crash report forms in Illinois.
- *Lane closure databases* (OPER 2410) for points and segments that document road restrictions on IDOT roads. This information is used to inform the Illinois motoring public of road obstructions and restrictions at any given time and is available on GIS maps on the internet.
- *Roadway network database*, containing the base map and attributes of roads in Illinois.

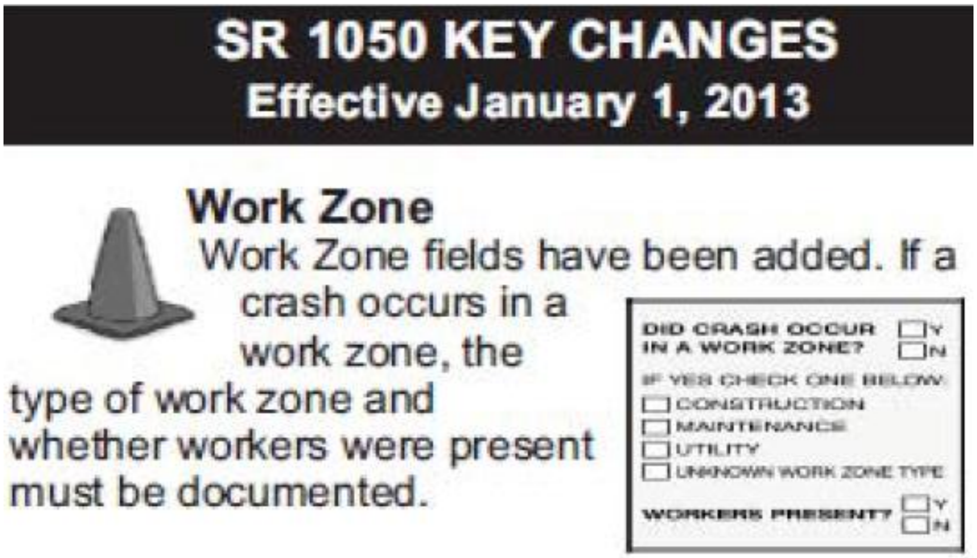
The three databases were fused to obtain work zone information in terms of traffic crash frequencies and work zone exposure variables in Illinois.

4.1.1 Traffic Crash Database

The Illinois statewide traffic crash database in ArcGIS for a five-year period (2013 to 2017) was used to query work zone crashes. The traffic crash report form SR 1050 from 2013 onwards contains work zone attributes (Figure 4.1) and asks the following questions to be answered and recorded:

- Did the crash occur in a work zone (yes/no)?
- If yes, what was the type of work zone (construction, maintenance, utility, unknown)?
- Were workers present (yes/no)?

The corresponding fields in IDOT’s crash database for the work zone attributes are identified as WorkZone, WorkZoneTy, and WorkersPre, respectively. In addition to these key work zone attributes, other information is available from the police crash report forms such as location, date and time of the crash, crash characteristics (collision type, severity, vehicle direction, and maneuver), and environmental factors such as lighting, weather, and surface condition.



SR 1050 KEY CHANGES
Effective January 1, 2013

Work Zone

Work Zone fields have been added. If a crash occurs in a work zone, the type of work zone and whether workers were present must be documented.

DID CRASH OCCUR IN A WORK ZONE? ☐Y ☐N
IF YES CHECK ONE BELOW:
☐ CONSTRUCTION
☐ MAINTENANCE
☐ UTILITY
☐ UNKNOWN WORK ZONE TYPE
WORKERS PRESENT? ☐Y ☐N

Figure 4.1. Work zone attribute in police crash report form (SR 1050).

4.1.2 Lane Closure Database

The lane closure database, OPER 2410, contains records of road closures and restrictions under IDOT's jurisdiction. It contains information such as contract number of the project, start and end dates, from and to location of the work zones, route name and direction, type of construction (lane reduction/lane closure, intermittent road work, one-way traffic with flaggers/temporary signals, etc.), number of lanes closed, suggestions to motorists, and other information. Two databases were available for segments and points. The segment database contained information on work zones over a recorded roadway segment. The point database contained data for spot road closures for smaller projects such as bridge painting, bridge repair, structure replacement, drainpipe repair, etc.

4.1.3 Roadway Network Database

IDOT's roadway network database contains a base map of all roads in Illinois. The key attributes extracted from this database include functional classification, speed limits, AADT, road names, etc. Additional information for site-specific work zones, when needed, were obtained from IDOT's maintenance of traffic plans.

4.1.4 Data Issues and Assumptions

While preparing the data for the analysis, several data issues were identified with the lane closure database. This is primarily because the purpose of the OPER 2410 form is to notify the traveling public of obstructions and restrictions on IDOT roads at any given time. It was not intended to provide detailed information on work zones. The following provides a summary of the data issues, assumptions, and resolutions made as a part of this research.

4.1.4.1 Construction Type

The information on type of construction that correspond to the attribute name "ConstructionType" in the database contains 15 categories: bridge closed, closed due to flooding, intermittent roadwork, intersection restrictions, lane reduction/lane closures, one-way traffic with flaggers, one-way traffic with temporary signals, permanent restriction, railroad closed, ramp closed, rest area closed, road closed, shoulder closed, temporary changes, and weight station closed. Categories closed because of flooding, permanent restriction, railroad closed, rest area closed, temporary changes, and weight station closed did not represent work zones. These categories were eliminated from the analysis in this study, as per approval from the TRP.

4.1.4.2 Contract Number

Another issue identified was the variability in work zone contract data. Some contract numbers represented a single work zone entry while some had multiple work zone entries associated with it. The multiple work zone entries associated to one contract number contained unique work zone events as well as duplicates. The Bradley University research team categorized these issues into six situations for work zone segments and three situations for point work zones. Assumptions were made to convert these varying data recordings into one consistent method of recording. The list of assumptions for segments and points were sent to the TRP and were subsequently reviewed and approved including the TRP's feedback. Table 4.1 lists the situations and assumptions for exposure variable counts. For the Point database issues, situations 1 and 2 had corresponding e-plans available, and the length of the work zones could be validated. For the records in situation 3, where no e-plans were available, lengths had to be estimated. Detailed illustrations for the situations and assumptions are included in Appendix A.

4.1.4.3 Work Zone Length and Duration

The lengths of the work zone segments were calculated by measuring the length between the start and end points in GIS. The duration of the work zone was calculated as the difference in start and end date as recorded in the lane closure database. In some cases, the duration of the work zone may not be accurate for multiyear projects, but because of lack of information about inactive durations of the work zones such as winter shutdowns, the entire duration of the project was considered as the work zone duration.

Table 4.1. Situations and Assumptions for Segment and Point Lane Closure Data

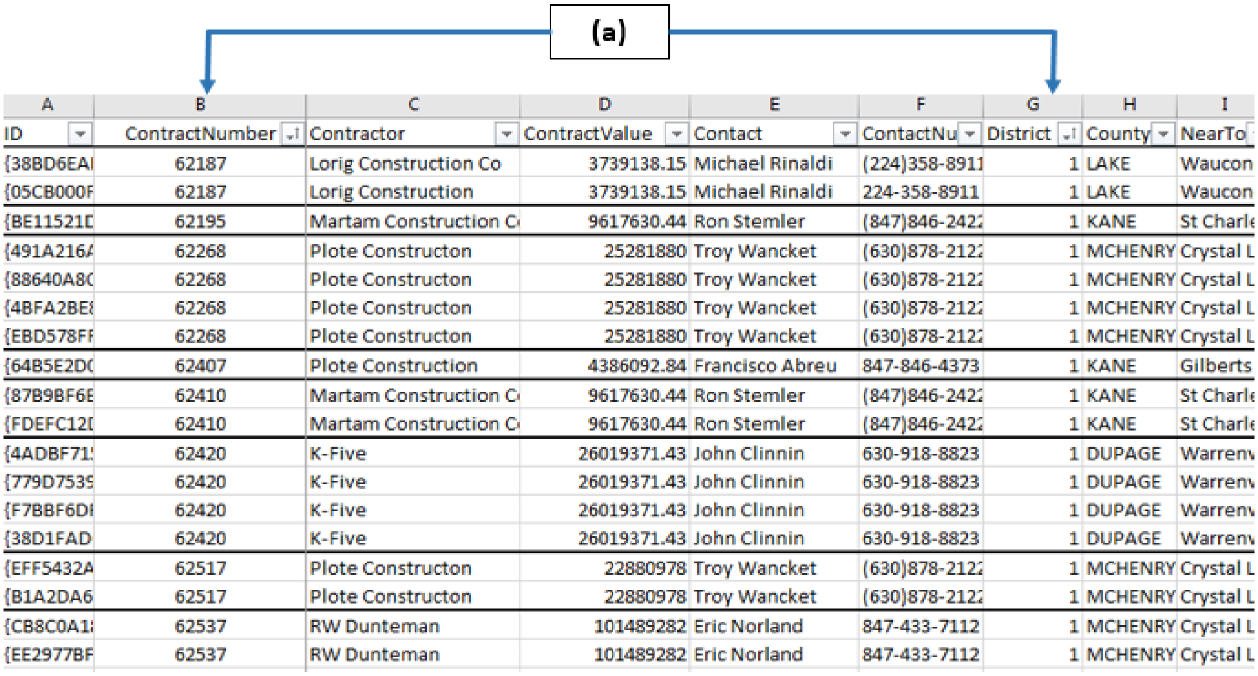
No.	Situation/Issue	Assumption for Count
For Work Zone Segments		
1	1 entry with 1 contract ID, 1 Length, and 1 Duration	Count as 1 work zone with recorded length and duration
2	2 entries with same contract ID, same route, different route directions (EB/WB, NB/SB), same location, same length and duration	Count as 1 work zone with recorded length and duration
3	2 or more entries with same contract ID, same route and direction, different locations/ different lengths, and same duration	Count as 1 work zone, sum the individual lengths, and use recorded duration
4	Multiple entries with same contract ID, different routes/locations, & different dates	Count as separate work zones and use recorded lengths and durations
5	2 or more entries with same contract ID, same route/location, and different durations	Count as separate work zones unless the end date of one is the start date of the next
6	Ramp Closures	Excluded

No.	Situation/Issue	Assumption for Count
For Point Work Zones		
1	2 or more points close in distance (a mile or less a part) over a bridge/culvert	Count as single work zone if the duration match up, else count as different work zones
2	2 or more points more than one mile apart	Count as multiple work zones, each with their individual lengths and durations
3a	Length—if no e-plans are available Bridge/culvert project	Structure length measured from Google maps + 0.25 mi upstream and downstream to account for lane closure taper length
3b	Length—if no e-plans are available Road project	Length assumed as 1,000′ if located on an Interstate, and 500′ for non-Interstate
3c	Length—if no e-plans are available At-grade rail-highway crossing	Length assumed as 500′

4.1.5 Methodology for Extracting Work Zone Exposure Data

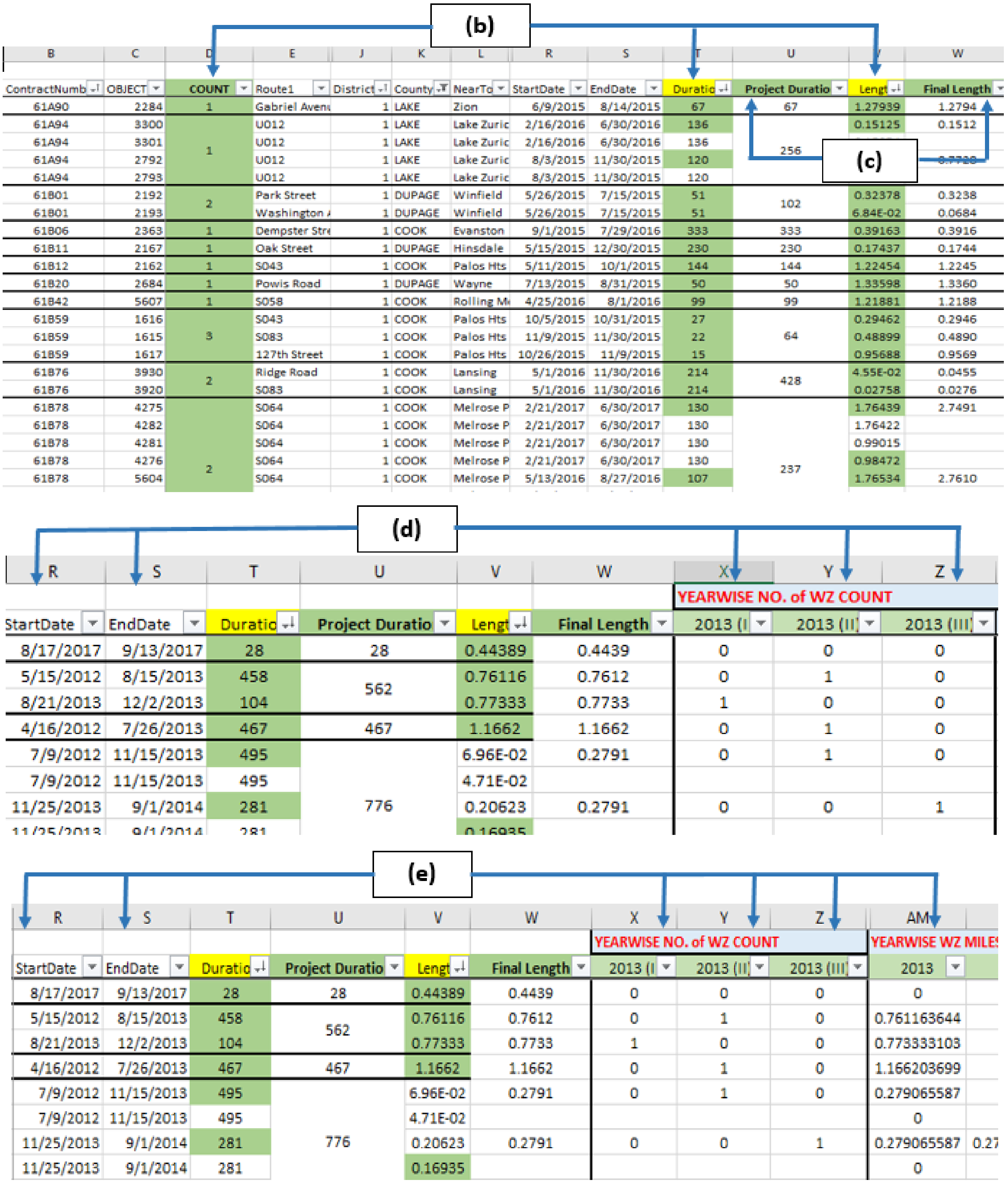
Figure 4.2 provides an example of the output from the statewide computerized GIS lane closure database, illustrating the methodology to obtain the exposure variable of number of work zones. This procedure is currently a manual process and is incredibly labor intensive.

The first step was sorting and grouping the records by district and work zone contract number (Figure 4.2a). Once this was done, the assumptions from Table 4.1 were applied to each contract to determine the number of work zone count for each contract as well as the work zone durations and lengths (Figure 4.2b). Application of the assumptions were done manually by visually inspecting the records in GIS and by checking the maintenance of traffic plans from IDOT's e-plans. Durations and lengths for each contract number were analyzed, and the total project duration and final length of the project were calculated (Figure 4.2c).



A	B	C	D	E	F	G	H	I
ID	ContractNumber	Contractor	ContractValue	Contact	ContactNu	District	County	NearTo
{38BD6EA	62187	Lorig Construction Co	3739138.15	Michael Rinaldi	(224)358-891	1	LAKE	Waucon
{05CB000F	62187	Lorig Construction	3739138.15	Michael Rinaldi	224-358-8911	1	LAKE	Waucon
{BE11521	62195	Martam Construction C	9617630.44	Ron Stemler	(847)846-242	1	KANE	St Charl
{491A216	62268	Plote Constructon	25281880	Troy Wancket	(630)878-212	1	MCHENRY	Crystal L
{88640A8	62268	Plote Constructon	25281880	Troy Wancket	(630)878-212	1	MCHENRY	Crystal L
{4BFA2BE	62268	Plote Constructon	25281880	Troy Wancket	(630)878-212	1	MCHENRY	Crystal L
{EBD578F	62268	Plote Constructon	25281880	Troy Wancket	(630)878-212	1	MCHENRY	Crystal L
{64B5E2D	62407	Plote Construction	4386092.84	Francisco Abreu	847-846-4373	1	KANE	Gilberts
{87B9BF6	62410	Martam Construction C	9617630.44	Ron Stemler	(847)846-242	1	KANE	St Charl
{FDEFC12	62410	Martam Construction C	9617630.44	Ron Stemler	(847)846-242	1	KANE	St Charl
{4ADBF71	62420	K-Five	26019371.43	John Clinnin	630-918-8823	1	DUPAGE	Warren
{779D753	62420	K-Five	26019371.43	John Clinnin	630-918-8823	1	DUPAGE	Warren
{F7BBF6D	62420	K-Five	26019371.43	John Clinnin	630-918-8823	1	DUPAGE	Warren
{38D1FAD	62420	K-Five	26019371.43	John Clinnin	630-918-8823	1	DUPAGE	Warren
{EFF5432A	62517	Plote Constructon	22880978	Troy Wancket	(630)878-212	1	MCHENRY	Crystal L
{B1A2DA6	62517	Plote Constructon	22880978	Troy Wancket	(630)878-212	1	MCHENRY	Crystal L
{CB8C0A1	62537	RW Dunteman	101489282	Eric Norland	847-433-7112	1	MCHENRY	Crystal L
{EE2977BF	62537	RW Dunteman	101489282	Eric Norland	847-433-7112	1	MCHENRY	Crystal L

Figure 4.2. Example of work zone exposure data extraction.

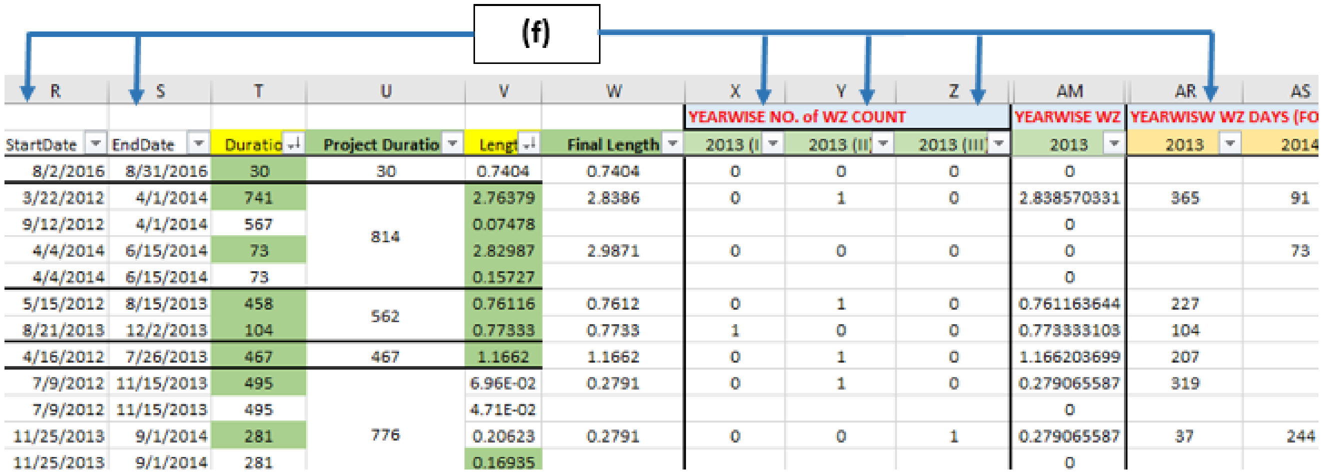


B	C	D	E	J	K	L	R	S	T	U	V	W
ContractNumb	OBJECT	COUNT	Route1	District	County	NearTo	StartDate	EndDate	Duratio	Project Duratio	Lengt	Final Length
61A90	2284	1	Gabriel Aven	1	LAKE	Zion	6/9/2015	8/14/2015	67	67	1.27939	1.2794
61A94	3300	1	U012	1	LAKE	Lake Zuric	2/16/2016	6/30/2016	136	256	0.15125	0.1512
61A94	3301		U012	1	LAKE	Lake Zuric	2/16/2016	6/30/2016	136			
61A94	2792		U012	1	LAKE	Lake Zuric	8/3/2015	11/30/2015	120			0.7720
61A94	2793		U012	1	LAKE	Lake Zuric	8/3/2015	11/30/2015	120			
61B01	2192	2	Park Street	1	DUPAGE	Winfield	5/26/2015	7/15/2015	51	102	0.32378	0.3238
61B01	2193		Washington A	1	DUPAGE	Winfield	5/26/2015	7/15/2015	51		6.84E-02	0.0684
61B06	2363	1	Dempster Stre	1	COOK	Evanston	9/1/2015	7/29/2016	333	333	0.39163	0.3916
61B11	2167	1	Oak Street	1	DUPAGE	Hinsdale	5/15/2015	12/30/2015	230	230	0.17437	0.1744
61B12	2162	1	S043	1	COOK	Palos Hts	5/11/2015	10/1/2015	144	144	1.22454	1.2245
61B20	2684	1	Powis Road	1	DUPAGE	Wayne	7/13/2015	8/31/2015	50	50	1.33598	1.3360
61B42	5607	1	S058	1	COOK	Rolling M	4/25/2016	8/1/2016	99	99	1.21881	1.2188
61B59	1616	3	S043	1	COOK	Palos Hts	10/5/2015	10/31/2015	27	64	0.29462	0.2946
61B59	1615		S083	1	COOK	Palos Hts	11/9/2015	11/30/2015	22		0.48899	0.4890
61B59	1617		127th Street	1	COOK	Palos Hts	10/26/2015	11/9/2015	15		0.95688	0.9569
61B76	3930	2	Ridge Road	1	COOK	Lansing	5/1/2016	11/30/2016	214	428	4.55E-02	0.0455
61B76	3920		S083	1	COOK	Lansing	5/1/2016	11/30/2016	214		0.02758	0.0276
61B78	4275	2	S064	1	COOK	Melrose P	2/21/2017	6/30/2017	130	237	1.76439	2.7491
61B78	4282		S064	1	COOK	Melrose P	2/21/2017	6/30/2017	130		1.76422	
61B78	4281		S064	1	COOK	Melrose P	2/21/2017	6/30/2017	130		0.99015	
61B78	4276		S064	1	COOK	Melrose P	2/21/2017	6/30/2017	130		0.98472	
61B78	5604		S064	1	COOK	Melrose P	5/13/2016	8/27/2016	107		1.76534	2.7610

R	S	T	U	V	W	X	Y	Z
						YEARWISE NO. of WZ COUNT		
StartDate	EndDate	Duratio	Project Duratio	Lengt	Final Length	2013 (I	2013 (II)	2013 (III)
8/17/2017	9/13/2017	28	28	0.44389	0.4439	0	0	0
5/15/2012	8/15/2013	458	562	0.76116	0.7612	0	1	0
8/21/2013	12/2/2013	104		0.77333	0.7733	1	0	0
4/16/2012	7/26/2013	467	467	1.1662	1.1662	0	1	0
7/9/2012	11/15/2013	495	776	6.96E-02	0.2791	0	1	0
7/9/2012	11/15/2013	495		4.71E-02				
11/25/2013	9/1/2014	281		0.20623	0.2791	0	0	1
11/25/2013	9/1/2014	281		0.16935				

R	S	T	U	V	W	X	Y	Z	AM	
						YEARWISE NO. of WZ COUNT			YEARWISE WZ MILE	
StartDate	EndDate	Duratio	Project Duratio	Lengt	Final Length	2013 (I	2013 (II)	2013 (III)	2013	
8/17/2017	9/13/2017	28	28	0.44389	0.4439	0	0	0	0	
5/15/2012	8/15/2013	458	562	0.76116	0.7612	0	1	0	0.761163644	
8/21/2013	12/2/2013	104		0.77333	0.7733	1	0	0	0.773333103	
4/16/2012	7/26/2013	467	467	1.1662	1.1662	0	1	0	1.166203699	
7/9/2012	11/15/2013	495	776	6.96E-02	0.2791	0	1	0	0.279065587	
7/9/2012	11/15/2013	495		4.71E-02					0	
11/25/2013	9/1/2014	281		0.20623	0.2791	0	0	1	0.279065587	0.27
11/25/2013	9/1/2014	281		0.16935					0	

Figure 4.2. Example of work zone exposure data extraction (continued).



R	S	T	U	V	W	X	Y	Z	AM	AR	AS
						YEARWISE NO. of WZ COUNT			YEARWISE WZ	YEARWISW WZ DAYS (FO	
StartDate	EndDate	Duratio	Project Duratio	Lengt	Final Length	2013 (I	2013 (II)	2013 (III)	2013	2013	2014
8/2/2016	8/31/2016	30	30	0.7404	0.7404	0	0	0	0		
3/22/2012	4/1/2014	741	814	2.76379	2.8386	0	1	0	2.838570331	365	91
9/12/2012	4/1/2014	567		0.07478					0		
4/4/2014	6/15/2014	73		2.82987	2.9871	0	0	0	0		73
4/4/2014	6/15/2014	73		0.15727					0		
5/15/2012	8/15/2013	458	562	0.76116	0.7612	0	1	0	0.761163644	227	
8/21/2013	12/2/2013	104		0.77333	0.7733	1	0	0	0.773333103	104	
4/16/2012	7/26/2013	467	467	1.1662	1.1662	0	1	0	1.166203699	207	
7/9/2012	11/15/2013	495	776	6.96E-02	0.2791	0	1	0	0.279065587	319	
7/9/2012	11/15/2013	495		4.71E-02					0		
11/25/2013	9/1/2014	281		0.20623	0.2791	0	0	1	0.279065587	37	244
11/25/2013	9/1/2014	281		0.16935					0		

Figure 4.2. Example of work zone exposure data extraction (continued).

After the output was organized in this manner, additional fields were created (Figure 4.2d) to count the annual number of work zone, work zone length (miles), and work zone duration (days). The work zone start and end date ranges were broken down into three cases:

1. Starting and ending in the year of interest
2. Starting before a year of interest and ending in/after the year of interest
3. Starting in the year of interest and ending in a different year

The nested "IF" functions were used to represent the three cases that returned 1 (true) or 0 (false) for the given condition. For example, if 2013 was the year of interest, then the Excel formulas used for 2013(a), 2013(b), and 2013(c) were as follows:

1. 2013(I) = IF (AND (Start Date>=DATEVALUE ("1/1/2013"), End Date<=DATEVALUE ("12/31/2013")),1,0)
2. 2013(II) = IF (AND (Start Date< DATEVALUE ("01/01/2013"), End Date>=DATEVALUE ("01/01/2013")),1,0)
3. 2013(III) = IF (AND (Start Date>=DATEVALUE ("01/01/2013"), Start Date<=DATEVALUE ("12/31/2013"), End Date>DATEVALUE ("12/31/2013")),1,0)

The annual count of work zone length was based on the results from the categories listed above. The final length of the work zone was counted in the year it occurred if one of the above three cases were true (Figure 4.2e). For example, for the year 2013, this was computed using the Excel expression:

= ((Final Length × 2013(I)) +(Final Length × 2013(II)) +(Final Length × 2013(III))

Work zone duration was computed based on the output of the above three cases of work zone date range. The count of work zone days (Figure 4.2f) was calculated using the following Excel expression for 2013:

```
=IF(2013(I)=1, Duration, IF(2013(II)=1, IF (End Date>DATE (2013,12,31),365, (End Date-(DATE
(2013,1,1)) +1)), IF(2013(III)=1, ((DATE(2013,12,31))-StartDate+1)," "))).
```

Finally, once these steps were completed for all the years from 2013–2017, the exposure columns were summed to find the total work zone exposures (count, length, and duration).

4.2 DATA ANALYSIS AND RESULTS

4.2.1 Work Zone Crash Frequencies

The statewide work zone crash and injury frequencies were quantified by querying the statewide traffic crash database for crashes marked as a "Yes" for a work zone crash. Queries were made for all roads in Illinois and for those roads under IDOT jurisdiction. The roadway network database consists of attribute (JUR_TYPE) that indicates which agency has jurisdictional responsibility of a highway or roadway. The crash database was overlaid with the road network database, and queries were made based on the jurisdiction type attribute to obtain four work zone crash count measures on IDOT roads:

1. Total work zone (WZ) crashes
2. WZ fatal (K) and A-injury crashes
3. WZ fatal and injury (K, A, B, C) crashes
4. WZ fatalities and injuries

It was necessary to query the work zone crashes for IDOT roads specifically, because the work zone exposure variables are only available for IDOT roads.

Figures 4.3 through 4.6 show the annual trends of work zone crash frequencies for total WZ crashes, WZ K-A injury crashes, WZ fatal and injury crashes, and WZ fatalities and injuries, respectively, for 2013 to 2017, for all roads and IDOT roads.

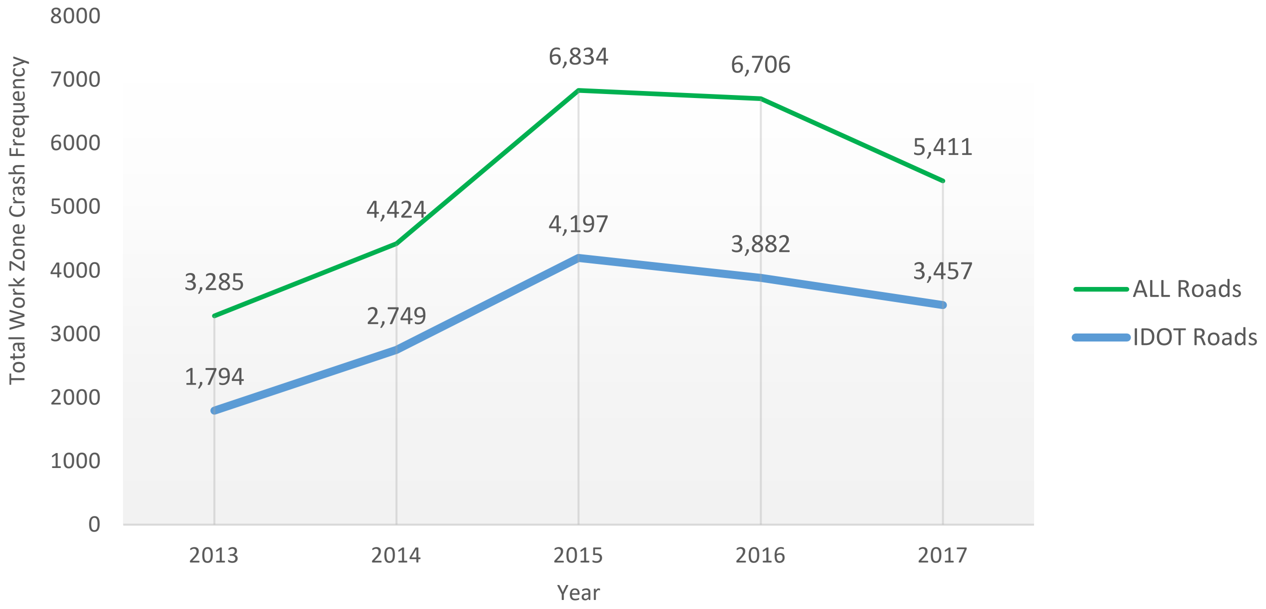


Figure 4.3. Total work zone crashes—all severities.

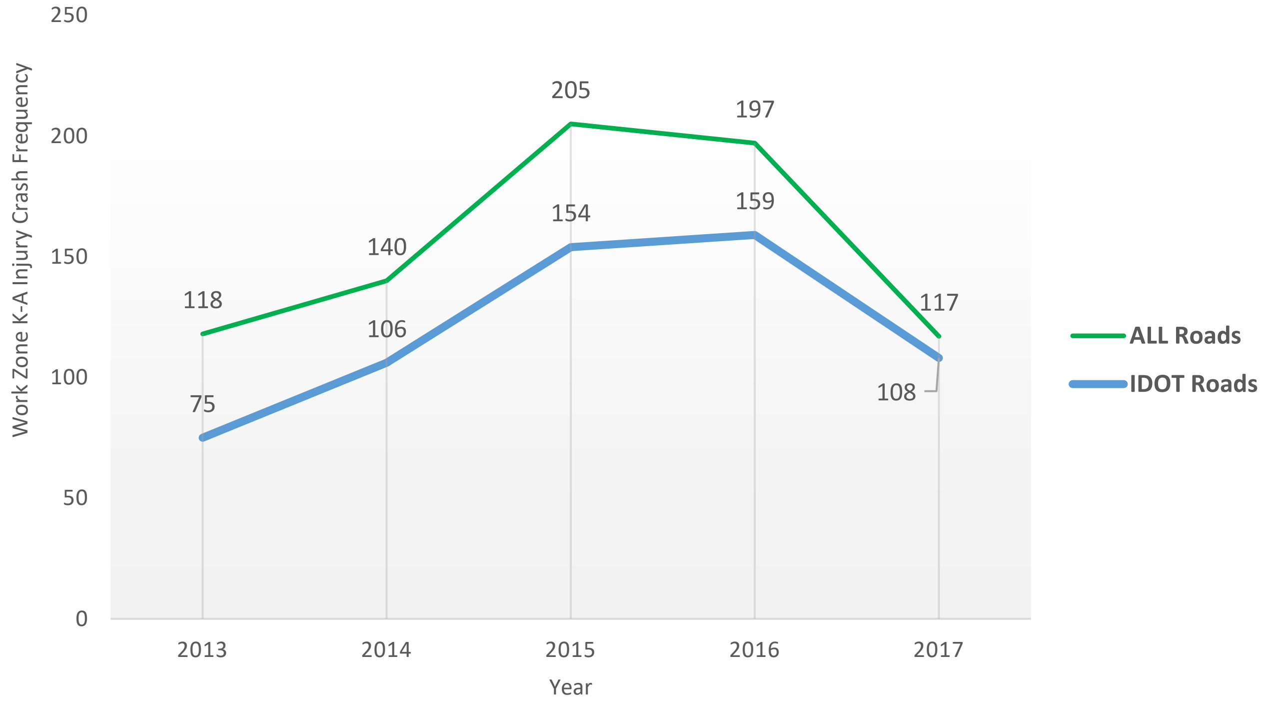


Figure 4.4. Work zone K-A injury crashes.

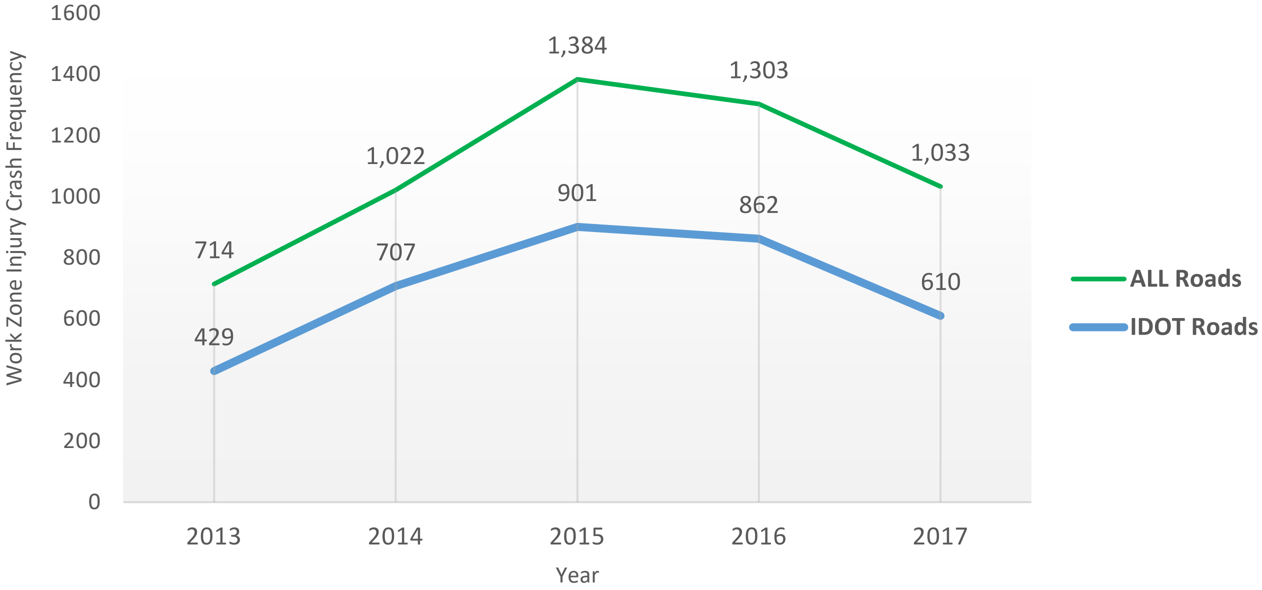


Figure 4.5. Work zone fatal/injury crashes (K, A, B, and C).

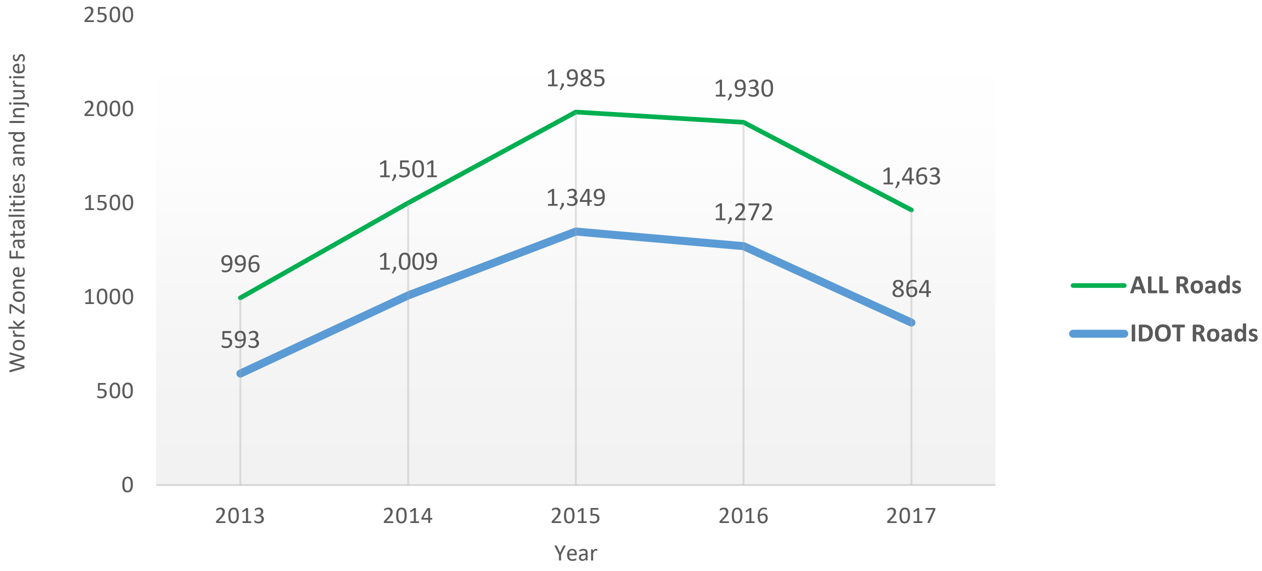


Figure 4.6. Work zone fatalities and injuries.

Observation of the work zone crash trends show that work zone crash frequency increased from 2013 to 2015 and then decreased for 2016 and 2017 across all crash categories and roads (IDOT and All roads). The lowest work zone crash and injury frequencies were observed in 2017.

A comparison of the proportion of work zone crashes occurring on IDOT roads versus all roads from 2013 to 2017 range from 55% to 64% for total crashes and 64% to 92% for K-A crashes.

4.2.2 Work Zone Exposure Variables

The assumptions discussed in Table 4.1 were applied on IDOT's OPER 2410 lane closure databases (segments and points) to calculate annual numbers of four exposure measures for work zones on IDOT roads:

a. Number of work zones
b. Work zone miles
c. Work zone days
d. Work zone day-miles

Figures 4.7 through 4.10 show the annual trends of the work zone exposure variables, respectively, for number of IDOT work zones, work zone miles, work zone days, and work zone day-miles from 2013 to 2017.

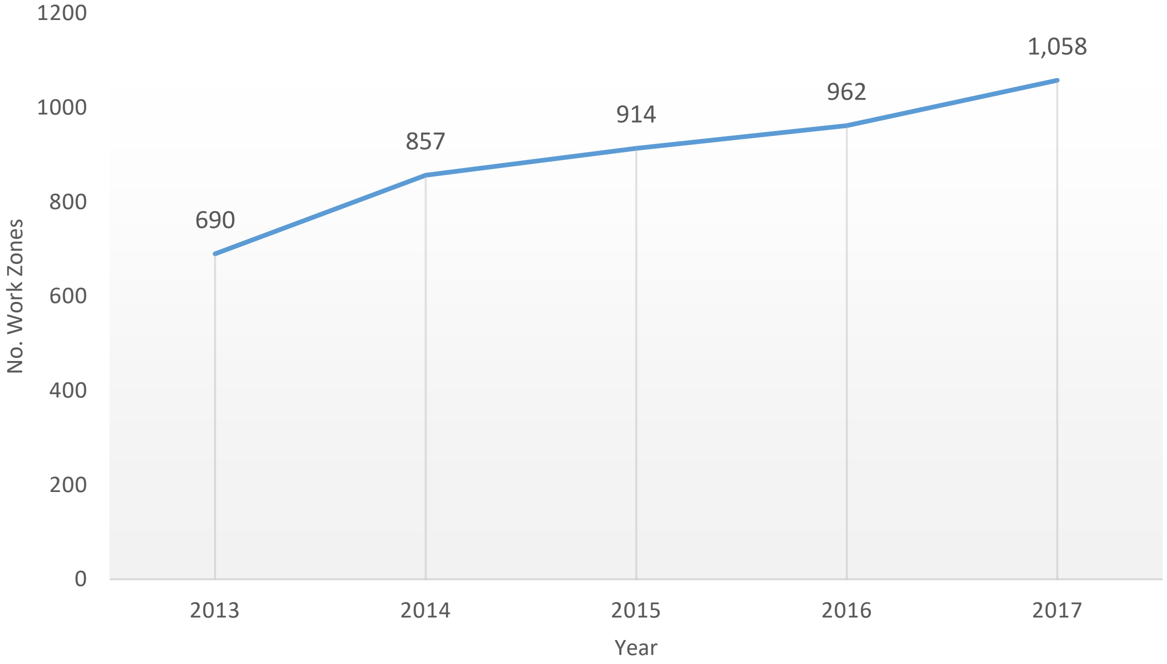


Figure 4.7. Annual number of work zones—IDOT roads.

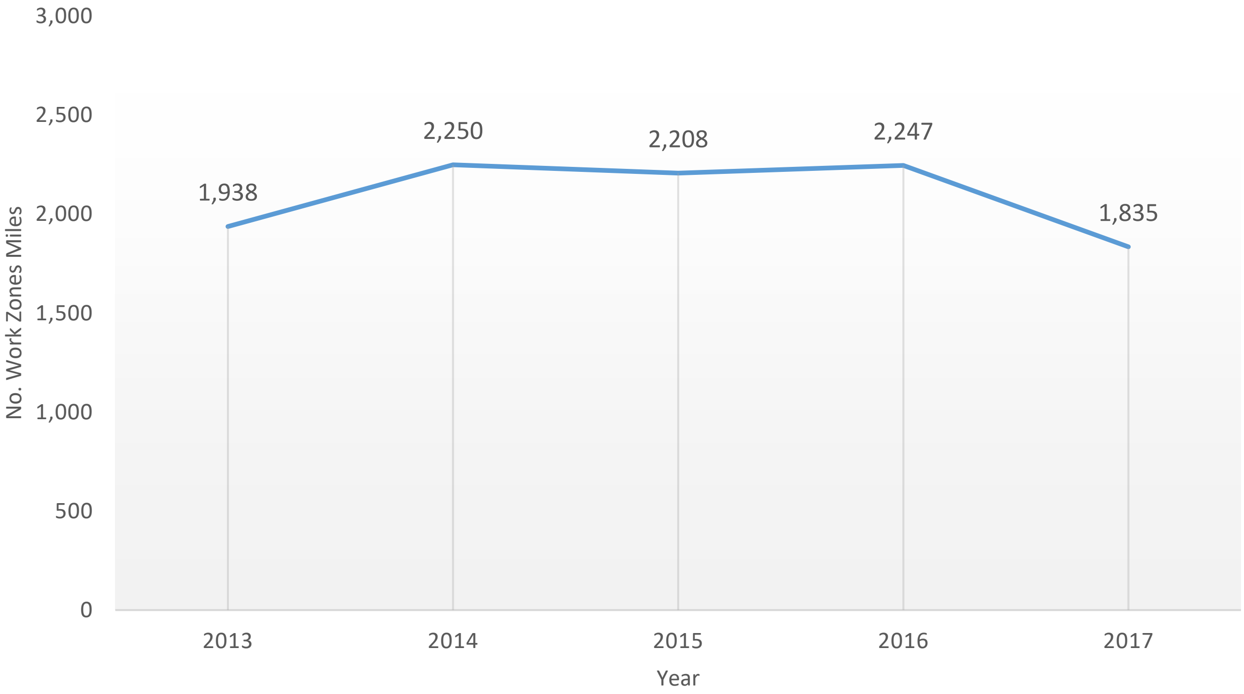


Figure 4.8. Annual number of work zone miles—IDOT roads.

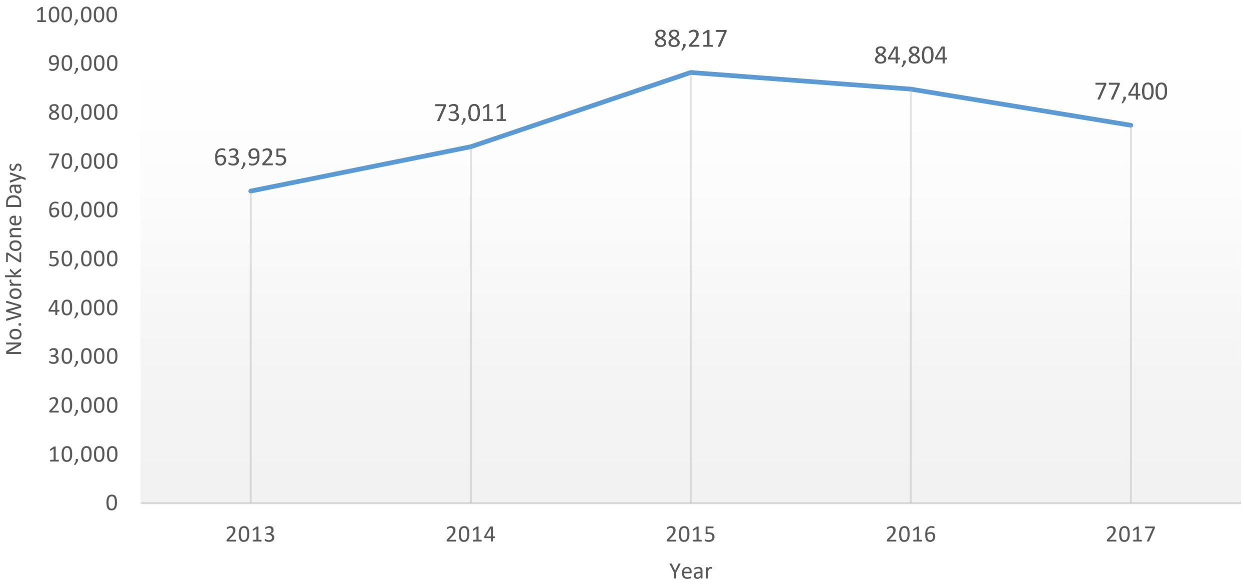


Figure 4.9. Annual number of work zone days—IDOT roads.

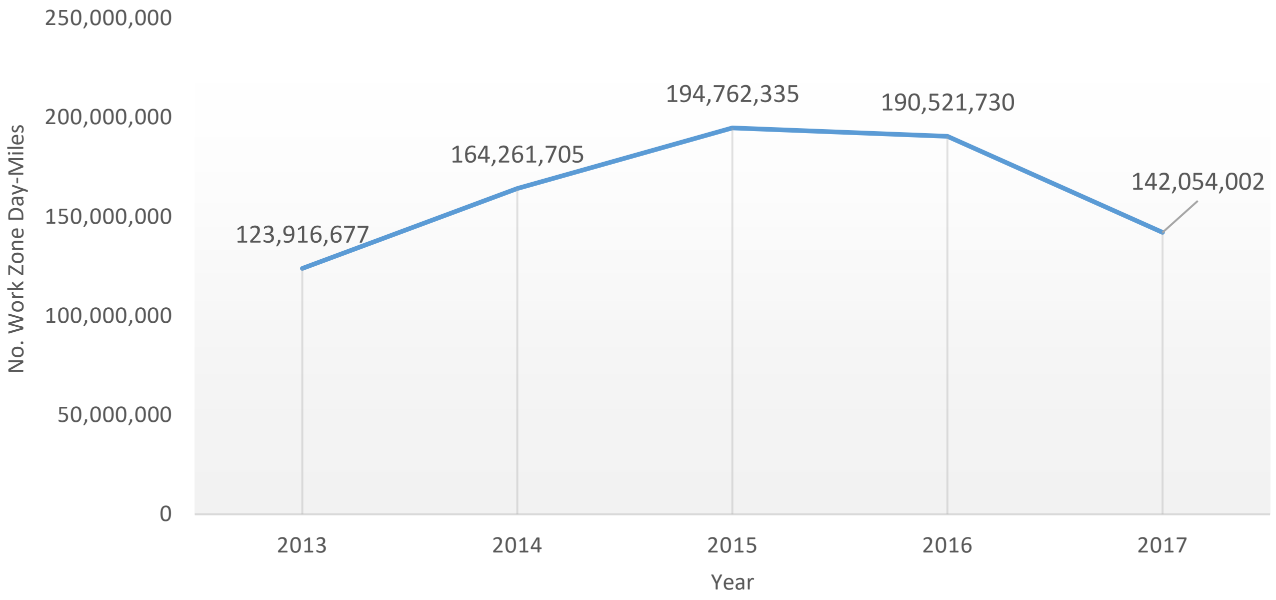


Figure 4.10. Annual number of work zone day-miles—IDOT roads.

The work zone exposure trends reveal that the annual number of IDOT work zones increased steadily from 690 in 2013 to 1,058 in 2017. The annual number of IDOT work zone miles was relatively constant from 2014 to 2016 at 2,250 to 2,247 mi, while in 2017, the work zone miles decreased to 1,835. In terms of total annual work zone duration, the number of work zone days increased from 2013 to 2015 and decreased in 2016 and 2017. The trends for annual IDOT work zone day-miles also increased from 2013 to 2015 and decreased in 2016 and 2017.

4.2.3 Work Zone Crash Rates

Figures 4.11 to 4.14 depict the annual work zone crash rates for the four crash categories and four work zone variables from 2013 to 2017 for IDOT roads.

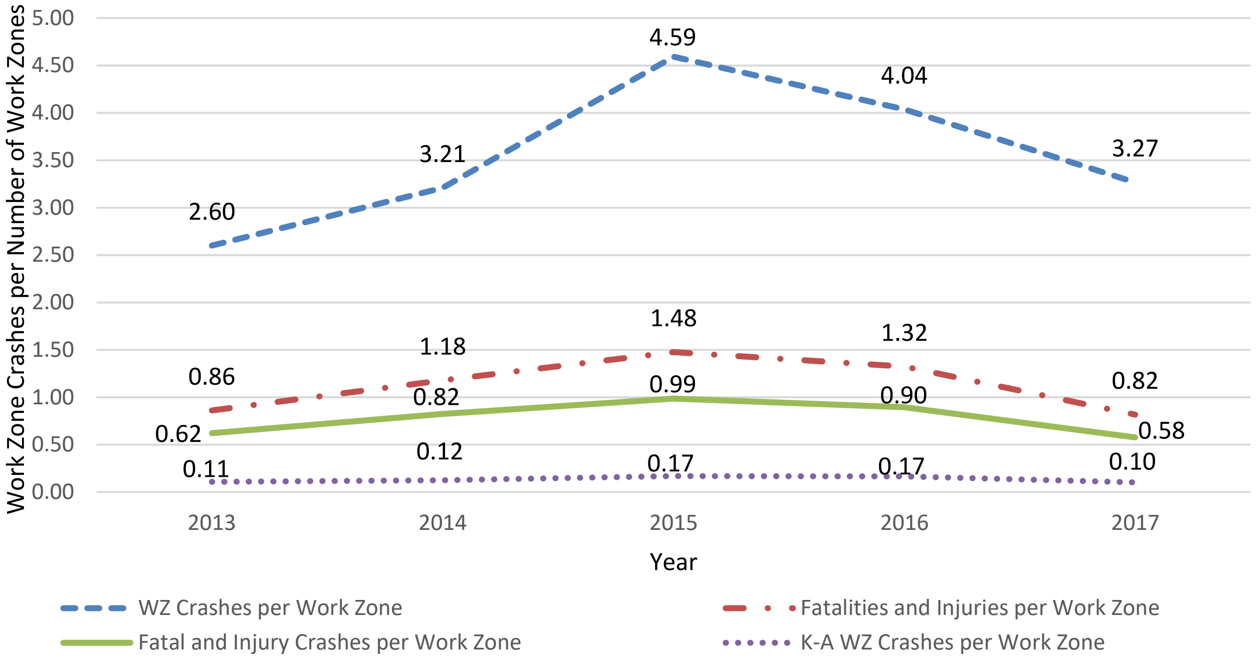


Figure 4.11. Work zone crash rate per number of work zones.

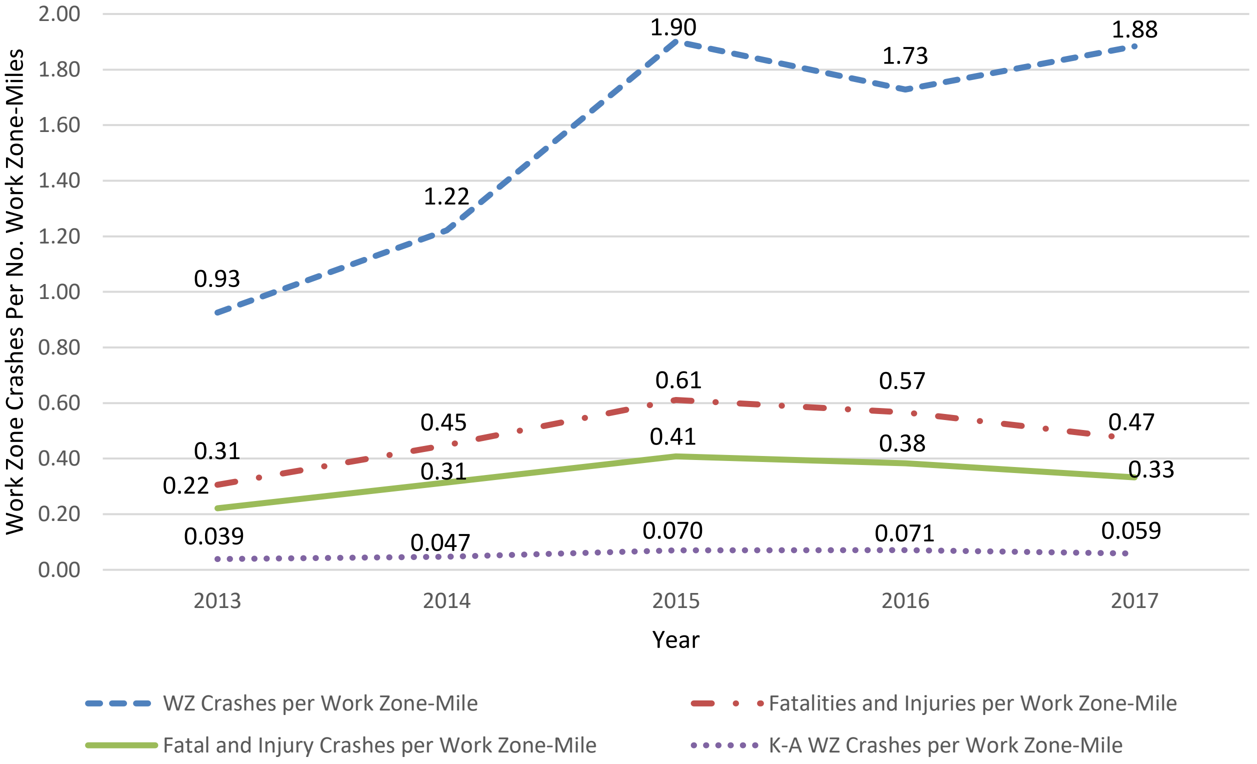


Figure 4.12. Work zone crash rate per work zone-mile.

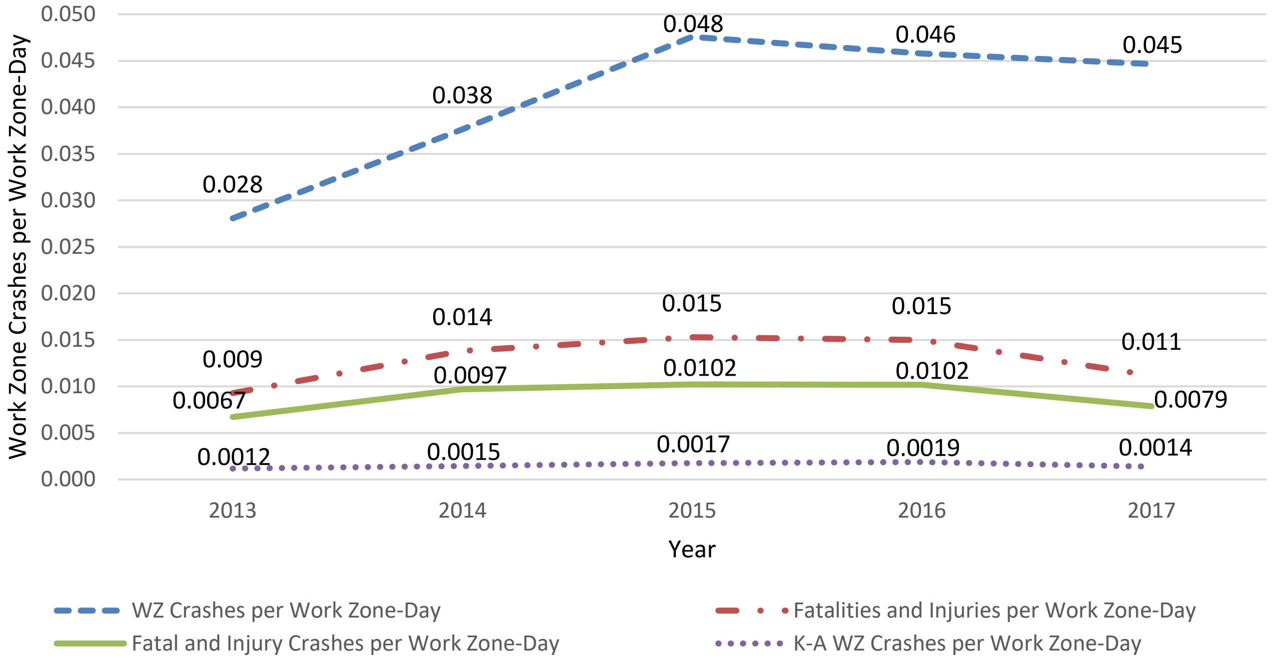


Figure 4.13. Work zone crash rate per work zone-day.

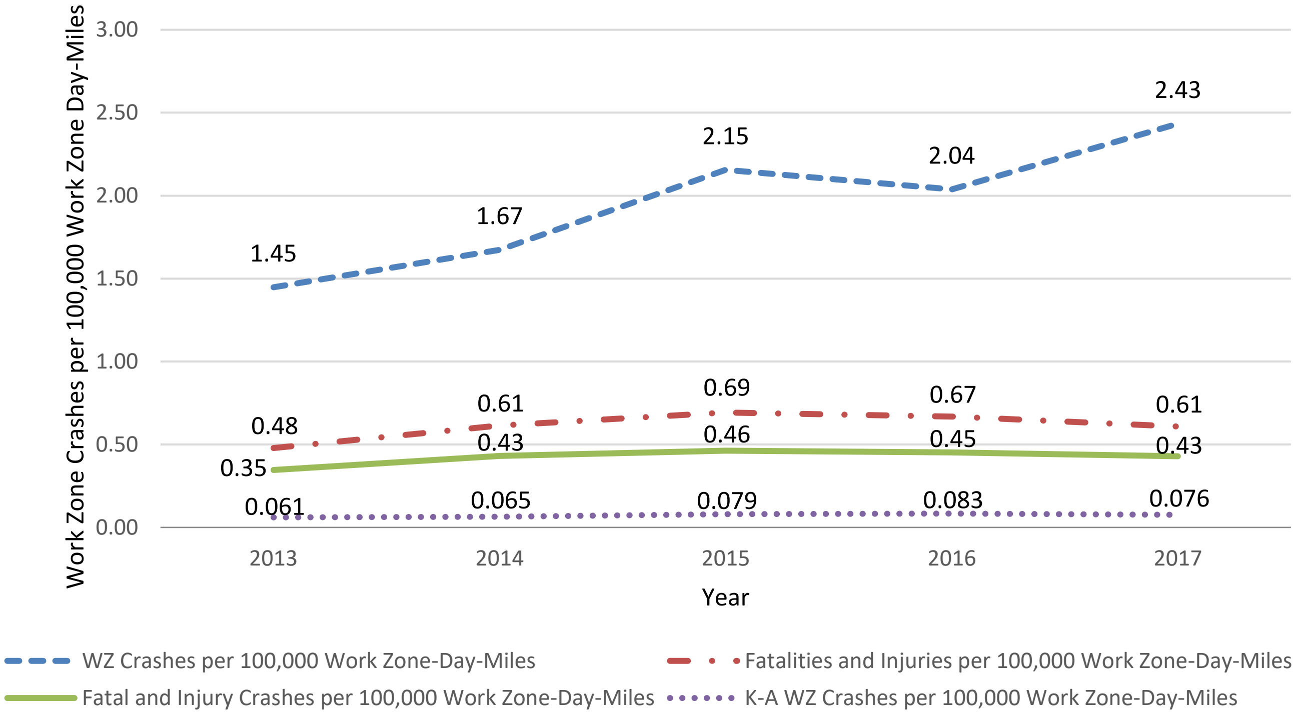


Figure 4.14. Work zone crash rate per 100,000 work zone day-miles.

The following observations can be made for IDOT work zone crash rates:

- For **work zone crashes per number of work zones**, in general, an increasing trend was observed for the four crash severity categories from 2013 to 2015, with decreasing rates in 2016 and 2017. The lowest annual rates over the analysis period were observed in 2017 for fatalities and injuries per work zone, fatal and injury crashes per work zone, and K-A crashes per work zone.
- For **work zone crashes per work zone mile**, the total work zone crash rate increased from 0.93 in 2013 to 1.90 in 2015, the rate decreased to 1.73 in 2016, and then increased to 1.88 in 2017. The rates based on fatalities and injuries per work zone mile and fatal and injury crashes per work zone mile increased from 2013 to 2015 and then decreased in 2016 and 2017. The K-A work zone crashes per work zone mile increased from 2013 to 2016 but decreased in 2017.
- For **work zone crashes per work zone day**, the total work zone crash rate increased from 2013 to 2015 (from 0.028 to 0.048) and then decreased slightly to 0.046 and 0.045 in 2016 and 2017, respectively. The rates based on fatalities and injuries per work zone day and fatal and injury crashes per work zone day increased from 2013 to 2015, remained constant in 2016, and then decreased in 2017. The K-A work zone crashes per work zone day increased from 2013 to 2016 but then decreased in 2017.
- For **work zone crashes per 100,000 work zone day-miles**, the total work zone crash rate increased from 2013 to 2015 (from 1.45 to 2.15), then decreased 2.04 in 2016, and increased again to 2.43 in 2017. The rates based on fatalities and injuries per 100,000 work zone day-miles and fatal and injury crashes per 100,000 work zone day-miles increased from 2013 to 2015 and then decreased in 2016 and 2017. The K-A work zone crashes per 100,000 work zone day-miles increased from 2013 to 2016 but then decreased in 2017.
- Overall, from 2016 to 2017, 14 of the 16 of the work zone crash and injury rates decreased. The two exceptions where increases were observed from 2016 to 2017 were for total work zone crashes per work zone mile and total work zone crashes per 100,000 day-miles.

The trend analysis of work zone crash frequencies and crash rates reveals that the work zone exposure variables do provide additional insights into work zone safety performance and should continue to be collected in the future. Even though the lane closure databases contained imperfect data, it was still possible to find exposure measures from them through the manual process documented in this report. Improvements to collecting more accurate work zone exposure variables will help in automating the extraction of work zone crash and exposure data and make the process easier to conduct in the future.

Details of the work zone crash frequencies, work zone exposure variables, and crash rates for each year from 2013 to 2017 are included in Appendix B.

CHAPTER 5: SITE-SPECIFIC WORK ZONE ANALYSIS

Information from the Illinois traffic crash, lane closure, and road network databases were linked using GIS geoprocessing tools and structure query language. The key data elements from the Illinois statewide traffic crash database used to process, match, and locate work zone crashes include crash date, location (X and Y coordinates), route name, and vehicle direction. The key data elements of the lane closure database for Illinois roads used in this research include start and end date, starting and ending location of the work zone, route, and route direction of the work zone. A work zone crash was considered to be successfully matched if the crash location and date of crash was within the work zone length and duration, and if the route and vehicle direction of the crash matched with route and closure direction of the work zone between these two databases and GIS layers.

Work zone segments with matching fatal and A-injury crashes were first selected for inclusion in the site-specific work zone analysis. Additional matching was conducted to identify work zone segments with B- and C-injury crashes and property damage only (PDO) crashes. This resulted in the total sample of 384 work zone sites for the site-specific analysis.

In the case of injury crashes, traffic crash severity is defined as follows: K represents a fatal crash, A represents a crash with an incapacitating injury, B represents a crash with a non-incapacitating injury, and C represents a crash with a possible injury.

The total sample of 384 work zone sites were randomly divided into two categories, one for model calibration and the other for model validation. Two-thirds of the data (256 sites) were used for model calibration and the remaining one-third (128 sites) was used for model validation.

5.1 DATA COLLECTION

Data for the 384 work zone sites were queried from three IDOT sources: the traffic crash, lane closure, and roadway network (base map) databases. Data collection included work zone crashes and injuries, pre-work zone crashes and injuries, duration, length, functional classification, speed limit, work zone speed limit, AADT, number of lanes, number of lanes reduced, type of road closure, activity type, and type of work zone. The contract identification numbers of the work zones were used to access the maintenance of traffic plans and additional data on type of project and work zone speed limits. Historic AADT values were obtained from IDOT’s Traffic Count Database System and represent the non-work-zone traffic volumes in vehicles per day.

The lengths of the work zones were estimated from the lane closure database and consisted of the length from the advance warning area to the termination area. However, lengths were not consistently recorded for work zones among the districts in Illinois. To account for this inconsistency, a 0.25-mi buffer was applied upstream and downstream of the work zone segments, and the crashes were queried in this distance. This buffer is similar to work zone length buffers of 0.25 and 0.5 mi used in other studies (Khattak et al., 2002; Sun et al., 2014; Cheng et al., 2015). A 0.25-mi buffer was used in this study because detailed information for work zone lengths was available from the MOT plans for most sites.

In addition to obtaining and analyzing traffic crash data for crashes occurring within the work zone, the pre-construction crash frequency was also collected and analyzed for the same duration (same months and days) but for the previous non-work-zone time period, with no overlap. The pre-construction crash frequencies provide a basis for comparing how the presence of work zone changes the crash pattern compared to normal roadway conditions.

5.2 ANALYSIS OF WORK ZONE CRASHES

The statewide traffic crash database consists of information from Illinois Traffic Crash Report SR 1050. In 2013, work zone fields were added to the RS 1050 crash report form, including if a crash occurs in a work zone, the type of work zone (construction, maintenance, utility, or other), and whether workers were present at the time of the crash. In this research an in-depth crash analysis was performed for all 384 work zone sites from 2013 to 2017 to reduce the effects of coding errors reported on the traffic crash report forms.

The analysis of crashes did not rely on the recorded attribute of whether the crash occurred in a work zone, as it did not clearly indicate if the coded work zone crash was due to the presence of the work zone. For each work zone site, the police traffic crash report forms were downloaded and then a detailed crash analysis was conducted. By carefully reviewing the information from crash report narratives, crashes were aggregated into four categories as a part of a more detailed crash analysis (as previously defined in chapter 3):

1. Confirmed work zone crash
2. Likely work zone crash
3. Probable work zone crash
4. Not a work zone crash

These categories were developed to provide increased accuracy in quantifying work zone crashes and provided additional flexibility during the modeling process.

5.3 SAFETY PERFORMANCE FUNCTION CALIBRATION AND VALIDATION

A SPF is an equation that estimates the average number of crashes per unit time at a location as a function of exposure and other characteristics. SPFs are used to predict crash frequency for a given set of site conditions or to compare the safety performance of a specific site under various conditions. They are also used to explain the correlation between work zone crashes and specific work zone exposures.

5.3.1 Safety Performance Functions

The work zone characteristics, other geometric characteristics, crash history, and traffic volumes of the 256 work zone sites comprising the calibration data set and the 128 work zone sites comprising the validation data set were compiled and analyzed using the IBM SPSS statistical analysis software. Details of the crash data, traffic volume, and other characteristics for the calibration sites can be found in Appendix C. Work zone crashes and injuries were the dependent variables. Twelve independent variables were considered in the regression/modeling analysis: pre-construction crashes and injuries, work zone duration, length of work zone, functional classification, speed limit, work zone speed limit, AADT, number of lanes, number of lanes reduced, type of road closure, activity type, and type of work zone. Assuming an underlying Poisson/negative binomial distribution, which is a common assumption in modeling traffic crashes per the *HSM* (AASHTO, 2010), SPF models were then developed to predict crashes using variables that were found to have a statistically significant influence on crashes.

Following the iterative process, three SPF models were developed to predict total work zone crashes, and one model was developed to predict work zone fatal/injury crashes (K-fatal and A-, B-, and C-injury crashes). All three models are considered viable models because the overall regression equations were statistically significant and the variable coefficients were also significant at 95% level of confidence or higher. Equations 1, 2, 3, and 4 show the general form of the SPFs developed.

$$\mu_{Total} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \qquad \text{Model 1 (1)}$$

$$\mu_{Total} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \times AADT^{\beta_3} \qquad \text{Model 2 (2)}$$

$$\mu_{Total} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \times AADT^{\beta_3} \times e^{\beta_4 * (NWZ\ SL \times WZ\ SL)} \qquad \text{Model 3 (3)}$$

$$\mu_{Fatal/Injury} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \times e^{\beta_3 * (NWZ\ SL \times WZ\ SL)} \qquad \text{Fatal/Injury Model (4)}$$

where,

μ_{Total} = Average predicted work zone crashes (confirmed, likely, probable)

$\mu_{Fatal/Injury}$ = Average predicted work zone injury crashes (confirmed, likely, probable) for K, A, B, and C crashes combined

D = Duration of the work zone (end date – start date +1) (days)

L = Length of the work zone (miles)

AADT = Annual average daily traffic (vehicles/day)

NWZ SL = Non-work-zone speed limit (mph)

WZ SL = Work zone speed limit (mph)

NWZ SL × WZ SL = Product of non-work-zone and work zone speed limits

α = Regression model intercept

β_1, β_2, β_3, β_4 = Regression coefficients

Tables 5.1 and 5.2 show the coefficients, standard error, and overdispersion factors for the SPFs developed, using the calibration data set of 256 sites and the validation data set with 128 sites for total work zone crashes (Table 5.1) and fatal/injury work zone crashes (Table 5.2). The estimated parameters are for the logarithmic transformation of the variables work zone duration, length, and AADT.

Table 5.1. Variable Coefficients for SPFs Developed for Total Work Zone Crashes

Model	Regression Coefficients					
	Intercept (α) (St. Error) (P-Value)	Coefficient (β_1) Duration (St. Error) (P-Value)	Coefficient (β_2) Length (St. Error) (P-Value)	Coefficient (β_3) AADT (St. Error) (P-Value)	Coefficient (β_4) NWZ×WZ SL (St. Error) (P-Value)	Overdispersion Parameter, k (St. Error)
Calibration Model 1 n = 256	-2.444 (0.4062) (< 0.001)	0.781 (0.0726) (< 0.001)	0.170 (0.0443) (< 0.001)	NA	NA	0.768 (0.0744)
Calibration Model 2 n = 256	-6.977 (0.8130) (< 0.001)	0.743 (0.0695) (< 0.001)	0.150 (0.0421) (< 0.001)	0.469 (0.0741) (< 0.001)	NA	0.663 (0.0663)
Calibration Model 3 n = 256	-6.119 (0.8049) (< 0.001)	0.725 (0.0680) (< 0.001)	0.329 (0.0566) (< 0.001)	0.464 (0.0708) (< 0.001)	-0.00035 (0.0001) (< 0.001)	0.596 (0.0620)
Validation Model 1 n = 128	-4.888 (0.6640) (< 0.001)	1.277 (0.1108) (< 0.001)	0.153 (0.0670) (0.05)	NA	NA	1.055 (0.0744)
Validation Model 2 n = 128	-9.007 (1.3597) (< 0.001)	1.155 (0.1131) (< 0.001)	0.179 (0.0666) (0.01)	0.475 (0.1385) (< 0.001)	NA	0.978 (0.1214)
Validation Model 3 n = 128	-7.585 (1.3031) (< 0.001)	1.079 (0.1136) (< 0.001)	0.339 (0.0711) (< 0.001)	0.466 (0.1279) (< 0.001)	-0.00044 (0.0001) (< 0.001)	0.871 (0.1114)

NA = Not Available

Table 5.2. Variable Coefficients for SPFs Developed for Fatal/Injury Work Zone Crashes

Model	Regression Coefficients				
	Intercept (α) (St. Error) (P-Value)	Coefficient (β_1) Duration (St. Error) (P-Value)	Coefficient (β_2) Length (St. Error) (P-Value)	Coefficient (β_3) NWZ×WZ SL (St. Error) (P-Value)	Overdispersion Parameter, k (St. Error)
Calibration Model n = 256	-1.824 (0.5900) (0.005)	0.572 (0.096) (< 0.001)	0.312 (0.0817) (< 0.001)	-0.00042 (0.0001) (< 0.001)	0.880 (0.1405)
Validation Model n = 128	-4.371 (1.0548) (< 0.001)	1.110 (0.1570) (< 0.001)	0.342 (0.1066) (< 0.001)	-0.001 (0.0001) (0.05)	1.269 (0.2285)

5.3.2 CURE Plots for Calibration Data Set

To determine how the residuals are distributed with respect to the independent variables and in comparing multiple alternative SPFs, CURE plots were used. Hauer recommends the use of CURE plots to obtain further insight into whether the selected appropriate functional form was reasonable (Hauer, 2004; Srinivasan & Bauer, 2013). The general concept is that for a model of the appropriate functional form and to have a good fit, the CURE plot is expected to oscillate randomly about zero (such that the mean of all the residuals is 0). The following are the steps involved in making CURE plots:

- Step 1: For the sites used to calibrate the SPF, obtain the Pearson residuals (or the scaled residuals) from SPSS or calculate the raw residual divided by the square root of the variance as follows (Equation 5):

  $$\text{res} = \Sigma_{i:x_i \le j} \frac{(y_i - \hat{y}_i)}{\sqrt{\hat{y}_i + K\,\hat{y}_i^{2}}} \tag{5}$$

  where,

  y_i = observed crash frequency at site i

  $\hat{y}_i$ = estimated/predicted mean accident count at site number i (according to the model)

  K = overdispersion parameter of the model

  N = sample size to which the model is applied

- Step 2: Sort the data set in increasing order of an explanatory variable of interest.
- Step 3: Calculate the cumulative residuals (CURE) for each observation.
- Step 4: Calculate squared of the residuals (res^2) for each site.
- Step 5: Calculate the cumulative of the squared residuals, σ^2 (*n*).
- Step 6: Sum the squared residuals, σ^2 (*N*).
- Step 7: Estimate the variance of the CURE/ random walk, σ^{*2} (Equation 6).

  $$\sigma *^{2} = \sigma^{2}\ (\mathrm{n})[1 - \frac{\sigma^{2}(n)}{\sigma^{2}(N)}] \tag{6}$$

- Step 8: For each site, calculate the 95% CI of $\pm 2\sqrt{\sigma *^{2}}$.
- Step 9: Plot, CURE from step 3, lower and upper limits from step 7 on the y-axis against the explanatory variable of interest on the x-axis.

Figures 5.1 through 5.4 show the CURE plot for the dependent variables of (a) duration, (b) length, (c) AADT, and (d) NWZ×WZ SL, respectively, for the calibration SPF models (with n = 256) for total work zone crashes.

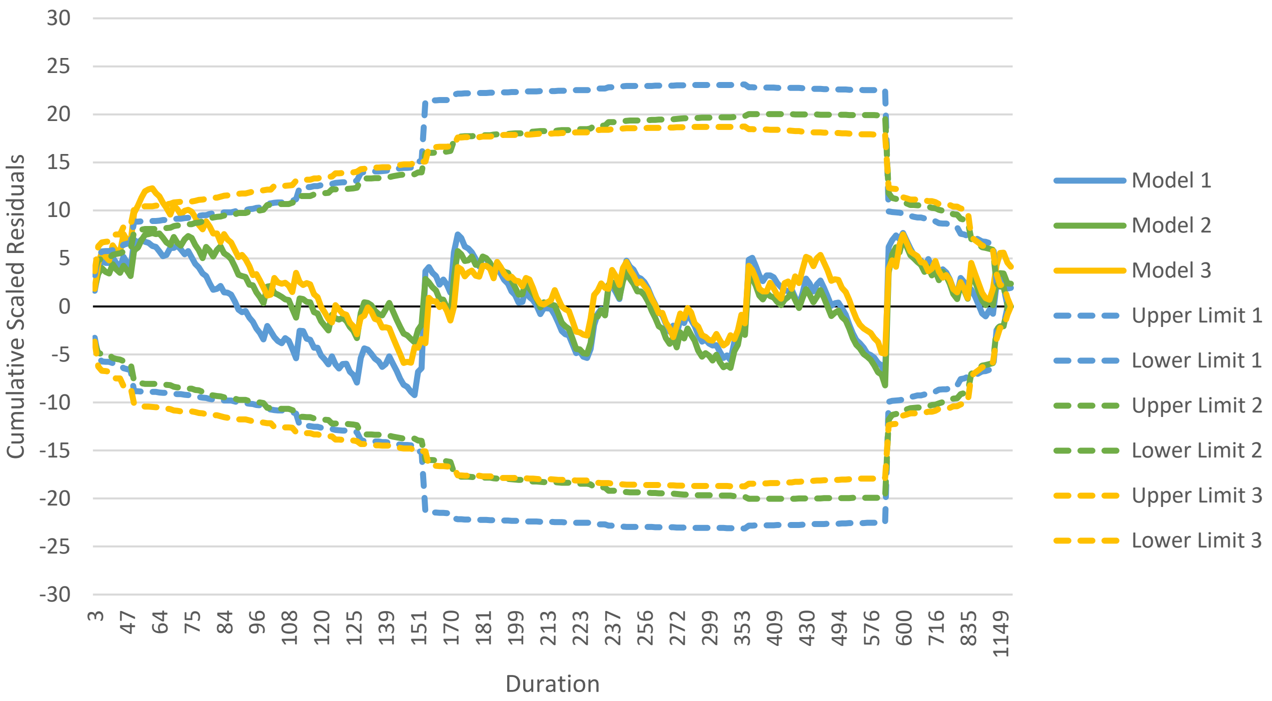


Figure 5.1. CURE plots for "duration" for total work zone crashes.

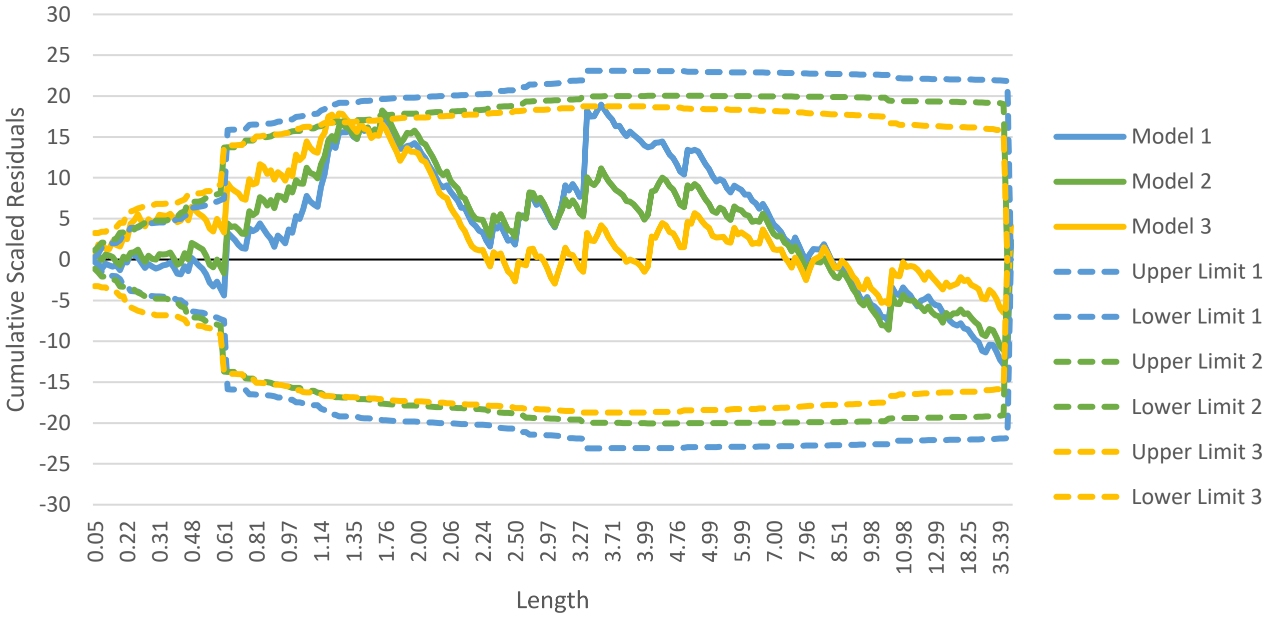


Figure 5.2. CURE plots for "length" for total work zone crashes.

Figure 5.3. CURE plots for "AADT" for total work zone crashes.

Figure 5.4. CURE plots for "NWZ SL × WZ SL" for total work zone crashes.

A consistent upward drift of the cumulative residuals within a particular range of exposure variables indicates that the SPF model is underpredicting the crashes. A consistent downward drift within a particular range of exposure variables indicates that the SPF model is overpredicting the crashes. Despite underprediction and overprediction for some exposure variable ranges, the CURE plots for Model 1, Model 2, and Model 3 from Figures 5.1 through 5.4 are essentially random and are within the confidence limits of ± 2 standard deviations (σ). The upward drift of the CURE for the dependent variable of "Length" from the 2.29 mi to 7.96 mi range was observed for Model 1 and Model 2. But, Model 3 showed a marked improvement in comparison with a lower CURE deviation. Further, the CURE better oscillated about zero in Model 3 for the work zone "Length" variable.

Figures 5.5 through 5.7 are the CURE plots that show the distribution of residuals with respect to the independent variables for the work zone fatal/injury crash SPF. Despite underprediction and overprediction for some exposure variable ranges, the CURE plots for the fatal/injury SPF are essentially random and are within the confidence limits of ± 2σ.

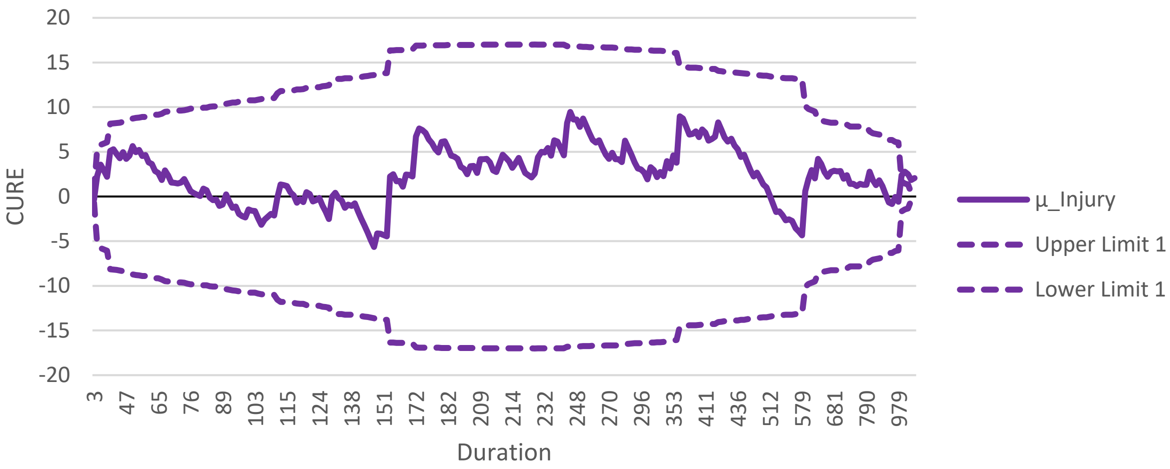


Figure 5.5. CURE plot for "duration" for fatal/injury work zone crashes.

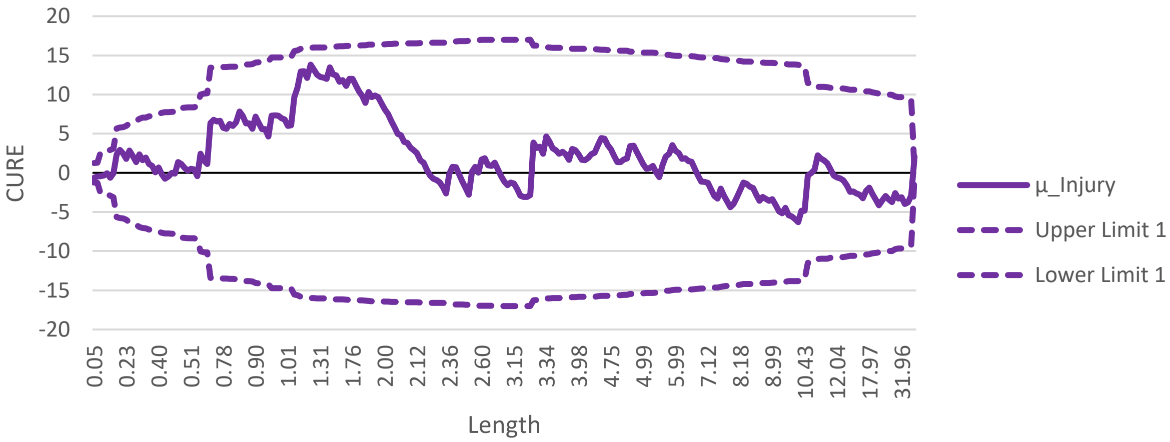


Figure 5.6. CURE plot for "length" for fatal/injury work zone crashes.

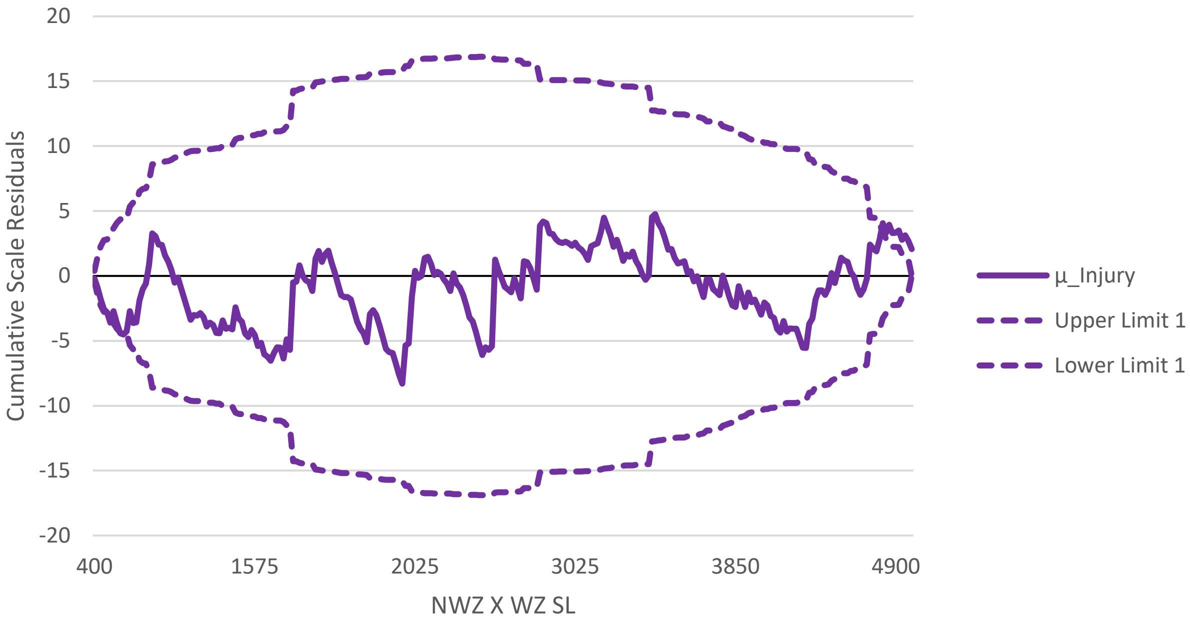


Figure 5.7. CURE plot for NWZ SL × WZ SL for fatal/injury work zone crashes.

5.3.3 Goodness-of-Fit Test

To compare the total and fatal/injury work zone crash prediction models in terms of overall goodness of fit to the calibrated data, the following assessment measures were used (Srinivasan & Bauer, 2013; Garber & Rivera, 2010): the overdispersion parameter, Pearson chi-square/degrees of freedom, Akaike's Information Criterion (AIC), and Bayesian Information Criterion (BIC) (Table 5.3). To test the transferability of the calibrated SPFs to the validation data, the mean absolute deviation (MAD), the mean predicted bias (MPB), the mean absolute scaled deviation (MASD), the Pearson product moment correlation (r), and the Freeman-Tukey R-squared measures were used (Table 5.3).

Analysis of the results in Table 5.3 indicate that total work zone crash Model 3 is the preferred model, as compared to Model 1 and Model 2 for the following reasons.

Based on Calibration Data—Total Work Zone Crashes:

- The goodness-of-fit statistics indicate that in terms of the overdispersion parameter, Model 3 is preferred over Models 1 and 2. It has the least overdispersion parameter of 0.596 for the calibration data. A lower overdispersion parameter means smaller variance and consequently lower standard error.
- The Pearson chi-square/degrees of freedom for Model 3 is closer to one, showing a better fit.
- The Pearson product moment correlation coefficient for Model 3 on calibration is 0.535, which is the highest of all the models, indicating higher linear association between observed and predicted data.

- The smaller AIC and BIC values for Model 3 also confirm the finding that it is superior to Model 1 and Model 2. Low AIC and BIC indicates a lower degree of information lost by the model (or less unexplained variation in the dependent variable and exposure variables) and indicate better in-sample fit.

Table 5.3. Goodness-of-Fit Statistics for Calibration Data and Validation Data for Total and Fatal/Injury Work Zone Crash Models

Goodness of Fit for Calibration Data	Total Work Zone Crash Models			Fatal/Injury Work Zone Crash Model	Desirable Condition
	Model 1	Model 2	Model 3		
No. of Sites	256	256	256	256	
Overdispersion	0.768	0.663	0.596	0.880	Lower value
Pearson chi-square/degrees of freedom	2.125	1.601	1.405	1.153	Close to 1.0
Pearson Product Moment Correlation (r)	0.4182	0.4281	0.5345	0.495	Higher value
Akaike's Information Criterion (AIC)	1532.816	1497.073	1478.678	905.722	Lower value
Bayesian Information Criterion (BIC)	1546.997	1514.799	1499.949	923.448	Lower value
Goodness of Fit for Validation Data	**Total Work Zone Crash Models**			**Fatal/Injury Work Zone Crash Model**	**Desirable Condition**
	Model 1	**Model 2**	**Model 3**		
No of Sites	128	128	128	128	
Mean Absolute Deviation (MAD)	17.016	16.504	16.211	3.44	Lower value
Mean Prediction Bias (MPB)	10.303	10.849	10.116	1.72	Lower value
Mean Absolute Scaled Deviation (MASD)	1.35	1.39	1.24	1.03	Lower value
Pearson Product Moment Correlation (r)	0.45	0.46	0.61	0.543	Higher value
Freeman-Tukey R^2	0.23	0.26	0.35	0.26	Higher value

Based on Validation Data—For Total Work Zone Crashes:

- From the validation data, Model 3 had the lowest average magnitude of variability of prediction (i.e., mean absolute deviation—MAD of 16.21 and mean prediction bias MPB of 10.12).
- Model 3 had the highest r value of 0.61, indicating better external validation.

For the fatal/injury work zone model, the overdispersion parameter for the calibration data was found to be 0.88. Also, the Pearson chi-square/degrees of freedom for the model is 1.153 (close to one), showing a good fit. The Pearson product moment correlation (r) for the calibration model was 0.54, which is higher than that of the calibration data of 0.26. The low values of MAD, MPB, and MASD of 3.44, 1.72, and 1.03, respectively, confirm a good fit.

5.3.4 Comparison of Coefficients—Calibration versus Validation Data Sets

In an ideal scenario, the variables found in the calibrated SPFs would be confirmed as statistically significant variables using the validation data, and the model coefficients would perfectly match with the calibrated model coefficients. Tables 5.1 and 5.2 show the parameter estimates obtained from calibration and validation datasets for the total and fatal/injury work zone crash models, respectively.

All variables from the calibrated SPFs were also found to be statistically significant in the validation dataset. However, the statistical significance of all variable coefficients in the validation dataset was best for total work zone crash Model 3 (P-value < 0.001). The variable coefficients, as expected, were not exactly the same because of differences in the calibration and validation datasets. A direct comparison of variable coefficient ratio between the calibrated SPFs and that from the validation data for the models is presented in Table 5.4 for total and fatal/injury work zone crashes.

Table 5.4. Variable Coefficient Ratios between the Calibration and Validation Models

Parameter	Coefficient Ratio			
	Total Work Zone Crash Models			Fatal/Injury Work Zone Crash Model
	Model 1	Model 2	Model 3	
α (Intercept Coefficient)	0.5	0.775	0.807	0.417
Duration Coefficient	0.612	0.666	0.672	0.515
Length Coefficient	1.11	0.838	0.971	0.910
AADT Coefficient	NA	0.987	1.040	NA
NWZ×WZ SL Coefficient	NA	NA	0.795	0.733

NA = Not Applicable

The variable coefficient ratios for the total work zone crash Model 3 are larger and closer to the value of 1.0, indicating a close agreement between the validation and calibration coefficients for Model 3.

For the fatal/injury work zone crash model, the variable coefficient ratio of 0.91 and 0.733 shows close agreement between the coefficient values for length and NWZ×WZ SL, respectively because they are closer to the value of 1.0. The duration coefficient and intercept coefficient ratio of 0.515 and 0.417, respectively, are not as close to 1.0 and thus do not indicate as close of an agreement.

5.3.5 Recommended SPFs and Analysis of Pooled Data Set (n = 384)

The results of individual variable coefficient comparison, goodness-of-fit statistics, and CURE plot analysis indicated that total work zone crash Model 3 is the best model of the three considered in this study. However, the comparatively large difference in the coefficient for the variable work zone “Duration” from the calibration to the validation datasets suggests that the sampling of the calibration data was not robust enough to represent all work zone duration conditions. To further evaluate the robustness of Model 3, the entire data set of 384 work zone sites (i.e., the pooled dataset, n = 384) was used to re-estimate the predictor variable coefficients. Table 5.5 shows the variable coefficients for Model 3 using the pooled data set. Similarly, modeling for fatal/injury work zone crashes using the pooled data set was conducted, and the results are also shown in Table 5.5.

Table 5.5. Variable Coefficients for Recommended SPFs—Pooled Data Set (n = 384)

Enhanced Models	Regression Coefficients Intercept (α) (St. Error) (P-Value)	Duration Coefficient (St. Error) (P-Value)	Length Coefficient (St. Error) (P-Value)	AADT Coefficient (St. Error) (P-Value)	NWZ×WZ SL Coefficient (St. Error) (P-Value)	Overdispersion Parameter, k (St. Error)
Total WZ Crashes Model 3	-7.049 (0.6982) (< 0.001)	0.904 (0.0588) (< 0.001)	0.317 (0.0436) (< 0.001)	0.486 (0.0643) (< 0.001)	-0.0004 (0.0001) (< 0.001)	0.739 (0.058)
Fata/Injury Model	-2.872 (0.5306) (< 0.001)	0.812 (0.0822) (< 0.001)	0.323 (0.0658) (< 0.001)	NA	-0.0005 (0.0001) (< 0.0001)	1.105 (0.1258)

NA = Not Available

The recommended SPF models for predicting work zone crashes and injuries on IDOT state routes and freeways are as follows in Equation 7 and Equation 8:

$$\mu_{Total} = e^{-7.049} \times D^{0.904} \times L^{0.317} \times AADT^{0.486} \times e^{-0.0004(NWZ\ SL \times WZ\ SL)} \tag{7}$$

$$\mu_{Fatal/Injury} = e^{-2.872} \times D^{0.812} \times L^{0.323} \times e^{-0.0005(NWZ\ SL \times WZ\ SL)} \tag{8}$$

The standard error of the coefficients helps measure the quality of an SPF and represents the ability of an SPF to predict crashes accurately. A small standard error indicates that the SPF predicts crashes accurately. As shown in Table 5.5, the standard errors are small, with values ranging from 0.0001 to 0.6982. The P-values are also very small < 0.001, indicating a 99.9% level of confidence (LOC) for the coefficients.

The overdispersion parameters (k) were derived from the negative binomial modeling process. Traffic crashes are typically assumed to follow a Poisson distribution, where the mean and variance are equal. If the mean and variance of the crashes are not equal, then the negative binomial model is used to account for this overdispersion. The overdispersion parameters were 0.739 for the total work zone crash model and 1.105 for the fatal/injury work zone crash model.

The estimated parameters for total and fatal/injury work zone crashes are for the logarithmic transformation of the variables work zone duration, length, and AADT, respectively. As such, the estimated log-transformed model parameters directly indicate the elasticity of the corresponding independent variable with respect to the dependent variable. From the final total work zone crash model results, crashes were found to increase at an average of 0.90% for every 1% increase in work zone duration. For the effect of work zone length, crashes would increase by an average of 0.32% for every 1% increase in work zone length. Similarly, a 1% increase in AADT leads to an increase of 0.49% in the number of total work zone crashes. AADTs are typically higher during non-work-zone conditions as compared to work zone conditions. Hence, the increase in crashes predicted by AADT criterion is likely and underestimate.

Although the SPFs include the variable NWZ SL x WZ SL, it is expected that IDOT's policy for setting work zone speed limits will be used. The SPFs are not intended to be used to recommend other values of work zone speed limit. This product may be more reflective of functional classification and type of work, rather than the effect of work zone speed limit and safety of the work zones. Note that Chicago suburban projects on arterials are a prevalent part of the data set. This product should not be adjusted. It must be based on IDOT policy.

The smaller the product value of work zone speed limit and non-work-zone speed limit, the higher the predicted work zone crashes. To illustrate this concept, if the following variables are held constant for WZ length = 5 miles, WZ duration = 100 days, and ADT = 50,000 vpd, the expected total WZ crashes per duration (per Equation 8) for three typical NWZ x WZ SL combinations are shown in Table 5.6.

Table 5.6 Effect of NWZ x WZ SL Product on Total Work Zone Crashes

NWZ SP/ WZ SL Combination	Product of NWZ x WZ SL	Predicted Total WZ Crashes per WZ Duration
45 mph / 45 mph An arterial without a WZ speed limit reduction	2,025 mph^2	7.95
55 mph / 45 mph Highway with 10 mph WZ speed limit reduction	2,475 mph^2	6.64
70 mph / 55 mph Freeway with 15 mph WZ speed limit reduction	3,850 mph^2	3.83

Thus, according to the work zone crash predictions with all other variables held constant, the higher the product of NWZ x WZ SL, the lower the work zone crashes. Using work zone speed reductions per IDOT policy, this also shows that the predicted number of work zone crashes are lower on freeways than on arterials.

From the final fatal/injury work zone crash model results, fatal/injury work zone crashes were found to increase at an average of 0.81% for every 1% increase in work zone duration and at an average of 0.32% for every 1% increase in work zone length. Non-work-zone and work zone speed limits had a similar effect on fatal/injury work zone crashes as total work zone crashes. Fatal/injury crashes tend to increase as the work zone speed limit decreases.

5.3.6 Comparison of Observed and Predicted Work Zone Crashes

Statistical analysis was conducted using the concocted chi-square tests (χ^2_c) at 95% LOC and significance level, $\alpha = 0.05$. The χ^2_c is considered more precise for the Poisson and negative binomial distribution (FHWA, 1998).

The null and alternative hypotheses are as follows:

H

H_o: Work zone crashes observed and predicted (according to the SPF) have the same mean.

H_a: Work zone crashes observed have a smaller or larger mean than the predicted mean.

The hypothesis test consists of computing a sample statistic calculated from the total data compared with a critical chi-square statistic (Equation 9).

$$\chi_c^2 = \sum_{i=1}^{N} \frac{(y_i-\hat{y}_i)^2}{\hat{y}_i+k\hat{y}_i^{\,2}} \tag{9}$$

where

y_i = observed work zone crashes at site number i
$\hat{y}_i$ = predicted work zone crashes at site number i (using the SPF)
k = overdispersion parameter of the model
N = sample size to which the model is applied

The χ^2_c test was performed using the total work zone crash model (Model 3) and the fatal/injury work zone crash model with coefficients based on all 384 work zone sites. The test results show a good fit for both the total and fatal/injury work zone crash prediction models with n = 384 at a 95% LOC.

Because the calculated chi-square values (428.4 and 263.4 for the total and fatal/injury work zone crash models, respectively) are less than the critical value (429.6), the null hypothesis is accepted for both the total and fatal/injury work zone models. This indicates that the total and fatal/injury work zone crashes observed and predicted (according to the SPFs) have the same mean at a 95% LOC and that the SPF models are validated and good predictors of work zone traffic crashes.

5.3.7 Relative Impact of Parameters in SPF Regression Equations—Monte Carlo

The two SPF models developed in this study, as presented in section 5.3.5, represent an important advancement with respect to predicting the number of work zone crashes under known work zone site-specific conditions. There is value in analyzing the relative contribution of each regression coefficient (for each SPF model) on the number of cashes. Thus, a Monte Carlo simulation was performed to analyze the relative contribution/strength of the parameters used to predict crashes per the two SPF regression equations developed.

Condition numbers (CNs) can be deployed to achieve this objective. The CN analysis method is a sensitivity analysis technique to evaluate the impact of the regression coefficients on the dependent variable. The CN analysis begins with the regression equation or the SPF model. For each regression coefficient in a particular regression equation, the CN is developed using the general formula: $CN_{\beta x} = \beta_x * f'(x)/f(x)$, where $f'(x)$ is the partial derivative.

As an example, the SPF model given by Equation 7 is selected.

$$\mu_{Total} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \times AADT^{\beta_3} \times e^{\beta_4(NWZ\ SL \times WZ\ SL)} \tag{7}$$

Equation 7 has four regression coefficients or parameters (β_1, β_2, β_3, and β_4) directly associated with four independent variables (duration, length, AADT, and NWZ SL × WZ SL), which are used to predict the average annual expected total work zone crashes. The fifth parameter, α, yields a value of 1.0 for the CN (Equation 10).

$$CN_{\alpha} = \left(\frac{\alpha}{\mu_{TOTAL}}\right)\left(\frac{\partial\mu_{TOTAL}}{\partial\alpha}\right) = 1.0 \tag{10}$$

No further analysis is required for α because this value (i.e., 1.000) remains a constant for all values of the regression coefficient. Essentially, the CN value for α indicates that any change in the value of α will impact the SPF model significantly. It is more important to evaluate the impact of the coefficients β_1, β_2, β_3 and β_4, because they are linked directly to variables that impact the number of crashes. The results from this CN analysis for these coefficients can yield important insights into the relative impact on the number of work zone crashes predicted by the SPF. Condition numbers for the four parameters (β_1, β_2, β_3, and β_4) for the Equation 7 SPF are defined in Equations 11–14:

$$CN_{\beta 1} = \left(\frac{\beta_1}{\mu_{TOTAL}}\right)\left(\frac{\partial \mu_{TOTAL}}{\partial \beta_1}\right) = (\beta_1)(x_1) \quad (11)$$

$$CN_{\beta 2} = \left(\frac{\beta_2}{\mu_{TOTAL}}\right)\left(\frac{\partial \mu_{TOTAL}}{\partial \beta_2}\right) = (\beta_2)(x_2) \quad (12)$$

$$CN_{\beta 3} = \left(\frac{\beta_3}{\mu_{TOTAL}}\right)\left(\frac{\partial \mu_{TOTAL}}{\partial \beta_3}\right) = (\beta_3)(x_3) \quad (13)$$

$$CN_{\beta 4} = \left(\frac{\beta_4}{\mu_{TOTAL}}\right)\left(\frac{\partial \mu_{TOTAL}}{\partial \beta_4}\right) = (\beta_4)(x_4) \quad (14)$$

The Monte Carlo simulation technique was then applied to analyze the relative contribution of the four variables in Equation 7 on the total number of work zone crashes at a site. To conduct the CN analysis, the average values of the variables' duration, length, AADT, and NWZ SL × WZ SL were estimated using sample data from the sites included in the model development.

First, an analysis of one randomly selected site was conducted, and the Monte Carlo simulation was performed 1,000 times to estimate the *relative impact and contribution* of each regression coefficient (e.g., β_1 β_2, β_3, and β_4 for Equation 7) on the total number of work zone crashes. Once the CNs were obtained from the Monte Carlo simulation (for 1,000 runs per site), the average CN for each variable was calculated and expressed as a percentage. The resulting CNs from the Monte Carlo analysis, for a single site, are shown in Table 5.6, depicting the maximum, minimum, and average CNs.

The Monte Carlo simulation indicated that the range of CN values for 1,000 trials for one site for β_1 (work zone duration), for example, was 6.4×10^{-1} to 8.6×10^{-1}, with an average of 7.5×10^{-1}. The remaining maximum, minimum, and average CNs for the remaining variables for Equations 7 and 8, based on one site, are shown in Table 5.6.

Table 5.6. Minimum, Maximum, and Average Condition Numbers for a Single Site

	Condition Numbers (CN)		
	Maximum	**Minimum**	**Average**
Equation for Predicting Total Work Zone Crashes $\mu_{Total} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \times AADT^{\beta_3} \times e^{\beta_4(NWZ\ SL \times WZ\ SL)}$ (7)			
β_1 Duration of WZ	8.6×10^{-1}	6.4×10^{-1}	7.5×10^{-1}
β_2 Length of WZ	1.2×10^{-1}	6.5×10^{-2}	9.6×10^{-2}
β_3 AADT in WZ	5.3×10^{-1}	3.4×10^{-1}	4.4×10^{-1}
β_4 NWZ SL × WZ SL	-8.4×10^{-1}	-18.2×10^{-1}	-13.7×10^{-1}
Equation for Predicting Total Work Zone Fatal/Injury Crashes $\mu_{Fatal/Injury} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \times e^{\beta_3(NWZ\ SL \times WZSL)}$ (8)			
β_1 Duration of WZ	8.1×10^{-1}	5.4×10^{-1}	6.8×10^{-1}
β_2 Length of WZ	1.4×10^{-1}	6.1×10^{-2}	1.03×10^{-1}
β_3 NWZ SL × WZ SL	-12.6×10^{-1}	-25.7×10^{-1}	-19.2×10^{-1}

While the results for a single site are interesting, it is more important to analyze the data trends in a larger data set of work zone sites. The first task was to estimate the required number of samples (work zone sites) to analyze as a part of the Monte Carlo analysis. To estimate the number of samples (out of the 384), Equation 15 was used:

$$n = \left(\frac{Z_{\alpha/2} \times s}{e} \right)^2 \tag{15}$$

where:

n = Estimated sample size for number of sites at the desired precision and LOC

s = Preliminary estimate of the population standard deviation for the relative percent impact

$Z_{\alpha/2}$ = Two-tailed value of the standardized normal deviate associated with the desired LOC (at a 95% LOC, $Z_{\alpha/2} = 1.96$)

e = Maximum allowable error for the estimate (assumed to be 3%)

For this study, the maximum percent error “e” was assumed to be 3%, and a preliminary estimate of standard deviation was conservatively estimated to be 11.50%. The largest standard deviation value among all variables was used to calculate the required sample size, in order to be conservative. Based on these values, a sample size of 56 was needed to conduct the Monte Carlo simulation.

The Monte Carlo simulation results from the 56 sites were further analyzed to determine the relative impact of each variable on predicting the number of work zone total crashes and injury crashes for each SPF equation developed in this study. Each line in Table 5.7 is a summary of 56,000 Monte Carlo simulations. The relative impact in percent and the 95% confidence interval of the relative impact of each variable (β_1 β_2, β_3, etc.) was obtained.

Table 5.7. Relative Impact of SPF Variables for 56 Sites

	Average CN	Average Relative Impact	Standard Deviation	95% Confidence Interval		
				±1.96 s/√n	Lower Limit	Upper Limit
Equation for Predicting Total Work Zone Crashes $\mu_{Total} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \times AADT^{\beta_3} \times e^{\beta_4(NWZ\ SL\ \times WZ\ SL)}$ (7)						
β_1 Duration of WZ	0.64035	**31.1%**	7.1%	±1.9%	29.2%	33.0%
β_2 Length of WZ	0.08075	**3.8%**	2.6%	±0.7%	3.1%	4.5%
β_3 AADT in WZ	0.42964	**20.7%**	4.26%	±1.1%	19.6%	21.8%
β_4 NWZ speed limit × WZ speed limit	-0.99893	**44.4%**	11.4%	±3.0%	41.4%	47.4%
Equation for Predicting Total Work Zone Fatal/Injury Crashes $\mu_{Fatal/Injury} = e^{\alpha} \times D^{\beta_1} \times L^{\beta_2} \times e^{\beta_3(NWZ\ SL\ \times\ WZSL)}$ (8)						
β_1 Duration of WZ	0.55910	**30.5%**	10.4%	±2.7%	27.8%	33.2%
β_2 Length of WZ	0.08057	**4.5%**	3.3%	±0.9%	3.6%	5.4%
β_3 NWZ speed limit × WZ speed limit	-1.39173	**65.0%**	11.5%	±3.0%	62.0%	68.0%

For the total work zone crash SPF, the relative impact (based on data from 56 sites) for β_1 is 31.1%, indicating that the duration of work zone is an important factor in determining the total number of work zone crashes. The length of the work zone (β_2) is important but not as impactful as the duration of the work zone in predicting the total number of crashes, as its relative impact is 3.8%. The relative impact of AADT (β_3) is 20.7%, which is logical because higher traffic volumes are likely to result in more crashes. Finally, the new parameter from this research, which is the product of the NWZ and WZ speed limits, appears to have the greatest impact on the prediction of total WZ crashes, with a relative impact of 44.4%.

For the work zone fatal/injury crash SPF, the results of 56,000 Monte Carlo simulations for the variables (β_1, β_2, β_3) are also presented in Table 5.7. The duration of the work zone (β_1) is again indicated to be an important parameter, with a 30.5% relative impact on the total number of work zone fatal/injury crashes. As in the case of the total work zone crash analyses, the work zone length had a relative smaller impact (4.5%) than the other two variables. Finally, the product of the non-work-zone (NWZ) and work zone (WZ) speed limits had the greatest relative impact (65%) on work zone fatal/injury crashes.

In addition to the average relative impact of each parameter for the two parametric equations developed in this research, the 95% confidence intervals were also estimated for each variable and SPF. For example, in Equation 7 to predict total WZ crashes, β_1 (duration of WZ) has a relative impact between 29.2% and 33.0% (average of 31.1%). Similarly, the confidence intervals for the other variables in both equations were estimated and are presented in Table 5.7. These data indicate that the 95% confidence intervals are narrow, suggesting that the variability in the relative impact for each of the parameters is minimal. This further indicates that the data and data analyses were robust.

The above analyses show the *relative impact* of the different regression coefficients (e.g., α, β_1, β_2, β_3, and β_4) on the dependent variable (e.g., total number of crashes). This method is not intended as a replacement to develop the appropriate regression equation(s) using standard sensitivity methods such as a Bayesian analysis using the negative binomial, Poisson, or other applicable distributions. In fact, these methods are necessary to develop the regression equations, which can then further be analyzed using the CN analysis presented.

CHAPTER 6: METHODOLOGY FOR WORK ZONE SAFETY

As a part of this research, SPFs, an Excel tool, and CMFs were developed to help improve work zone safety. The following sections highlight the recommended SPFs and CMFs developed to predict total and fatal/injury work zone crashes. Illustrations are also provided to show how the SPFs and Excel tool may be applied to practical scenarios where IDOT needs to make decisions about work zone length and expected duration in work zone based on safety considerations on state highways. The approach and methodology developed in this research can also serve as a platform to develop crash predictions and compare alternatives at a regional scale.

6.1 SAFETY PERFORMANCE FUNCTIONS

A SPF is an equation used to predict the average number of crashes per unit of time at a location as a function of exposure and other characteristics. SPFs are used to predict crash frequency for a given set of site conditions or to compare the safety performance of a specific site under various conditions. Work zone total crashes (K-fatal; A-, B-, and C-injury crashes; and PDO crashes) and fatal/injury crashes (K, A, B, and C) can be predicted using the SPFs shown below.

$$\mu_{Total} = e^{-7.049} \times D^{0.904} \times L^{0.317} \times AADT^{0.486} \times e^{-0.0004(NWZ\ SL \times WZ\ SL)} \tag{7}$$

$$\mu_{Fatal/Injury} = e^{-2.872} \times D^{0.812} \times L^{0.323} \times e^{-0.0005(NWZ\ SL \times WZ\ SL)} \tag{8}$$

where:

D = Work zone duration, in days
L = Work zone length, in miles
AADT = Annual average daily traffic, in vehicles per day
NWZ SL x WZ SL = Product of non-work-zone and work zone speed limits
α, β_1, β_2, β_3, β_4 = Coefficients for the respective variables

The safety performance can be predicted for alternative scenarios for a given roadway section with a known posted speed limit, AADT, and predetermined work zone speed limit according to IDOT policies. The alternative scenarios considered would have differing work zone lengths and durations.

IDOT's policy on establishing work zone speed limits (March 2011) recommends no speed limit reduction in the case of no lane reduction or apparent hazard on all roadway types and on a multilane road with an existing speed limit below 45 mph. The policy further recommends a 10-mph reduction in speed from the existing speed limit for work zones established on a multilane with existing speed of 55 mph or more. In case of workers' presence, the policy recommends speed limit reduction to 45 mph from the existing speed limit of 65 or 60 mph for multilane roads. The reduction in excess of 10 mph below the existing speed limit is recommended by IDOT only in special cases such as narrow pavement lane width, drop-offs, high-traffic volumes, inadequate sight distance, and space requirements (IDOT, 2011).

The WZ speed limit used in the SPF equation to predict work zone crashes must be input as the speed limit according to IDOT's policy for setting work zone speed limits. The SPFs are not intended to be used to recommend other values of speed limit or work zone speed limit. This product may be more reflective of functional classification and type of work, rather than the effect of work zone speed limit and safety of the work zones. This product should not be adjusted. It must be based on IDOT policy.

6.1.1 SPF Example for Comparison of Work Zone Alternatives

The following example illustrates how to apply Illinois SPFs that account for work zone duration and length. Engineers involved in work zone design and maintenance of traffic plans can then make more informed decisions during the work zone design process.

For a maintenance project conducted in a 5-mi highway, the Maintenance of Traffic design team can assess the expected change in crashes for three work zone duration and length scenarios. The three proposed scenarios (Figure 6.1) for consideration include: i) one 5-mi work zone in 60 days, ii) two 2.5-mi work zones with total duration of 90 days (with 45 days per segment and 2 segments), and iii) five 1-mi work zone sections with a total duration of 120 days (with 24 days per segment and 5 segments). Assume the AADT on the freeway is 50,000 vpd and the posted speed limit is 65 mph. According to IDOT policy, the work zone speed limit is 55 mph.

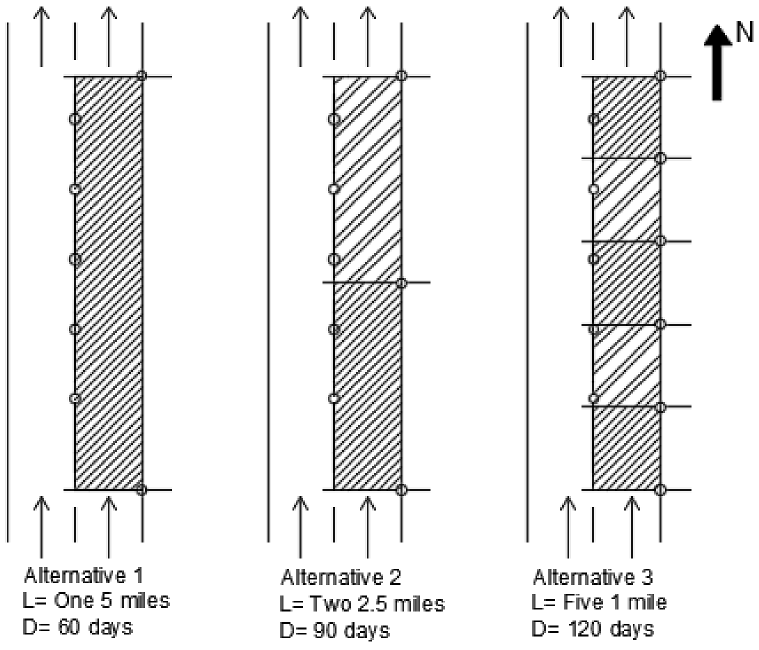


Figure 6.1. Work zone duration and length scenarios for comparison.

Using the SPFs for total and fatal/injury work zone crashes, the predicted crashes would be calculated for each segment and then multiplied by the total number of segments to determine the WZ crashes for the overall project. Sample calculations for total WZ crashes and fatal/injury WZ crashes are as follows for the three alternatives:

Total Work Zone Crashes (Equation 7)

Alternative 1 (L = 5 miles, D = 60 days, and 1 segment)

$$\mu_{Total} = e^{-7.049} \times (60\ days)^{0.904} \times (5\ miles)^{0.317} \times (50{,}000)^{0.486} \times e^{-0.0004(65 \times 55)}$$

= 2.69 Total work zone crashes per work zone segment duration

There is only one work zone segment in Alternative 1, and the total work zone crashes for the overall project duration (sum of all segments) would be:

= 2.69 WZ crashes per segment x 1 segment = 2.69 Total WZ crashes for overall project duration

∴ **For Alternative 1: 2.69 Total WZ crashes for overall project duration (for all segments)**

Alternative 2 (L = 2.5 miles, D = 45 days, and 2 segments)

$$\mu_{Total} = e^{-7.049} \times (45\ days)^{0.904} \times (2.5\ miles)^{0.317} \times (50{,}000)^{0.486} \times e^{-0.0004(65 \times 55)}$$

= 1.67 Total work zone crashes per work zone segment duration

There are two work zone segments in Alternative 2, and the total work zone crashes for the overall project duration (sum of all segments) would be:

= 1.67 WZ crashes per segment x 2 segments = 3.33 Total WZ crashes for overall project duration

∴ **For Alternative 2: 3.33 Total WZ crashes for overall project duration (for all segments)**

Alternative 3 (L = 1 mile, D = 24 days, and 5 segments)

$$\mu_{Total} = e^{-7.049} \times (24\ days)^{0.904} \times (1\ mile)^{0.317} \times (50{,}000)^{0.486} \times e^{-0.0004(65 \times 55)}$$

= 0.71 Total work zone crashes per work zone segment duration

There are five work zone segments in Alternative 3, and the total work zone crashes for the overall project duration (sum of all segments) would be:

= 0.71 WZ crashes per segment x 5 segments = 3.53 Total WZ crashes for overall project duration

∴ **For Alternative 3: 3.53 Total WZ crashes for overall project duration (for all segments)**

Fatal/Injury Work Zone Crashes (Equation 8)

Alternative 1 (L = 5 miles, D = 60 days, and 1 segment)

$$\mu_{Fatal/Injury} = e^{-2.872} \times (60\ days)^{0.812} \times (5\ miles)^{0.323} \times e^{-0.0005(65 \times 55)}$$

= 0.44 Fatal/Injury work zone crashes per work zone segment duration

There is only one work zone segment in Alternative 1, and the fatal/injury work zone crashes for the overall project duration (sum of all segments) would be:

= 0.44 WZ crashes per segment x 1 segment = 0.44 Fatal/Injury WZ crashes for overall project duration

∴ For Alternative 1: 0.44 Fatal/Injury WZ crashes for overall project duration (for all segments)

Alternative 2 (L = 2.5 miles, D = 45 days, and 2 segments)

$$\mu_{Fatal/Injury} = e^{-2.872} \times (45\ days)^{0.812} \times (2.5\ miles)^{0.323} \times e^{-0.0005(65 \times 55)}$$

= 0.28 Fatal/Injury work zone crashes per work zone segment duration

There are two work zone segments in Alternative 2, and the fatal/injury work zone crashes for the overall project duration (sum of all segments) would be:

= 0.28 WZ crashes per segment x 2 segment = 0.56 Fatal/Injury WZ crashes for overall project duration

∴ For Alternative 2: 0.56 Fatal/Injury WZ crashes for overall project duration (for all segments)

Alternative 3 (L = 1 mile, D = 24 days, and 5 segments)

$$\mu_{Fatal/Injury} = e^{-2.872} \times (24\ days)^{0.812} \times (1\ mile)^{0.323} \times e^{-0.0005(65 \times 55)}$$

= 0.13 Fatal/Injury work zone crashes per work zone segment duration

There are five work zone segments in Alternative 3, and the fatal/injury work zone crashes for the overall project duration (sum of all segments) would be:

= 0.13 WZ crashes per segment x 5 segments = 0.63 Fatal/Injury WZ crashes for overall project duration

∴ For Alternative 3: 0.63 Fatal/Injury WZ crashes for overall project duration (for all segments)

A summary of the results for all three scenarios are shown in Table 6.1.

Table 6.1. Work Zone Crash Predictions Using SPFs for Example Alternatives

Work Zone Crash Predictions	**Alternative 1** (L = 5 mi, D = 60 days, 1 segment)	**Alternative 2** (L = 2.5 mi, D = 45 days, 2 segments)	**Alternative 3** (L = 1 mi, D = 24 days, 5 segments)
Predicted total number of work zone crashes per work zone segment duration	2.69	1.67	0.71
Predicted fatal injury work zone crashes per work zone segment duration	0.44	0.28	0.13
Predicted total number of work zone crashes for overall project duration (for all segments)	2.69	3.33	3.53
Predicted fatal/injury work zone crashes for overall project duration (for all segments)	0.44	0.56	0.63

The results indicate that Alternative 1, a work zone with one 5-mi length and WZ duration of 60 days, has the lowest overall WZ crashes for total crashes and fatal/injury crashes. Drivers traveling through longer work zones in place over a longer duration may acclimatize themselves to a work zone over time and over longer distances.

6.2 EXCEL TOOL

An Excel tool was developed to facilitate the ease of the calculations for the SPFs and assess safety performance of work zones in Illinois. A user can analyze a single work zone, or up to three work zone alternatives at a time. The Excel tool contains:

- A tutorial worksheet that explains the basic components of a work zone and descriptions of the color-coding schemes for data input.
    - Yellow-colored cells: input information for a user to manually enter
    - Blue-colored cells: input information for a user to enter from a drop-down list
    - Green-colored cells: output from the SPF
- Work Zone Safety Performance—Analysis using work zone SPFs. A user would input and receive output for:
    - Yellow-colored cells (manually input)
        - Route name/number
        - Contract number
        - Location of road closure (from/to street or miles or other description)
        - Type of project (construction, maintenance, utility, other)
        - Total number of lanes of roadway
        - Number of lanes reduced
        - Posted, non-work-zone speed limit
        - Work zone speed limit, per IDOT policy
        - AADT
        - Work zone segment length in miles
        - Duration of work zone, in days

- Blue-colored cells (input from a drop-down list)
  - District number
  - County name
  - Urban or rural
  - Functional classification
  - Type of road closure
- Green-colored cells (output from the SPF for each alternative for one to three alternatives)
  - Predicted total number of work zone crashes per work zone duration
  - Predicted fatal/injury work zone crashes per work zone duration
  - Predicted total number of work zone crashes per year
  - Predicted fatal/injury work zone crashes per year

Screenshots of the Excel tool are included in Appendix D.

6.3 CRASH MODIFICATION FACTORS

A CMF is a multiplicative factor used to compute the estimated number of crashes after implementing a given countermeasure at a specific site. “A CMF represents the relative change in estimated average crash frequency due to differences for each specific condition and provides an estimate of the effectiveness of the implementation of a particular countermeasure” (Kolody et al., 2014, p. 2–13).

CMFs are available as a part of this study of Illinois work zones for duration and length for total WZ crashes and fatal/injury WZ crashes. Typically, one would use an SPF to estimate the number of crashes at a site, given traffic volumes, roadway geometry, etc. Then, CMFs would be used to determine the impact on crashes of various safety treatments or alternatives. Because the SPFs developed through this research also contain the variable of work zone duration and length and serve as the basis for the CMFs, using both the SPFs and CMFs together is not recommended.

Thus, it is recommended to use the SPFs to assess work zone total and fatal/injury crashes for different combinations of work zone duration and length. The Excel Tool developed through this research will help facilitate the ease of calculations for WZ total fatal/injury crashes.

To use CMFs, the expected number of crashes under the base condition is required. If the base expected crashes are known or can be estimated, then an analyst may use the CMFs.

If the SPF is used to determine the safety effect of a change in work zone duration from D_1 to D_2, then the CMF for a change in duration can be calculated in Equation 16 as:

$$CMF = \frac{e^{\alpha} \times {D_2}^{\beta_1} \times L^{\beta_2} \times AADT^{\beta_3} \times e^{\beta_4 * (NWZ \times WZ\ SL)}}{e^{\alpha} \times {D_1}^{\beta_1} \times L^{\beta_2} \times AADT^{\beta_3} \times e^{\beta_4 * (NWZ \times WZ\ SL)}} \qquad (16)$$

The equation above can be simplified to:

$$CMF = \left(\frac{D_2}{D_1}\right)^{\beta_1} \tag{17}$$

The CMF is a function of original duration D_1 and change in duration to D_2 and variable coefficient β_1. So, for a 1% increase in work zone duration from the base condition, β_1% increase in crashes would occur. The same would apply for determining the safety effect of changing the length of the work zone.

This method was used in the *HSM* to extract the work zone CMFs from Khattak's model (AASHTO, 2010; Khattak et al., 2002). Equations 18 and 19 below are the two CMFs illustrated in *HSM*, based on the California data, with a minimum duration of 16 days, minimum length of 0.51 mi, WZ duration CMF of 1.11, and WZ length CMF of 0.67 (AASHTO, 2010; Khattak et al., 2002).

$$CMF_{Duration\ for\ Total\ WZ\ Crashes} = 1.0 + \frac{(\%\ increase\ in\ duration\ from\ 16\ days * 1.11)}{100} \tag{18}$$

$$CMF_{Length\ for\ Total\ WZ\ Crashes} = 1.0 + \frac{(\%\ increase\ in\ length\ from\ 0.51\ miles * 0.67)}{100} \tag{19}$$

Equations 18 and 19 from the *HSM* (AASHTO, 2010; Kolody et al., 2014) were then modified as Equations 20 and 21 for the Illinois study for total WZ crashes, and as Equations 22 and 23 for fatal/injury WZ crashes, for duration and length as shown below.

$$CMF_{Duration\ for\ Total\ WZ\ Crashes} = 1.0 + \frac{(\%\ increase\ in\ duration\ from\ 3\ days * 0.904)}{100} \tag{20}$$

$$CMF_{Length\ for\ Total\ WZ\ Crashes} = 1.0 + \frac{(\%\ increase\ in\ length\ from\ 0.1\ miles * 0.317)}{100} \tag{21}$$

$$CMF_{Duration\ for\ Fatal/Injury\ WZ\ Crashes} = 1.0 + \frac{(\%\ increase\ in\ duration\ from\ 3\ days * 0.812)}{100} \tag{22}$$

$$CMF_{Length\ for\ Fatal/Injury\ WZ\ Crashes} = 1.0 + \frac{(\%\ increase\ in\ length\ from\ 0.1\ miles * 0.323)}{100} \tag{23}$$

Table 6.2 shows the comparison of effects of work zone duration and length found from this study in Illinois with that from the *HSM* and other states.

Table 6.2. Comparison of Effects of Work Zone Duration and Length from Studies

Variable	**California**	**Missouri**	**Indiana**	**Michigan**	**Illinois**	
	Total WZ CMF				Total WZ CMF	Fatal/Injury WZ CMF
Duration (Days)	1.11	1.01	1.00	0.90	0.904	0.812
Length (Miles)	0.67	0.58	0.80	0.82	0.317	0.323

Direct comparison shows that the difference between the magnitude of *HSM* estimate and Illinois estimate for duration was 0.206 and 0.353 for length. This difference could be due to the minimum length and duration considered in the data samples. The 384 work zone sites used for calibrating the Illinois estimate included a work zone duration minimum of three days and a work zone length minimum of 0.1 mi, while the base condition for the *HSM* of work zone duration was 16 days and work zone length was 0.51 mi. “The Michigan work zones included a number of projects with shorter durations (a minimum of 3 days) than those in the California and Missouri studies, both of which established minimum project durations of 15 to 16 days. The Indiana study compared per-month averages for longer-duration work zones” (Rista et al., 2017, p. 91).

CHAPTER 7: WORK ZONE DATA NEEDS

At the inception of this research project, IDOT expressed concern with its work zone data quality and thus added an objective to the research project to perform a needs assessment and recommend strategies for improving work zone data in Illinois. Lack of quality work zone data is an issue for many DOTs and transportation agencies in the US. FHWA states that "currently, work zone activity data (WZAD) collection is ad-hoc and limited in scope to address a specific need within agency workflows. Accordingly, it is not easily shared outside of proprietary or agency-specific systems and is difficult to use for purposes other than which it was originally designed" (FHWA, 2018, p. 1).

There is a current nationwide need to standardize work zone information so that it can be shared across jurisdictional boundaries for a variety of applications, including safety, operations, and preparing the highway system for connected and autonomous vehicles.

In response to this need, the FHWA has commissioned the Work Zone Data Initiative (WZDI). The purpose of the WZDI is to "develop a recommended practice for managing WZAD and to create a consistent language, through the development of a data dictionary and supporting implementation documents, for communicating information on work zone activity across jurisdictional and organizational boundaries" (FHWA, 2018, p. 1).

There are various uses of work zone data by many different professionals, some of which include (FHWA, 2018):

- Work zone safety analysis
- Work zone planning and design, maintenance of traffic plan development
- Work zone traffic control devices and Intelligent Transportation System (ITS) technologies
- Construction management, quality assurance, and inspection
- Transportation management center, traveler information, and restrictions
- Work zone mobility and impact analysis
- Law enforcement in work zones
- Oversized vehicle permitting
- Connected and autonomous vehicle integration
- Historical records and historical work zone patterns

Considering the needs of work zone data, the following tasks were performed to accomplish the work zone data needs assessment objective.

- Identify current IDOT data collection methods for work zone variables.
- Review FHWA's Work Zone Data Initiative (WZDI).
- Provide recommendations on how work zone variables should be collected and maintained by IDOT that are consistent with FHWA's WZDI.

7.1 IDOT'S EXISTING DATA FOR WORK ZONE INFORMATION

IDOT's current work zone information is gathered via the OPER 2410 form, which documents restrictions on IDOT roads. This information is primarily used for issuance of permit loads. It is also the source used to inform the Illinois motoring public of road obstructions and restrictions at any given time and is available on GIS maps. The data from this form is housed in databases for segments and points. IDOT's OPER 2410 Road Restriction Information form (Appendix E) contains the following data and instructions for completing the form, extracted directly from IDOT's OPER 2410 (IDOT OPER 2410, Rev 06/08/16):

7.1.1 Location Information

- **District/County Name**: District and county for construction location.
- **Route Type**: Type of route at construction location (interstate, US route, Illinois route, street, county road, or other).
- **Route Number or Street**: Route number (e.g., 90 for Interstate 90) or roadway name. Do not use FAP, FAU, etc.
- **Near Town**: Name of the town the construction zone is in or nearest to.
- **Direction of Route**: Official direction the route travels. Do not use cardinal direction. Example: INT 55 travels south to north, and INT 24 travels west to east. (north, south, north and south, east, west, east and west).
- **From/to Location or Mile**: Always use mile posts or exit numbers for interstate projects, e.g., MP 177 to 184 or MP 39 for a specific structure at MP 39. For all other roadways use intersecting streets, distance from state roadway, etc., e.g., "Elm St. to First Ave.," "2 miles south IL29 at BNSF RR," "Auburn Rd. to 5 miles north of Sydney." Do not use station numbers.

7.1.2 Road Restriction Information

- **Start/Stop Dates**: "These should be the dates which will affect motorists and not necessarily the official contract starting and stopping dates. The start and stop dates are in mm/dd/yyyy format. **The Stop Date is the day the motoring public will stop being affected. If you are not sure of the Stop Date make it longer and revise at a later date. Construction zones will be removed on the Stop Date, <u>if not revised prior to</u>**. Projects not requiring roadway closures or dimensional restrictions on vehicles should be submitted within 7 days of start date. Projects requiring roadway/ramp closures or oversize vehicle permit dimensional restrictions (maximum width or length restrictions on vehicles) should submit restrictions 21 days prior to the actual start date the roadway will be closed or a dimensional restriction will be in place to give motorists and oversize overweight permit loads advance notice.

  <u>Stop dates should be revised or modified as necessary during the life of the project</u>" (IDOT OPER 2410, Rev 06/08/16).
- **Contract Number**: If no contract number exists, a reason should be specified, such as an emergency. In those cases, a contract number will be assigned.
- **New, Revised, Delete**: Describes what kind of <u>temporary restriction</u> is being submitted. **New**—never submitted prior. **Revised**—for changing something submitted prior. **Delete**—to remove an active construction zone, prior to the stop date. (Restrictions will automatically be removed from the website after the stop date.)

- **Contractor**: Name of contractor or entity doing the work.
- **Contract Value**: Value of the construction work performed. (Some districts use this form to provide data for press releases.)
- **Type of Construction**: Lane reduction/lane closure, intermittent road work, intersection restrictions, temporary changes, one-way traffic with temporary signals, one-way traffic with flaggers, shoulder work, road closed, bridge closed, shoulder closed, ramp closed, railroad closure, weight station closed, rest area closed, or closed due to flooding.
- **Lanes/Ramp Closed**: Information on the number of lanes closed or if a ramp or shoulder is closed or restricted.
- **Suggestions to Motorists**: Information that would be helpful to motorists. Examples: Traffic restricted to one lane in each direction, road closed to place beams expect 15-min closures, expect lane closures with narrow lanes, traffic restricted to one lane directed by temporary traffic signals. Include general information on such things as delays, time of day, or days of week, etc. This is an input text line.
- **Traffic Alert**: Any special information, including special delays such as “Expect intermittent 20-minute delays on May 17,” “INT 57 SB ramp to IL 17 EB ramp closed,” etc.
- **Detour Route**: Detour route for standard vehicles and truck detour, if needed.
- **Current Structure Number**: Current structure number in the construction zone. Oversize vehicle permit restrictions will be placed on route specified at the structure only. If restrictions are needed on the crossing roadway as well, please specify. Enter what the structure is crossing to right under crossing (roadway, river, creek, etc.).
- **New Structure Number**: New structure number replacing the current structure in the construction zone.
- **Crossing**: When working at a structure/specific feature, enter what the structure is crossing like the Illinois River or Mud Creek. Please enter the current structure number, not the new structure number.
- **Oversize Vehicle Permit Restrictions**: This section is for submitting width or length restrictions placed on vehicles for construction zones. These restrictions are based on the limitations of the construction zone, not the dimensions of the construction zone. Max Width measurements shall be 1′ 6″ less than the actual opening (e.g., if actual opening measures 13′, width restriction should be reported as 11′ 6″ and signed as 11′ 6″). Max Length restriction measurements shall be determined by the turning radius and traffic patterns in the construction zone. Note: Length restrictions are usually not submitted unless you identify long vehicles are using the route, e.g., a windmill blade with overall length of vehicle at 205 ft. Max length is also used with permanent restrictions to report permanent turning radius issues.

  Examples: Report start and stop dates for restrictions if different than general construction start and stop dates, identify additional structures/locations with width restrictions and dates of, start and stop dates for Stage 1 or 2. (STR # 013-4569 6/15/2013–12/1/14 [Useful when **from/to Location** for paving is 5 mi long with width restriction at structure] or Stage 1 10′ 6″ on 5/15 Stage II 9′6″ on 7/7/13–11/1/13.) **Do not** consider marked detours when reporting restrictions. Permit loads cannot use detours. **If this will be a permanent restriction ignore the start and stop dates**.

- **Crossover**: Indicate if a crossover is being utilized and provide a description. The description should include where both crossovers are, especially in relation to vertical clearance issues, e.g., “East of Elm St. west of IC RR.” The description must also include which direction the traffic is traveling on, e.g., “Traffic on NB lanes.” Revise form 21 days prior to traffic moving to opposite direction of travel.
- **Web Address**: Specific website established for the project, if available.
- **Data Verification**: The accuracy of the information posted on the Road Construction Map and Weekly Restriction List should be verified. Discrepancies can be resolved by submitting a revised OPER 2410.
    - Road Construction Map
    - Weekly Restriction List

The two critical variables currently being collected by IDOT that are in dire need for increased level of accuracy are start/stop dates for WZ duration and begin/end locations for work zone length.

7.2 RECOMMENDATIONS FOR WORK ZONE DATA COLLECTION

To develop recommendations on how work zone data should be collected by IDOT in the future, the following FHWA Work Zone Data Initiative guidelines were used:

- Work Zone Activity Data (WZAD)—WZAD Needs and Opportunities (Draft), January 28, 2019 (Ullman and Finley, 2019)
- Work Zone Activity Data (WZAD)—Data Dictionary Report (Draft), March 15, 2019 (Okunieff et al., 2019)
- Guidance of Data Needs, Availability, and Opportunities for Work Zone Performance Measures (FHWA, 2013)
- A Framework for Work Zone Activity Data Collection and Management (Draft), January 11, 2019 (Stephens et al., 2019)

The following work zone data items are recommended to be collected by IDOT for work zones per the FHWA guidelines (Ullman & Finley, 2019; Okunieff et al., 2019; FHWA, 2013) for identifier, location, time, and impact attributes:

Identifier

Title	Description
Identifier[2]	Machine-generated ID number, permit number
Project ID[1]	Nomenclature for overall project
Owner Agency[1]	Agency primarily responsible for project oversight
Funding Allocation[1]	Status of funding allocation (e.g., planned, requested, pending, partially funded, or fully funded)
Owner Agency Project Manager[1]	Primary day-to-day project contact within the owner agency
Contractor[1]	Prime contractor responsible for project
Subcontractor[1]	Subcontractor(s) responsible for project

Title	Description
Expected Number of Phases[1]	Expected number of project phases
Actual Number of Phases[1]	Actual number of project phases
Project Event ID[2]	A unique identifier associated with one or more project event identifier types and other associated references identifier such as contract number
Phase[1]	Nomenclature for project phase(s)
Activity[1, 2]	Nomenclature for project activity(ies)[1] General description of event/subevent, description about maintenance of traffic approach, expected geometrics associated with each event/subevent, expected traffic control device(s) associated with each event/subevent, actual geometrics associated with each event/subevent, Actual traffic control device(s) associated with each event/subevent, indication that the maintenance of traffic requires coordination between the projects, reference to projects that need to coordinated with, planned number of lanes to be closed, description of planned lanes to be closed, total number of lanes, planned number of lanes to be open[2]
Event[2]	Work type (construction, maintenance, utility work), purpose or scope of work, planned versus actual work

(Source: [1] Ullman & Finley, 2019; [2] Okunieff et al., 2019)

Location Attributes

Title	Description
Roadway Name[1]	Roadway(s) where project/phase/activity will occur
Direction of Travel[1]	Cardinal/compass direction of roadway
Roadway Assigned Direction of Travel[2]	Route direction of road
Road Classification[2]	Functional classification of road
Facility[2]	Description of geometric element affected (e.g., connector, main lanes, or exit ramp)
Planned Begin Location[1,2]	Planned begin location where project/phase/activity is planned[1] Latitude/longitude coordinate, state plane coordinates, state linear referencing system (mile points, mile markers), address, cross-street, a spatial point feature (typically described in freeform text).[2] **The Begin Location should be referenced to the location nearest to the first advanced warning sign for the work zone.**
Actual Begin Location[1,2]	Actual begin location where project/phase/activity is occurring/occurred[1] Latitude/longitude coordinate, state plane coordinates, state linear referencing system (mile points, mile markers), address, cross-street, a spatial point feature (typically described in freeform text).[2] **The Begin Location should be referenced to the location nearest to the first advanced warning sign for the work zone.**

Title	Description
Planned End Location[1]	Planned end location where project/phase/activity is planned[1] Latitude/longitude coordinate, state plane coordinates, state linear referencing system (mile points, mile markers), address, cross-street, a spatial point feature (typically described in freeform text).[2] **The End Location should be referenced to the location nearest to the last work zone warning sign.**
Actual End Location[1]	Actual end location where project/phase/activity is occurring/occurred[1] Latitude/longitude coordinate, state plane coordinates, state linear referencing system (mile points, mile markers), address, cross-street, a spatial point feature (typically described in freeform text).[2] **The End Location should be referenced to the location nearest to the last work zone warning sign.**

(Source: [1] Ullman & Finley, 2019; [2] Okunieff et al., 2019)

Time Attributes

Title	Description
Planned Start Date/Time[1]	Start date/time/day of planned project/phase/activity
Planned End Date/Time[1]	End date/time/day of planned project/phase/activity
Planned Duration[1]	Planned duration of project/phase/activity
Level of Confidence in Planned Start Date[1]	Indicator for the level of confidence that the project will start as planned
Recurring[1]	Indicator that activity is a recurring event
Date/Time Advanced Notice Received[1]	Actual date/time advance notice for a lane closure or other activity received
Actual Start Date/Time[1]	Start date/time when project/phase/activity is occurring/occurred
Actual End Date/Time[1]	End date/time when project/phase/activity is occurring/occurred
Estimated Close[2]	General description of estimated time project/phase/activity is closed
Cancel Time[2]	Description that the project/phase/activity is cancelled
Status[1]	Descriptor of project/phase/activity status (e.g., planned, active, completed, cancelled)

(Source: [1] Ullman & Finley, 2019; [2] Okunieff et al., 2019)

Impact Attributes

Title	Description
Description of Work[1]	General description of project/phase/activity that impacts coordination
Description of Planned Geometric Changes[1]	General description of planned geometric changes to roadway(s)
Description of Planned Temporary Traffic Control (TTC)[1]	General description of planned TTC
Estimated Impact(s)[1,2]	General description of estimated impact(s)[1] Text descriptors of traffic conditions (e.g., heavy, congested, light), expected delay, current travel time on route[2]
Coordination Flag[1]	Indication that work requires coordination
Project(s) to Coordinate with[1]	Project nomenclature of project(s) to coordinate with
Planned Number of Lanes Closed[1]	Number of lanes planned to be closed

Title	Description
Description of Planned Lanes to Be Closed[1]	Description of the lanes planned to be closed
Planned Number Lanes To Be Open[1]	Number of lanes planned to be open
Total Number of Lanes[1]	Total number of lanes
Planned Number of Temporary Lane Closures[1]	Number of temporary lane closures planned for a project or phase
Description of Actual Geometric Changes[1]	General description of actual geometric changes implemented
Description of Actual TTC[1]	General description of actual TTC implemented
Actual Number of Lanes Closed	Number of lanes actually closed
Description of Actual Lanes to Be Closed[1]	Description of the lanes actually closed
Actual Number Lanes to Be Open[1]	Number of lanes actually open
Expected Effect on Mobility[1]	Impact on mobility (e.g., travel time delay)
Lane Closure Permit Number[1]	Lane closure permit number issued by owner agency
Pavement Cut[1]	Indication that work involves cutting or otherwise affecting the pavement
Temporary Restrictions[1, 2]	General description of temporary restrictions (e.g., height, width, weight)[1] A type of restriction that applies to the work zone road segment which is bounded by the begin / end locations[2]
Reduce Speed Limit[1]	Indication that the project/phase/activity had a reduced speed limit or variable speed limit system
Feature Modified[1]	Name of the feature being modified in the field
Description of Feature Modification[1]	General description of the change to the feature in the field
Infrastructure Devices Impacted[1]	General description of existing infrastructure device impact by project/phase/activity
Signal Timing Change[1]	Indication that the signal timing has changed
Description of Signal Time Change[1]	General description of the signal timing change
Detour Route[1]	Detour route information
Enforcement Presence[1]	Indication that law enforcement was present
Type of Enforcement Support[1]	General description of the type of law enforcement support
Law Enforcement Needed[1]	Number of work activities requiring law enforcement support or an indication that law enforcement support is required
Worker Present in Work Zone[2]	Agency documents and archives when workers are present in work zones to support contested citations
Posted Speed Limits[2]	Agency documents and archives posted speed limits in work zones to support contested citations
Mobility[3]	Throughput, travel time delay, average speed, travel time reliability, queue length and duration
Safety[3]	Traffic crashes, traffic operation and surrogate measures, worker accidents
Customer Satisfaction[3]	Driver ratings, complaints, contractor work efficiency
WZ-Geometry[2]	A set of attributes associated with the work zone geometry including but required not limited to begin and end locations
Annual Average Daily Traffic	ADT or AADT of road under normal conditions in vehicles per day
Work Zone Average Daily Traffic	ADT measured while work zone is in place, vehicles per day

(Source: [1] Ullman & Finley, 2019; [2] Okunieff et al., 2019; [3] FHWA, 2013)

It is recommended that a tiered approach by priority be used to begin improving the quality of work zone data in Illinois, based on ease of implementing the suggested changes. Some changes may be easier to implement than others, especially if the work zone data is currently being collected. Other variables suggested here and by FHWA may take a longer period to implement, as they are new variables not currently being collected by IDOT and additional forms or processes may need to be created to obtain them.

The following is the suggested priority list for improving the quality of work zone data in Illinois.

Priority 1 Work Zone Variables

- For number of work zones: Identifier, Project ID, Project event ID
- For work zone duration: Actual start date/time, Actual end date/time
- For work zone length: Actual begin location, Actual end location
- Other critical exposure variables:
    - AADT
    - Work zone average daily traffic
    - Speed limit of road under normal conditions
    - Work zone speed limit
    - Functional classification of road

Priority 2 Work Zone Variables

- Remaining variables listed in the identifier table
- Remaining variables listed in the time attributes table
- Remaining variables listed in the location attributes table

Priority 3 Work Zone Variables

- Remaining variables listed in the impact attributes table

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

Similar to the recent trends in the US, IDOT faces challenges in understanding the causes of increased work zone crashes. Although the direct safety metrics such as the number of work zone fatal and A-injury crashes are available, they do not completely reflect work zone safety performance measures. Three objectives were established for this research. The first objective is to more clearly quantify and report yearly trends on work zone crashes and injuries with an emphasis on fatal and A-injury crashes with respect to work zone exposure variables such as number of work zones, work zone length, and work zone duration. The second objective is to conduct an in-depth analysis of site-specific work zone sites and characteristics in Illinois to develop prediction tools such as SPFs and CMFs to assess work zone safety. The third objective is to identify gaps in existing work zone data in Illinois and make recommendations on data needs. Overall, it is expected that this research will aid in assessing safety aspects of work zones, which will enable IDOT to make progress towards achieving zero fatalities in work zones.

8.1 WORK ZONE SAFETY PERFORMANCE MEASURES

The three performance measures that were used to quantify the work zone safety in Illinois are traffic crash frequencies, exposure variables, and crash rate measures.

Data from three main sources were obtained from IDOT to analyze work zone safety performance in Illinois from 2013 to 2017. They are the traffic crash, lane closure, and roadway network databases. The three databases were fused to obtain work zone information in terms of traffic crash frequencies and work zone exposure variables in Illinois. Annual work zone frequencies were obtained and trend analyses were prepared for all roads and for IDOT roads for the following crash types: total work zone (WZ) crashes, WZ fatal (K) and A-injury crashes, WZ fatal and injury (K, A, B, C) crashes, and WZ fatalities and injuries.

Exposure variables were only available for IDOT roads. Thus, annual trends of work zone exposure variables were quantified for IDOT roads only for 2013 to 2017 for the following: number of IDOT work zones, WZ miles, WZ-days, and WZ day-miles.

Crash rates were then calculated for the four work zone crash types and four exposure variables. Annual trend analyses were then prepared for the following 16 crash rates for IDOT roads from 2013 to 2017. The following observations can be made for IDOT work zone crash frequencies, exposure variables, and crash rates.

8.1.1 Annual Work Zone Crash Frequency Trends

- Observation of the work zone crash trends show that work zone crash frequency increased from 2013 to 2015 and then decreased for 2016 and 2017 across all crash categories and roads (IDOT and all roads). The lowest work zone crash and injury frequencies were observed in 2017.
- A comparison of the proportion of work zone crashes occurring on IDOT roads versus all roads from 2013 to 2017 range from 55% to 64% for total crashes and 64% to 92% for K-A crashes.

8.1.2 Annual Work Zone Exposure Variable Trends

- The work zone exposure trends reveal that the annual number of IDOT work zones increased steadily from 690 in 2013 to 1,058 in 2017. The annual number of IDOT work zone miles was relatively constant from 2014 to 2016 at 2,250 to 2,247 mi, while in 2017, the work zone miles decreased to 1,835.
- In terms of total annual work zone duration, the number of work zone days increased from 2013 to 2015 and decreased in 2016 and 2017.
- The trends for annual IDOT work zone day-miles also increased from 2013 to 2015 and decreased in 2016 and 2017.

8.1.3 Annual Work Zone Crash Rate Trends

- For **work zone crashes per number of work zones**, in general, an increasing trend was observed for the four crash severity categories from 2013 to 2015, with decreasing rates in 2016 and 2017. The lowest annual rates over the analysis period were observed in 2017 for fatalities and injuries per work zone, fatal and injury crashes per work zone, and K-A crashes per work zone.
- For **work zone crashes per work zone mile**, the total work zone crash rate increased from 0.93 in 2013 to 1.90 in 2015. The rate decreased to 1.73 in 2016 and then increased to 1.88 in 2017. The rates based on fatalities and injuries per work zone mile and fatal and injury crashes per work zone mile increased from 2013 to 2015 and then decreased in 2016 and 2017. The K-A work zone crashes per work zone mile increased from 2013 to 2016 but decreased in 2017.
- For **work zone crashes per work zone day**, the total work zone crash rate increased from 2013 to 2015 (from 0.028 to 0.048) and then decreased slightly to 0.046 and 0.045 in 2016 and 2017, respectively. The rates based on fatalities and injuries per work zone day and fatal and injury crashes per work zone day increased from 2013 to 2015, remained constant in 2016, and then decreased in 2017. The K-A work zone crashes per work zone day increased from 2013 to 2016 but then decreased in 2017.
- For **work zone crashes per 100,000 work zone day-miles**, the total work zone crash rate increased from 2013 to 2015 (from 1.45 to 2.15), decreased 2.04 in 2016, and increased again to 2.43 in 2017. The rates based on fatalities and injuries per 100,000 work zone day-miles, and fatal and injury crashes per 100,000 work zone day-miles increased from 2013 to 2015 and then decreased in 2016 and 2017. The K-A work zone crashes per 100,000 work zone day-miles increased from 2013 to 2016 but then decreased in 2017.
- Overall, from 2016 to 2017, 14 of the 16 of the work zone crash and injury rates decreased. The two exceptions where increases were observed from 2016 to 2017 were for total work zone crashes per work zone mile and total work zone crashes per 100,000 day-miles.

The trend analysis of work zone crash frequencies and crash rates reveals that the work zone exposure variables do provide additional insights into work zone safety performance and should continue to be collected in the future. Even though the lane closure databases contained imperfect data, it was still possible to find exposure measures from them through the manual process documented in this report. Improvements to collecting more accurate work zone exposure variables will help in automating the extraction of work zone crash and exposure data and make the process easier to conduct in the future.

8.2 SITE-SPECIFIC WORK ZONE ANALYSIS

For the site-specific work zone analysis, data for 384 work zone sites were used in a model calibration and validation study, using multiple statewide databases. SPFs were developed assuming an underlying Poisson/negative binomial distribution to predict total work zone crashes (for all crash severities—K, A, B, C, and PDO) and work zone fatal/injury crashes (K-fatal and A-, B-, and C-injury crashes).

8.2.1 Safety Performance Functions

Twelve data elements for each of the 384 work zone sites were queried from the three IDOT databases: the traffic crash, lane closure, and road network (base map) databases. The 12 data elements included work zone crash, operational and characteristic data, and non-work-zone crashes, geometry, and characteristics. The characteristics of the 384 work zone sites were compiled and analyzed using the IBM SPSS statistical analysis software. Assuming an underlying Poisson/negative binomial distribution, which is a common assumption in modeling traffic crashes per the *HSM*, SPF models were then developed to predict crashes using variables that were found to have a statistically significant influence on work zone crashes.

Three statistically significant models were developed for total work zone crashes and one for work zone fatal/injury crashes. Statistically significant results for a work zone K-A crash model specifically could not be developed, and thus was not able to be included in this research.

The 384 work zone sites were initially divided into a calibration group or a validation group. The calibration data set included 256 randomly selected work zone sites. Of the 12 variables considered, the resulting variables that were found to have a statistically significant impact on crashes were work zone duration (D), work zone length (L), annual average daily traffic (AADT), and the product of non-work-zone speed limit and work zone speed limit (NWZ SL x WZSL).

The remaining 128 sites were used to develop validation models. Analyses were conducted to confirm the models developed with the calibration data set through comparisons with the validation models. Such analyses included:

- Analysis of cumulative residual (CURE) plots
- Goodness-of-fit statistics
- Comparison of individual variable coefficients, standard errors, and p-values between the calibration and validation data sets

The results of these analyses identified which of the three resulting total work zone crash SPF models was superior and that the fatal/injury work zone model was validated. Once the general form of the total and fatal/injury work zone models were validated, the two subsets were combined to develop the final values of the coefficients for the SPF variables in each model, using the pooled set consisting of all 384 sites. A statistical analysis of the observed and predicted work zone crashes was conducted to determine if there were significant differences. The results indicated a nonsignificant difference, which means that the models are accurately able to predict work zone crashes and injuries. All statistical analyses were conducted at 95% LOC. The recommended SPF models for predicting work zone total and fatal/injury crashes on IDOT highways and roads are as follows:

$$\mu_{Total} = e^{-7.049} \times D^{0.904} \times L^{0.317} \times AADT^{0.486} \times e^{-0.0004(NWZ\ SL \times WZ\ SL)} \tag{7}$$

$$\mu_{Fatal/Injury} = e^{-2.872} \times D^{0.812} \times L^{0.323} \times e^{-0.0005(NWZ\ SL \times WZ\ SL)} \tag{8}$$

Although the SPFs include the variable NWZ SL x WZ SL, it is expected that IDOT's policy for setting work zone speed limits be used. The SPFs are not intended to be used to recommend other values of work zone speed limit.

Additional analyses were conducted to further explore the total and fatal/injury work zone SPFs, including a Monte Carlo simulation analysis to determine the relative impact of the variables in each model. Both the total and fatal/injury work zone crash models revealed that the variable with the highest relative impact is NWZ SL x WZ SL, followed by work zone duration.

8.2.2 Excel Tool for SPF Calculations

An Excel tool was developed to facilitate the ease of the calculations for the SPFs and assess safety performance of work zones in Illinois. A user can analyze a single work zone, or up to three work zone alternatives at a time. It includes a tutorial worksheet that explains the basic components of a work zone and descriptions of the color-coding schemes for data input and a Work Zone Safety Performance—Analysis using work zone SPFs worksheet. In the latter worksheet, a user would input data and the results would be generated for total and fatal/injury work zone crashes per WZ duration.

8.2.3 Crash Modification Factors

CMFs were extracted from the SPF coefficients for total crashes for work zone length (0.317) and work zone duration (0.904), and fatal/injury WZ crashes for work zone length (0.323) and duration (0.812). Comparisons of the CMFs developed for Illinois roads were compared with those developed in the past, which revealed similarities for duration. Differences in the CMF for WZ length were observed, which may be due to the minimum length and duration considered in the data samples. Methodologies and examples on how to use the SPFs developed as a part of this research are presented in the report.

The SPF models developed in this research may be applied to practical scenarios where IDOT can make decisions about work zone length and duration in work zones based on safety considerations on state highways. The approach and methodology developed in this research may serve as a platform to develop crash predictions and compare alternatives at a regional scale as well.

These methodologies and tools can be used by work zone planners when designing the MOT plans to identify which work zone layout and staging will result in fewer work zone crashes and injuries.

8.3 WORK ZONE DATA NEEDS

Several issues with the work zone data currently collected by IDOT were identified. FHWA's Work Zone Data Initiative reports provide recommended practice for collecting and managing uniform work zone activity data across jurisdictional and organizational boundaries. These reports were used as the basis for developing recommendations in a tiered priority list of work zone data improvement needs in Illinois.

The following is the suggested priority list for improving the quality of work zone data in Illinois.

8.3.1 Priority 1 Work Zone Variables

- For number of work zones: Identifier, Project ID, Project event ID
- For work zone duration: Actual start date/time, Actual end date/time
- For work zone length: Actual begin location, Actual end location
- Other critical exposure variables
    - AADT
    - Work zone average daily traffic
    - Speed limit of road under normal conditions
    - Work zone speed limit
    - Functional classification of road

The results of this research will provide IDOT with a better understanding of the causes of increased work zone crashes, which will then lead to recommended steps toward making data-driven and systematic enhancements to work zone safety at an agency level. It will aid in determining how a specific work zone design feature or combination of features, operating strategy, etc., affects the safety performance of a work zone, so that future decisions about the work zone design or maintenance of traffic plans are improved. This research will assist in the development of optimal strategies for alleviating work zone crash and fatal/injury problems and help meet future statewide goals in Illinois.

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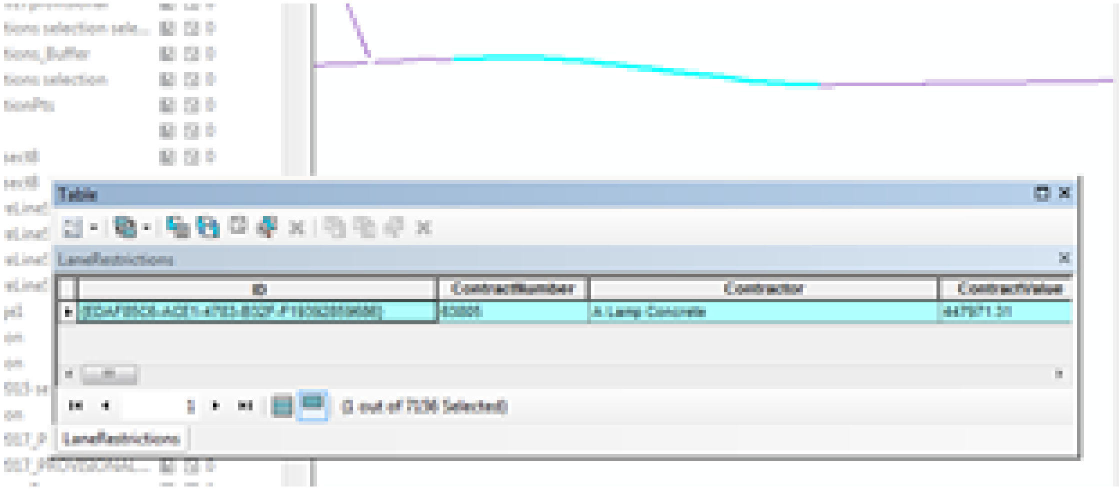
APPENDIX A: ILLUSTRATIONS OF ISSUES AND ASSUMPTIONS FOR NO. WORK ZONES, LENGTH, AND DURATION FOR SEGMENT AND POINT DATABASES

Segment
Work Zone Situations
Issues and Assumptions for Counts

Situation 1

Situation: One entry- one contract ID, one length, one duration

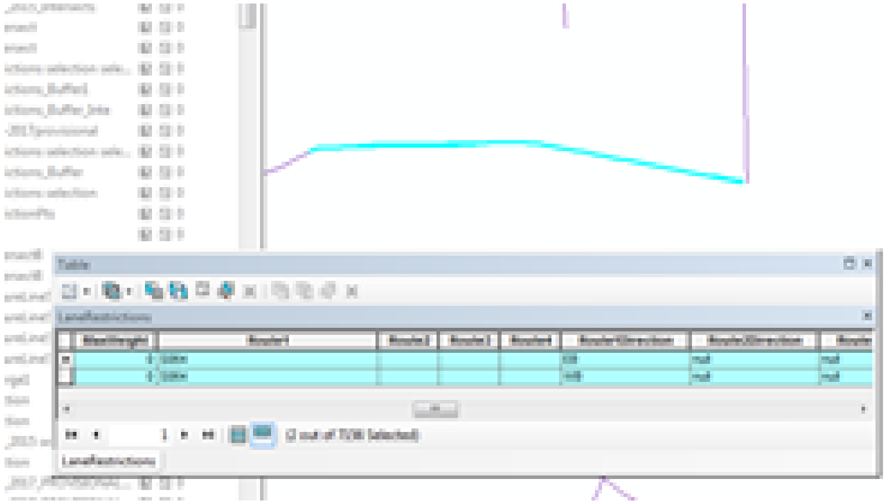
Assumption: Count as one work zone, with recorded length and duration



Situation 2

Situation: Two entries- same contract ID, same route, *different route direction (i.e. EB & WB)*, same location, same duration, and same length

Assumption: Count as one work zone, with recorded length and duration

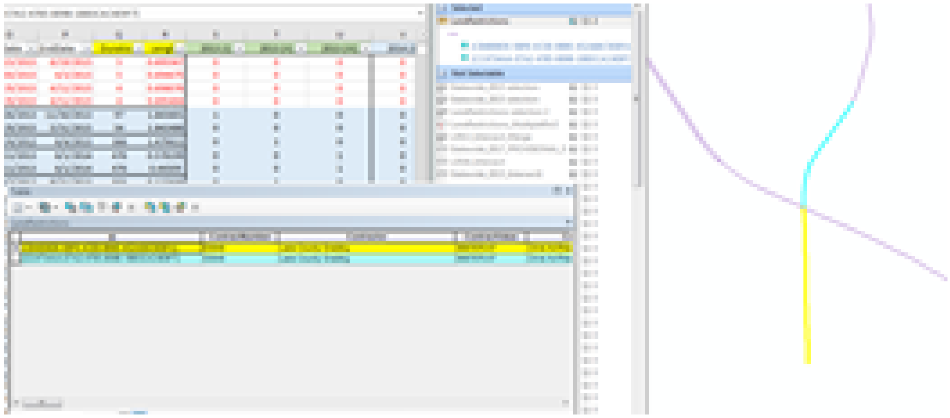


Situation 3

Situation: Two or more entries- same contract ID, same route, same route direction, *different location/different lengths*, same duration

Assumption:

- If the multiple entries are adjacent to each other: count as one work zone, sum the individual lengths, and recorded duration.
- If the multiple entries have a gap between them: treat them as separate work zones.



Situation 4

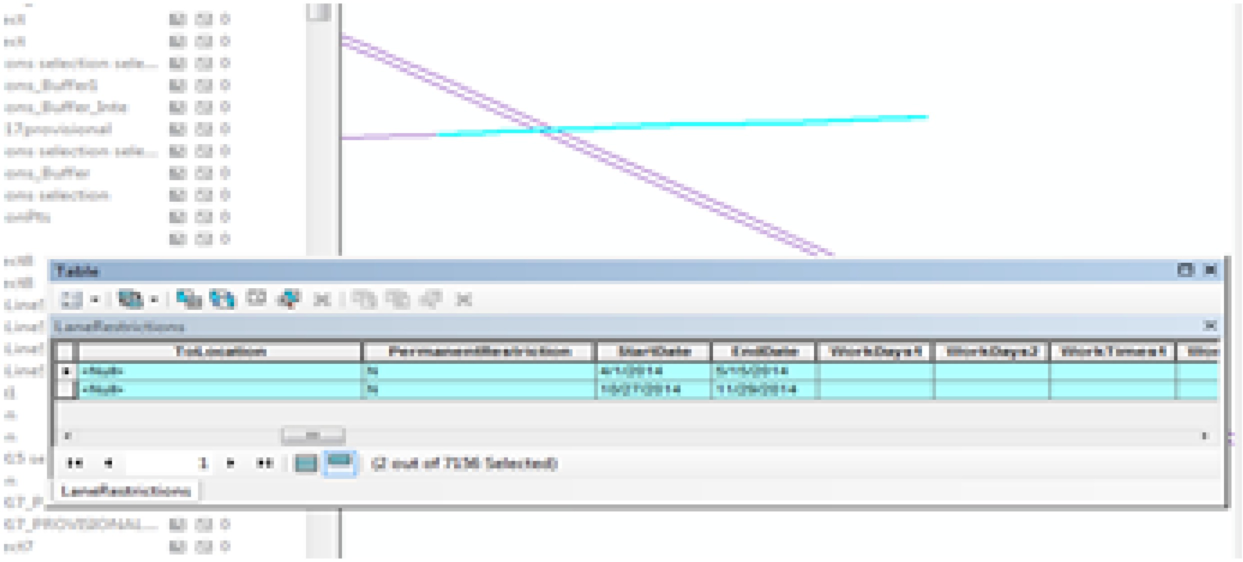
Situation: Multiple entries- Same contract ID, same contractor, *different routes/locations, different dates/durations*

Assumption: Count each as separate work zones with recorded lengths and durations for each

Situation 5

Situation: Two or more entries- same contract ID, same route/location, *different durations*

Assumption: Count as two separate work zones unless the end date of one is the start date of the next

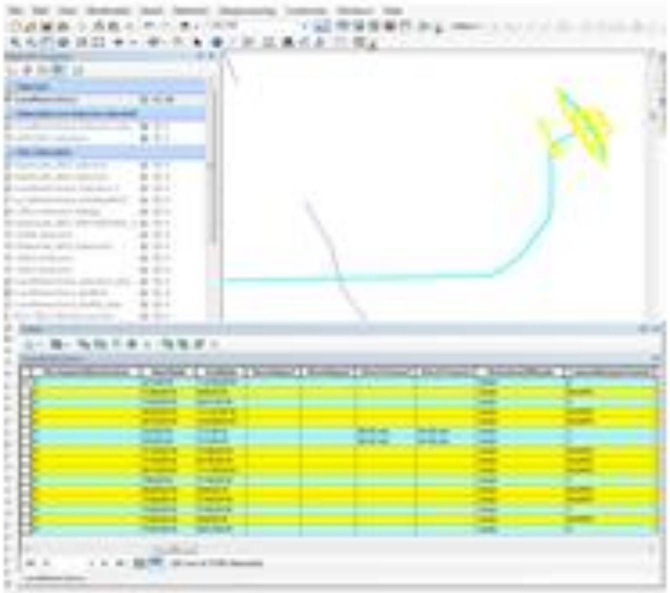


ToLocation	PermanentRestriction	StartDate	EndDate	WorkDays1	WorkDays2	WorkTimes1
<Null>	N	4/1/2014	5/15/2014			
<Null>	N	10/27/2014	11/29/2014			

Situation 6

Situation: "Ramp closure"- same contract ID, different durations

Assumption: Do not take the length of the ramps into consideration but note that the roadway work zone has ramp closures



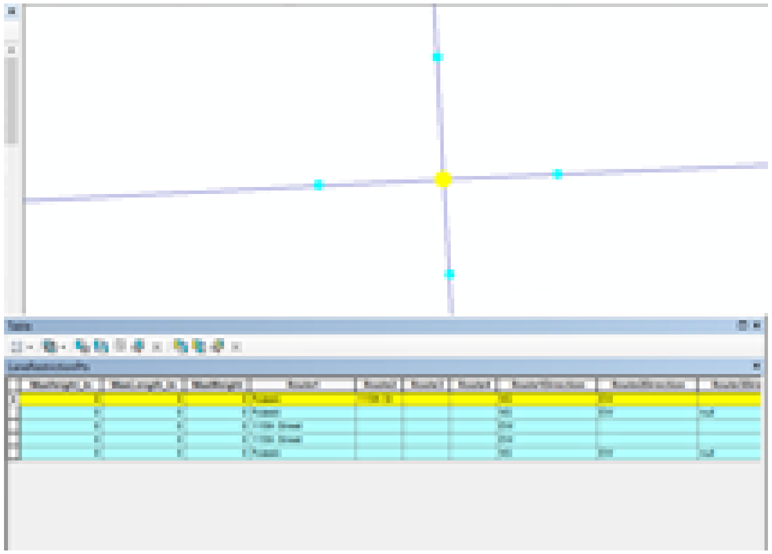
Point Work Zone Situations Issues and Assumptions for Counts

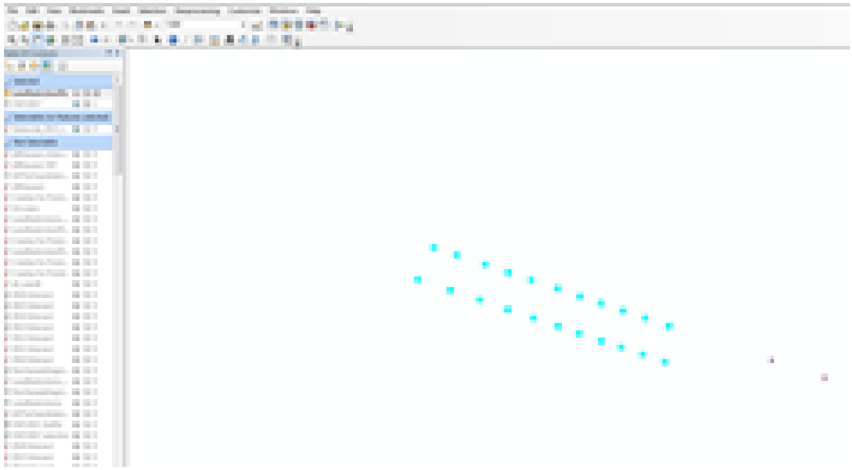
Situation 1

Situation: 2 or more points close in distance (a mile or less a part)

Assumption: Count as one work zone, add the lengths and take one duration

- Multiple points should be considered a single work zone only if the durations match up, otherwise count as different work zones.

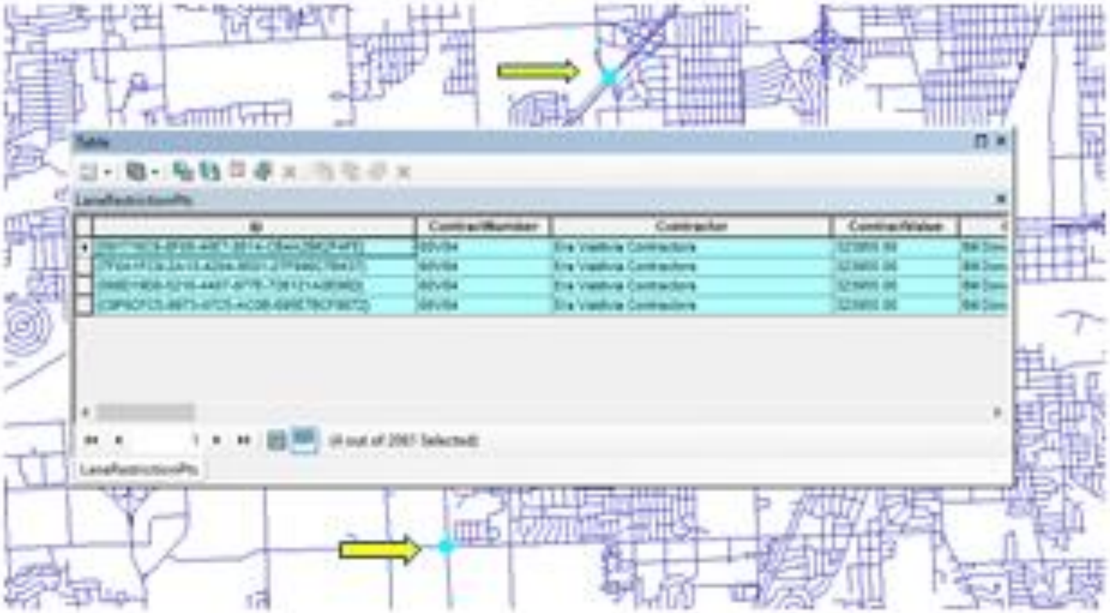




Situation 2

Situation: Two or more points more than a mile a part

Assumption: Count as multiple work zones, take their individual lengths and take their individual durations

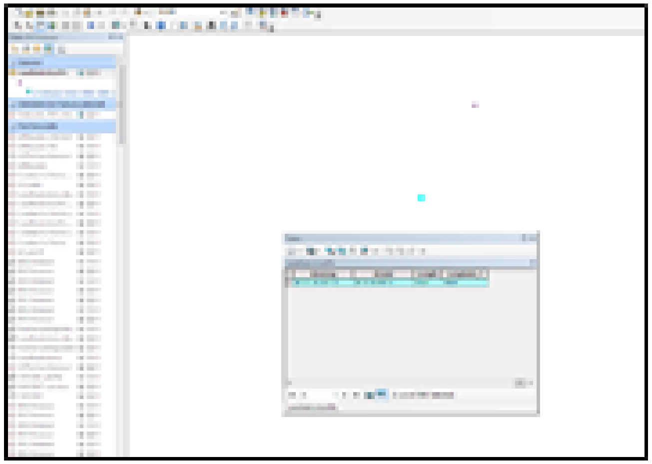


Situation 3

Situation: The length of the point work zone is not provided in GIS

Assumption:

- If the eplans have a length: take that as the length of the work zone.
- If the eplans do not have a length, follow situations 3a, 3b, or 3c



HIGHWAY PLANS

Situation 3a

Situation: the point has no length in the eplans and shows up as a bridge in Google Earth

Assumption: take the length of the bridge plus 0.25 miles upstream and downstream as the length of the work zone

Situation 3b

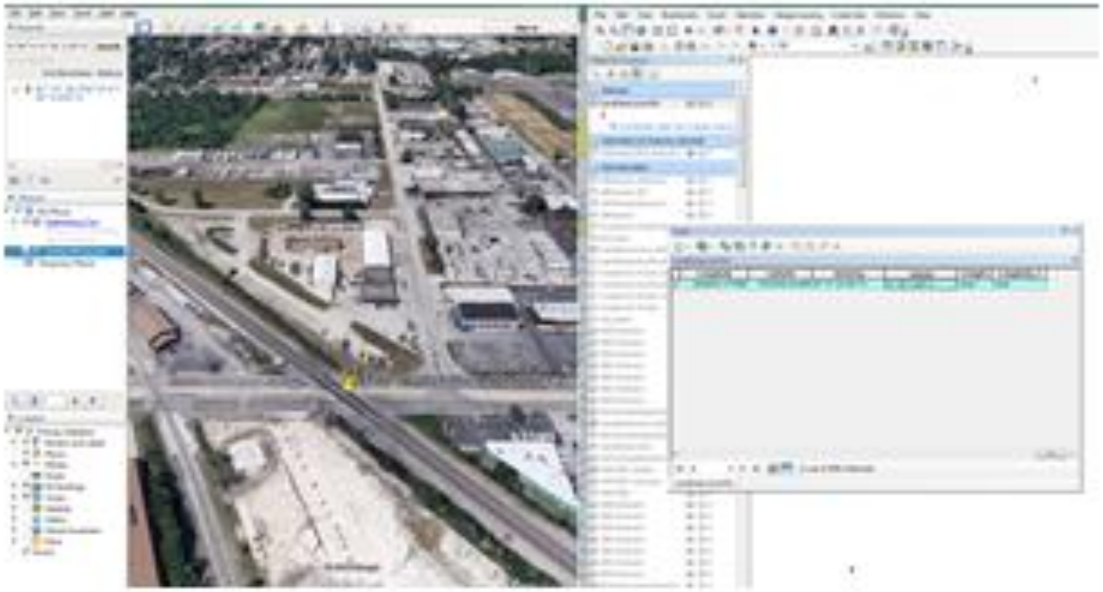
Situation: the point has no length in the eplans and shows up as a road in Google Earth

Assumption: length assumed as 1,000’ if located on an Interstate, and 500’ for non-Interstate

Situation 3c

Situation: the point has no length in the eplans and shows up as a railroad in Google Earth

Assumption: length assumed as 500’



APPENDIX B: ANNUAL WORK ZONE CRASH FREQUENCIES, EXPOSURE VARIABLES, AND CRASH RATES FOR IDOT ROADS 2013–2017

Description		Years				
		2013	2014	2015	2016	2017
Work Zone Crash Frequencies (IDOT Roads)	No. of Work Zone (WZ) Crashes	1,794	2,749	4,197	3,882	3,457
	No. of Fatal (K) WZ Crashes	15	13	33	32	11
	No. of A-Injury WZ crashes	60	93	121	127	97
	No. of K-A WZ Crashes	75	106	154	159	108
	No. of Injury WZ Crashes (A,B,C)	414	694	868	830	599
	No. of Fatal and Injury (K, A,B,C) WZ crashes	429	707	901	862	610
	No. of WZ Fatalities	17	18	41	27	11
	No. of WZ Injuries	576	991	1,308	1,245	853
	No. of WZ Fatalities and Injuries	593	1,009	1,349	1,272	864
Wok Zone Exposure Measures (IDOT Roads)	No. of Work Zones	690	857	914	962	1,058
	Work Zone Length (Miles)	1,938	2,250	2,208	2,247	1,835
	Work Zone Duration (Days)	63,925	73,011	88,217	84,804	77,400
	Work Zone Day-Miles	123,916,677	164,261,705	194,762,335	190,521,730	142,054,002
Work Zone Crash Rates (IDOT Roads)	WZ Crashes per Work Zone	2.60	3.21	4.59	4.04	3.27
	WZ Crashes per Work Zone-Day	0.028	0.038	0.048	0.046	0.045
	WZ Crashes per Work Zone-Mile	0.93	1.22	1.90	1.73	1.88
	WZ Crashes per 100,000 Work Zone-Day-Mile	1.45	1.67	2.15	2.04	2.43
	Fatal and Injury WZ Crashes per Work Zone	0.62	0.82	0.99	0.90	0.58
	Fatal and Injury WZ Crashes per Work Zone-Day	0.0067	0.0097	0.0102	0.0102	0.0079
	Fatal and Injury WZ Crashes per Work Zone-Mile	0.22	0.31	0.41	0.38	0.33
	Fatal and Injury WZ Crashes per 100,000 Work Zone-Day-Mile	0.35	0.43	0.46	0.45	0.43
	WZ Fatalities and Injuries per Work Zone	0.86	1.18	1.48	1.32	0.82
	WZ Fatalities and Injuries per Work Zone-Day	0.009	0.014	0.015	0.015	0.011
	WZ Fatalities and Injuries per Work Zone-Mile	0.31	0.45	0.61	0.57	0.47
	WZ Fatalities and Injuries per 100,000 Work Zone-Day-Mile	0.48	0.61	0.69	0.67	0.61
	K-A WZ Crashes per No. Work Zones	0.11	0.12	0.17	0.17	0.10
	K-A WZ Crashes per Work Zone Days	0.0012	0.0015	0.0017	0.0019	0.0014
	K-A WZ Crashes per Work Zone Miles	0.039	0.047	0.070	0.071	0.059
	K-A WZ Crashes per 100,000 Work Zone-Day-Mile	0.061	0.065	0.079	0.083	0.076

APPENDIX C: DETAILS OF 384 SITE-SPECIFIC WORK ZONES

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
1	1	Interstate	158	3.2762	122,500	1	55	45	2	14	60
2	1	Interstate	108	2.5678	100,300	0	55	45	2	2	6
3	1	Other Principal Arterial	1,043	2.5068	38,000	4	45	45	2	20	87
4	1	Other Principal Arterial	372	0.6210	43,700	1	45	35	3	15	67
5	1	Other Principal Arterial	237	2.5960	23,100	2	40	35	1	8	27
6	1	Other Principal Arterial	232	0.7927	22,200	1	45	35	1	3	20
7	1	Freeway and Expressway	594	0.8168	9,100	1	55	40	1	6	20
8	1	Other Principal Arterial	244	1.1429	45,900	1	45	45	2	9	22
9	1	Other Principal Arterial	353	0.4844	20,100	2	40	30	2	6	19
10	1	Minor Arterial	594	0.2852	18,500	1	40	35	1	5	15
11	1	Other Principal Arterial	244	1.1431	45,900	1	45	35	1	5	16
12	1	Other Principal Arterial	113	1.1453	45,900	1	45	45	2	4	14
13	1	Minor Arterial	484	0.8073	24,100	1	45	35	2	4	13
14	1	Other Principal Arterial	130	2.3569	26,400	1	40	40	3	7	16
15	1	Other Principal Arterial	209	0.9034	22,300	1	35	30	1	6	13
16	1	Other Principal Arterial	494	1.2869	19,400	1	40	35	1	1	12
17	1	Other Principal Arterial	237	1.5004	23,100	2	40	35	1	2	8
18	1	Other Principal Arterial	281	0.2062	25,000	1	40	30	2	6	11
19	1	Other Principal Arterial	344	0.4045	28,100	0	40	40	1	3	29
20	1	Other Principal Arterial	131	0.4808	20,100	2	40	30	1	2	7
21	1	Minor Arterial	237	0.9686	29,600	1	45	35	1	2	18
22	1	Minor Arterial	425	0.4742	13,400	4	40	35	1	3	8
23	1	Other Principal Arterial	118	6.5237	33,500	1	55	45	1	1	5
24	1	Minor Arterial	321	1.9482	10,600	1	55	45	1	5	9
25	1	Other Principal Arterial	248	1.7597	38,600	1	55	40	1	2	5

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
1	25	8	Lane Reduction/Closure	34	24
2	10	9	Lane Reduction/Closure	4	0
3	164	4	Lane Reduction/Closure	66	18
4	112	10	Lane Reduction/Closure	40	12
5	72	12	Lane Reduction/Closure	18	8
6	16	12	Lane Reduction/Closure	10	9
7	61	5	Lane Reduction/Closure	17	2
8	15	6	Lane Reduction/Closure	11	11
9	22	4	Lane Reduction/Closure	16	2
10	13	2	Lane Reduction/Closure	12	3
11	18	6	Lane Reduction Closure	8	7
12	15	9	Lane Reduction/Closure	11	3
13	40	3	Intermittent Roadwork	11	3
14	37	12	Intermittent Roadwork	11	4
15	24	2	Lane Reduction/Closure	7	6
16	30	4	Lane Reduction/Closure	4	4
17	60	7	Lane Reduction/Closure	6	2
18	16	2	Intersection Restrictions	8	3
19	0	2	Intermittent Roadwork	5	3
20	3	4	Lane Reduction/Closure	2	5
21	43	7	Lane Reduction/Closure	4	3
22	15	0	Lane Reduction/Closure	6	1
23	20	13	Lane Reduction/Closure	4	1
24	5	3	Lane Reduction/Closure	5	4
25	11	7	Lane Reduction/Closure	0	5

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
26	1	Other Principal Arterial	299	0.5038	15,700	1	40	40	1	1	4
27	1	Other Principal Arterial	122	5.6486	11,400	0	55	55	1	3	9
28	1	Other Principal Arterial	124	4.2304	43,100	1	45	45	3	2	7
29	1	Other Principal Arterial	406	0.7411	11,100	0	50	45	1	2	4
30	1	Other Principal Arterial	84	4.5258	9,350	1	55	55	1	2	5
31	1	Other Principal Arterial	436	0.6060	15,300	1	45	45	1	1	4
32	1	Interstate	65	12.0361	120,300	0	55	45	2	1	4
33	1	Other Principal Arterial	217	0.2197	33,500	0	40	40	1	2	4
34	1	Major Collector	64	0.7403	3,550	1	20	20	1	1	1
35	1	Minor Arterial	345	0.4931	12,200	2	35	35	1	1	4
36	1	Minor Arterial	99	0.9990	16,500	1	40	35	1	1	1
37	1	Minor Arterial	82	3.2441	14,100	1	50	40	1	1	1
38	1	Other Principal Arterial	103	0.4816	33,000	1	35	35	1	1	1
39	1	Other Principal Arterial	138	5.9790	33,100	1	35	35	2	4	4
40	1	Interstate	31	0.5748	11,300	0	65	45	1	2	2
41	1	Other Principal Arterial	73	2.8299	24,300	1	45	45	1	1	4
42	1	Minor Arterial	173	8.3460	5,050	1	55	55	1	1	2
43	1	Other Principal Arterial	794	1.4832	33,700	1	45	35	1	11	43
44	1	Interstate	430	3.0524	33,412	1	65	45	0	1	25
45	1	Other Principal Arterial	1,370	1.9921	36,300	1	35	35	0	9	75
46	1	Other Principal Arterial	724	2.4317	17,500	1	40	35	0	5	28
47	1	Interstate	430	3.1413	49,000	1	65	45	0	3	29
48	1	Other Principal Arterial	712	1.2113	43,700	1	45	35	0	4	27
49	1	Interstate	232	0.9808	132,900	0	65	45	0	1	13
50	1	Minor Arterial	345	1.2823	30,550	2	35	30	0	9	24

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
26	12	1	Lane Reduction/Closure	3	1
27	5	7	Lane Reduction/Closure	5	1
28	18	25	Lane Reduction/Closure	3	1
29	15	1	Intersection Restriction	1	3
30	2	8	One-Way Traffic with Flaggers	2	2
31	7	2	Lane Reduction/Closure	2	0
32	39	15	Shoulder Closed	0	2
33	7	13	Intersection Restrictions	3	0
34	1	7	Lane Reduction/Closure	1	0
35	6	3	Lane Reduction/Closure	1	0
36	6	2	Lane Reduction/Closure	1	0
37	15	13	One-Way Traffic with Flaggers	1	0
38	48	3	Intersection Restrictions	0	1
39	54	32	Lane Reduction/Closure	4	0
40	3	2	Lane Reduction/Closure	2	0
41	11	5	Lane Reduction/Closure	1	0
42	3	9	Lane Reduction/Closure	0	1
43	69	4	Lane Reduction/Closure	30	10
44	39	4	Lane Reduction/Closure	19	3
45	720	8	Lane Reduction/Closure	24	5
46	95	13	Lane Reduction/Closure	19	3
47	23	4	Lane Reduction/Closure	18	2
48	171	7	Lane Reduction/Closure	13	4
49	32	6	Lane Reduction/Closure	6	7
50	28	16	Lane Reduction/Closure	16	4

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
51	1	Other Principal Arterial	372	1.3083	55,000	1	40	35	0	2	11
52	1	Other Principal Arterial	864	1.3748	41,000	1	50	40	0	3	13
53	1	Other Principal Arterial	724	0.7986	33,700	1	40	30	0	3	10
54	1	Other Principal Arterial	409	0.1180	22,300	0	35	30	0	2	10
55	1	Minor Arterial	296	2.0539	19,700	2	35	30	0	3	10
56	1	Interstate	158	3.2753	122,500	1	55	45	0	2	8
57	1	Interstate	847	2.0569	257,000	1	55	45	0	1	6
1058	1	Other Principal Arterial	409	1.2992	55,000	1	40	30	0	1	10
579	1	Other Principal Arterial	139	5.0874	16,500	1	55	30	0	3	7
650	1	Other Principal Arterial	411	2.1205	15,300	0	45	35	0	2	5
61	1	Other Principal Arterial	182	0.1142	22,900	2	40	35	0	1	3
62	1	Minor Arterial	409	0.0912	19,100	1	40	30	0	3	5
63	1	Interstate	199	2.4212	68,900	0	70	55	0	2	4
64	1	Minor Arterial	61	6.7434	7,800	1	55	55	0	1	2
65	1	Interstate	151	3.1524	65,600	1	65	45	0	1	18
66	1	Other Principal Arterial	442	1.6173	18,400	1	45	35	0	4	32
67	1	Other Principal Arterial	223	0.3466	37,700	1	40	35	0	1	6
768	1	Other Principal Arterial	503	3.9599	37,300	1	45	45	0	1	7
69	1	Other Principal Arterial	835	5.0076	19,900	1	50	45	0	2	5
70	1	Minor Arterial	533	0.9797	27,100	1	35	30	0	4	8
71	1	Other Principal Arterial	85	2.1334	36,900	1	35	35	0	1	3
72	1	Other Principal Arterial	124	3.8917	52,500	1	50	45	0	2	5
73	1	Other Principal Arterial	115	0.7889	18,800	1	40	40	0	1	3
74	1	Other Principal Arterial	98	3.7132	22,600	0	45	45	0	1	2
75	1	Other Principal Arterial	141	3.2285	29,900	1	40	25	0	0	9

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
51	60	3	Lane Reduction/Closure	10	1
52	27	6	Lane Reduction/Closure	11	0
53	42	1	Lane Reduction/Closure	6	4
54	24	1	Temporary Changes	5	4
55	53	19	Lane Reduction/Closure	6	4
56	30	10	Lane Reduction/Closure	3	5
57	545	3	Lane Reduction/Closure	3	3
58	57	3	Lane Reduction/Closure	2	3
59	27	22	One-Way Traffic with Flaggers	6	1
60	10	8	Lane Reduction/Closure	4	1
61	15	1	Lane Reduction/Closure	3	0
62	24	1	Temporary Changes	4	1
63	3	2	Lane Reduction/Closure	4	0
64	0	9	One-Way Traffic with Flaggers	2	0
65	17	4	Lane Reduction/Closure	14	1
66	53	3	Lane Reduction/Closure	13	2
67	15	5	Lane Reduction/Closure	4	2
68	54	14	Lane Reduction/Closure	4	1
69	48	7	Lane Reduction/Closure	3	2
70	56	5	Lane Reduction/Closure	5	2
71	44	15	Lane Reduction/Closure	3	0
72	13	26	Lane Reduction/Closure	2	2
73	11	4	Lane Reduction/Closure	2	1
74	13	11	Lane Reduction/Closure	2	0
75	65	21	Intermittent Roadwork	6	2

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
76	1	Freeway and Expressway	594	0.7812	38,000	1	40	35	0	0	8
77	1	Other Principal Arterial	345	0.3076	12,000	2	40	40	0	0	8
78	1	Minor Arterial	414	0.5556	16,300	1	45	35	0	0	5
79	1	Interstate	577	0.4505	36,500	0	55	45	0	0	5
80	1	Other Principal Arterial	201	0.3727	25,100	2	35	35	0	0	5
81	1	Freeway and Expressway	852	2.1288	31,700	1	55	45	0	0	4
82	1	Interstate	65	12.0059	147,100	0	55	45	0	0	6
83	1	Other Principal Arterial	94	2.5015	38,500	0	45	35	0	0	4
84	1	Interstate	712	0.5789	20,200	1	45	45	0	0	3
85	1	Other Principal Arterial	54	1.9892	11,500	1	50	50	0	0	3
86	1	Interstate	107	2.5842	139,600	0	55	50	0	0	3
87	1	Other Principal Arterial	531	0.8428	22,500	1	35	30	0	0	4
88	1	Freeway and Expressway	853	2.1531	43,800	1	55	45	0	0	4
89	1	Interstate	67	0.1184	194,400	4	45	45	0	0	2
90	1	Other Principal Arterial	243	0.2588	23,000	1	45	40	0	0	2
91	1	Other Principal Arterial	125	0.2937	26,100	0	40	40	0	0	2
92	1	Other Principal Arterial	131	0.0534	17,400	0	40	35	0	0	2
93	1	Other Principal Arterial	148	3.5225	27,500	1	40	35	0	0	2
94	1	Other Principal Arterial	256	2.0505	27,500	1	50	45	0	0	5
95	1	Other Principal Arterial	135	1.2519	26,000	2	35	35	0	0	2
96	1	Other Principal Arterial	67	7.5306	17,500	1	45	45	0	0	2
97	1	Minor Arterial	342	0.1106	12,000	5	30	30	0	0	2
98	1	Collector	122	0.9396	8,500	0	35	35	0	0	2
99	1	Other Principal Arterial	283	1.9167	43,000	1	50	40	0	0	1
100	1	Interstate	144	0.2365	45,500	3	35	35	0	0	1

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
76	36	2	Lane Reduction/Closure	4	3
77	21	2	Lane Reduction/Closure	5	0
78	20	2	Lane Reduction/Closure	3	1
79	226	4	Lane Reduction/Closure	3	1
80	32	4	Lane Reduction/Closure	3	1
81	42	2	Lane Reduction/Closure	2	1
82	49	21	Shoulder Closed	3	0
83	13	6	Lane Reduction/Closure	3	0
84	85	4	Lane Reduction/Closure	2	1
85	7	12	Lane Reduction/Closure	0	3
86	5	14	Lane Reduction/Closure	3	0
87	51	7	Lane Reduction/Closure	2	1
88	38	1	Lane Reduction/Closure	1	1
89	23	3	Lane Reduction/Closure	0	2
90	6	1	Lane Reduction/Closure	2	0
91	7	2	Lane Reduction/Closure	0	2
92	7	2	Lane Reduction/Closure	2	0
93	30	18	Lane Reduction/Closure	1	1
94	56	4	Lane Reduction/Closure	2	0
95	33	17	Lane Reduction/Closure	2	0
96	9	14	Lane Reduction/Closure	0	2
97	42	5	Bridge Closed	2	0
98	6	6	Lane Reduction/Closure	1	0
99	20	7	Lane Reduction/Closure	0	1
100	5	3	Lane Reduction/Closure	1	0

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
101	1	Collector	193	1.4914	6,700	1	30	25	0	0	2
102	1	Other Principal Arterial	64	0.9638	15,210	0	35	25	0	0	1
103	1	Minor Arterial	394	2.4594	20,600	1	45	45	0	0	10
104	1	Collector	183	1.6117	30,700	1	45	35	0	0	2
105	1	Other Principal Arterial	3	0.9975	11,000	4	45	45	0	0	1
106	1	Other Principal Arterial	723	2.4323	22,400	1	35	35	0	0	20
107	1	Other Principal Arterial	120	7.1521	17,800	1	55	35	0	0	1
108	1	Interstate	222	2.9777	46,500	0	55	45	0	0	1
109	1	Other Principal Arterial	143	2.0365	33,100	0	40	40	0	0	1
110	1	Other Principal Arterial	96	1.8436	26,400	1	35	35	0	0	1
111	1	Other Principal Arterial	247	2.5034	32,200	1	45	45	0	0	3
112	1	Interstate	90	14.7429	50,200	0	70	55	1	1	2
113	1	Interstate	608	0.4770	31,000	0	45	45	2	18	136
114	1	Other Principal Arterial	794	1.4901	33,700	1	45	35	1	38	97
115	1	Other Principal Arterial	724	0.8024	33,700	1	45	40	6	36	75
116	1	Other Principal Arterial	409	0.7256	37,100	1	45	35	2	2	30
117	1	Other Principal Arterial	1,043	1.9955	36,300	4	35	35	3	70	320
118	1	Other Principal Arterial	372	1.3001	55,000	1	40	35	1	14	40
119	1	Other Principal Arterial	906	0.6387	22,000	1	50	35	2	7	33
120	1	Minor Arterial	481	0.8023	24,100	1	45	35	2	8	21
121	1	Other Principal Arterial	1,370	1.4966	35,600	1	45	35	1	32	178
122	1	Other Principal Arterial	409	1.3051	55,000	1	40	35	1	15	61
123	1	Other Principal Arterial	716	3.3013	14,700	1	50	45	1	6	21
124	1	Interstate	969	0.9879	37,500	0	50	45	1	1	10
125	1	Other Principal Arterial	275	2.4878	31,100	1	40	40	1	3	10

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
101	8	14	Lane Reduction/Closure	1	0
102	2	14	Lane Reduction/Closure	1	0
103	36	3	Intermittent Roadwork	0	1
104	37	9	Lane Reduction/Closure	0	1
105	0	6	Road Closed	1	0
106	88	13	Lane Reduction/Closure	1	0
107	14	13	One-Way Traffic with Flaggers	1	0
108	10	2	Lane Reduction/Closure	0	1
109	44	12	Intermittent Roadwork	1	0
110	14	12	Lane Reduction/Closure	0	1
111	99	10	Lane Reduction/Closure	0	1
112	16	8	Lane Reduction/Closure	0	1
113	233	2	Lane Reduction/Closure	86	50
114	120	4	Lane Reduction/Closure	66	17
115	74	1	Lane Reduction/Closure	55	16
116	92	6	Lane Reduction/Closure	11	6
117	534	8	Lane Reduction/Closure	270	50
118	52	3	Lane Reduction/Closure	28	7
119	50	1	Lane Reduction/Closure	14	7
120	40	2	Intermittent Roadwork	12	9
121	314	7	Lane Reduction/Closure	136	42
122	59	3	Lane Reduction/Closure	43	14
123	67	6	One-Way Traffic with Flaggers	12	9
124	127	10	Lane Reduction/Closure	7	3
125	124	15	Lane Reduction/Closure	5	4

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
126	1	Minor Arterial	810	1.0707	22,500	1	35	35	4	17	81
127	1	Other Principal Arterial	122	5.6202	11,100	0	55	45	1	2	3
128	1	Other Principal Arterial	807	1.7295	22,000	2	30	30	4	16	172
129	1	Interstate	713	0.4035	116,400	1	50	50	0	2	48
130	1	Interstate	754	3.4912	137,136	1	55	45	3	4	25
131	1	Other Principal Arterial	772	2.2374	14,300	1	50	30	0	3	14
132	1	Minor Arterial	68	2.2439	22,500	1	35	35	0	1	3
133	1	Other Principal Arterial	102	4.0008	11,600	1	55	30	0	1	2
134	1	Other Principal Arterial	409	1.2064	45,000	1	45	35	0	8	69
135	1	Other Principal Arterial	216	0.9306	39,088	2	35	35	0	9	29
136	1	Other Principal Arterial	1,043	2.5012	38,000	4	45	45	0	2	10
137	1	Minor Arterial	469	0.1515	19,500	4	30	30	1	2	22
138	1	Other Principal Arterial	97	0.4681	26,800	0	35	35	0	2	8
139	1	Other Principal Arterial	133	4.5410	32,800	0	35	35	0	1	4
140	1	Other Principal Arterial	716	3.3037	14,700	1	50	45	0	2	3
141	1	Interstate	303	0.6799	10,600	0	35	45	0	1	26
142	1	Minor Arterial	232	0.0979	19,000	1	40	35	0	1	7
143	1	Other Principal Arterial	937	1.7372	46,000	1	50	45	0	1	7
144	1	Interstate	741	0.6781	206,700	1	55	45	0	1	2
145	1	Other Principal Arterial	223	0.4099	37,700	2	40	35	0	0	9
146	1	Other Principal Arterial	299	0.1602	11,100	1	40	40	0	0	4
147	1	Minor Arterial	208	0.0835	28,600	0	35	35	0	0	3
148	1	Other Principal Arterial	39	5.3349	18,300	1	40	30	0	0	2
149	1	Other Principal Arterial	495	0.6078	32,200	1	35	35	0	0	8
150	1	Interstate	576	0.1224	61,100	0	50	45	0	0	3

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
126	169	10	Lane Reduction/Closure	50	28
127	10	6	Lane Reduction/Closure	2	1
128	118	16	Lane Reduction/Closure	56	26
129	102	7	Lane Reduction/Closure	29	18
130	119	11	Lane Reduction/Closure	15	9
131	66	7	One-Way Traffic with Flaggers	10	4
132	15	26	Lane Reduction/Closure	2	1
133	9	3	One-Way Traffic with Flaggers	1	1
134	302	9	Lane Reduction/Closure	24	13
135	53	9	Lane Reduction/Closure	17	7
136	139	4	Lane Reduction/Closure	7	2
137	186	10	Lane Reduction/Closure	13	2
138	9	1	Lane Reduction/Closure	4	4
139	29	21	Lane Reduction/Closure	1	2
140	16	4	One-Way Traffic with Flaggers	1	2
141	61	16	Lane Reduction/Closure	13	13
142	13	1	Intersection Restrictions	5	2
143	15	5	Lane Reduction/Closure	4	0
144	30	4	Lane Reduction/Closure	0	2
145	24	4	Lane Reduction/Closure	9	0
146	7	1	Lane Reduction/Closure	3	1
147	18	2	Intersection Restrictions	0	3
148	12	26	Lane Reduction/Closure	2	0
149	72	11	Lane Reduction/Closure	8	0
150	190	1	Lane Reduction/Closure	2	1

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
151	1	Other Principal Arterial	294	4.0734	37,600	1	50	35	0	0	2
152	1	Other Principal Arterial	60	0.4941	30,000	1	45	40	0	0	2
153	1	Interstate	366	0.1782	60,400	0	70	55	0	0	2
154	1	Minor Arterial	547	0.1480	21,00	1	45	45	0	0	1
155	1	Other Principal Arterial	137	0.2616	22,400	1	40	35	0	0	1
156	1	Other Principal Arterial	98	2.4253	15,000	1	35	35	0	0	1
157	1	Interstate	54	0.1837	23,700	0	40	35	0	0	1
158	1	Interstate	198	2.4595	85,400	0	70	55	0	0	2
159	1	Other Principal Arterial	182	0.0338	41,900	1	35	35	0	0	1
160	1	Other Principal Arterial	123	4.2301	45,900	1	45	45	0	0	4
161	1	Local	65	0.7276	10,400	1	45	25	0	0	2
162	1	Other Principal Arterial	33	0.6627	31,700	2	40	40	0	0	1
163	1	Interstate	215	22.2101	30,500	1	70	55	2	3	7
164	2	Interstate	580	37.1387	45,700	1	65	45	7	34	302
165	2	Other Principal Arterial	600	3.3447	12,700	1	45	45	1	13	25
166	2	Other Principal Arterial	172	1.7459	14,200	2	30	30	1	5	15
167	2	Interstate	579	22.2442	30,300	1	70	55	3	2	17
168	2	Interstate	181	22.2458	30,500	1	70	55	2	4	16
169	2	Other Principal Arterial	626	0.8287	7,250	1	45	45	1	1	5
170	2	Interstate	255	17.9531	18,800	1	70	55	3	4	9
171	2	Interstate	153	12.2476	21,300	1	70	55	1	1	9
172	2	Other Principal Arterial	135	0.4908	11,800	2	30	30	1	1	7
173	2	Other Principal Arterial	66	4.3416	5,750	1	55	55	1	2	3
174	2	Interstate	209	3.2671	28,800	1	70	55	1	1	1
175	2	Interstate	47	18.5559	12,600	1	70	70	1	1	1

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
151	43	103	Lane Reduction/Closure	2	0
152	3	3	Lane Reduction/Closure	2	0
153	21	1	Lane Reduction/Closure	2	0
154	17	1	Intersection Restrictions	1	0
155	6	3	Lane Reduction/Closure	0	1
156	14	13	Lane Reduction/Closure	0	1
157	4	13	Ramp Closed	1	0
158	3	4	Lane Reduction/Closure	1	0
159	18	1	Intermittent Roadwork	0	1
160	18	37	Lane Reduction/Closure	0	1
161	4	9	One-Way Traffic with Flaggers	1	0
162	9	4	Lane Reduction/Closure	0	1
163	93	22	Lane Reduction/Closure	6	1
164	318	35	Lane Reduction/Closure	5	0
165	60	9	Lane Reduction/Closure	22	3
166	39	15	Lane Reduction/Closure	9	5
167	72	22	Lane Reduction/Closure	8	3
168	17	19	Lane Reduction/Closure	9	3
169	6	2	Lane Reduction/Closure	4	1
170	23	12	Lane Reduction/Closure	5	3
171	2	11	Lane Reduction/Closure	5	0
172	11	5	Lane Reduction/Closure	2	0
173	11	6	Lane Reduction/Closure	0	1
174	6	4	Lane Reduction/Closure	1	0
175	2	16	Lane Reduction/Closure	0	1

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
176	2	Interstate	579	22.2248	31,263	1	70	70	0	1	1
177	2	Other Principal Arterial	467	0.8604	14,500	1	45	15	0	1	1
178	2	Interstate	267	5.3062	24,851	1	65	55	0	0	5
179	2	Interstate	234	18.0803	16,100	1	70	55	0	0	4
180	2	Interstate	59	18.2488	16,100	1	70	55	0	0	3
181	2	Interstate	159	11.8066	16,100	1	70	55	0	0	3
182	2	Other Principal Arterial	250	2.0045	26,200	1	55	45	0	0	2
183	2	Freeway and Expressway	269	1.8741	34,300	1	65	45	0	0	1
184	2	Interstate	87	6.6690	23,800	1	70	45	0	0	1
185	2	Interstate	47	18.5311	15,700	1	70	45	0	0	1
186	2	Interstate	258	9.2566	20,200	1	70	65	0	0	1
187	2	Interstate	262	4.9360	21,100	1	70	45	2	2	7
188	2	Other Principal Arterial	423	1.7595	9,450	2	45	45	1	5	12
189	2	Interstate	580	37.2252	45,700	1	65	45	3	34	290
190	2	Other Principal Arterial	217	0.4907	11,800	5	30	30	1	3	4
191	2	Interstate	217	9.0979	20,200	1	70	55	1	1	5
91392	3	Interstate	217	9.1792	20,100	1	70	55	0	3	9
193	3	Interstate	255	17.9531	17,700	1	65	55	0	0	3
194	3	Other Principal Arterial	236	3.3452	19,000	1	45	35	0	0	2
195	3	Interstate	152	18.5590	18,600	1	70	45	0	0	1
196	3	Interstate	743	0.5085	31,800	0	70	45	1	2	5
197	3	Interstate	743	0.5106	31,800	0	70	55	1	1	1
198	3	Interstate	192	12.9703	18,900	1	70	55	1	1	3
199	3	Major Collector	75	5.0203	3,400	1	55	55	1	1	1
200	3	Interstate	89	31.9647	22,300	1	70	70	1	1	1

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
176	93	23	Lane Reduction/Closure	1	0
177	9	5	Lane Reduction/Closure	1	0
178	7	3	Lane Reduction/Closure	2	1
179	11	16	Lane Reduction/Closure	4	0
180	8	17	Lane Reduction/Closure	3	0
181	3	9	Lane Reduction/Closure	2	1
182	29	5	Lane Reduction/Closure	1	1
183	19	2	Lane Reduction/Closure	1	0
184	4	7	Lane Reduction/Closure	0	1
185	1	15	Lane Reduction/Closure	1	0
186	19	3	Lane Reduction/Closure	1	0
187	2	3	Lane Reduction/Closure	7	0
188	15	7	Lane Reduction/Closure	9	1
189	339	38	Lane Reduction/Closure	147	25
190	20	6	Lane Reduction/Closure	5	1
191	10	2	Lane Reduction/Closure	196	21
192	8	5	Lane Reduction/Closure	3	6
193	23	11	Lane Reduction/Closure	2	1
194	23	11	Lane Reduction/Closure	2	0
195	9	15	Lane Reduction/Closure	1	0
196	2	1	Shoulder Work	4	1
197	2	1	Shoulder Work	1	0
198	12	8	Lane Reduction/Closure	1	0
199	2	16	One-Way Traffic with Flaggers	1	0
200	34	33	Lane Reduction/Closure	1	0

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
201	3	Interstate	426	4.9866	17,200	1	70	55	2	5	15
202	3	Interstate	185	6.9104	16,800	1	70	55	1	1	11
203	3	Minor Arterial	560	2.0111	8,450	0	55	45	1	1	10
204	3	Minor Arterial	78	13.6292	2,000	1	55	50	1	1	3
205	3	Other Principal Arterial	121	0.6580	23,400	0	35	35	1	2	2
206	3	Other Principal Arterial	507	3.9076	7,150	1	55	45	0	2	5
207	3	Other Principal Arterial	643	0.1366	9,400	0	45	35	0	3	4
208	3	Interstate	92	5.9861	17,200	1	70	55	0	2	3
209	3	Interstate	36	36.9698	17,200	1	70	55	0	1	1
210	3	Other Principal Arterial	84	1.9985	21,100	1	45	35	0	1	4
211	3	Other Principal Arterial	292	3.3034	17,100	1	35	35	0	1	3
212	3	Other Principal Arterial	121	2.0626	21,700	0	45	35	0	1	2
213	3	Other Principal Arterial	108	0.2986	13,900	1	45	45	0	1	2
214	3	Interstate	435	2.0000	30,800	1	70	55	0	0	6
215	3	Interstate	426	4.9915	17,200	1	70	55	0	0	3
216	3	Interstate	281	4.9916	17,200	1	70	55	0	0	3
217	3	Interstate	182	5.9880	17,200	1	70	55	0	0	3
218	3	Other Principal Arterial	174	0.2275	11,500	1	45	45	0	0	3
219	3	Interstate	362	4.8634	33,100	1	70	55	0	0	2
220	3	Interstate	26	12.9879	24,600	1	70	45	0	0	1
221	3	Interstate	38	4.7479	17,400	1	70	55	0	0	1
222	3	Interstate	195	0.4701	17,600	1	70	55	0	0	1
223	3	Other Principal Arterial	84	2.0199	26,600	1	35	35	0	0	1
224	3	Other Principal Arterial	495	2.6429	25,600	1	55	45	3	19	49
225	3	Other Principal Arterial	464	3.4264	22,400	1	35	30	3	7	32

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
201	11	3	Lane Reduction/Closure	11	4
202	3	6	Lane Reduction/Closure	10	1
203	18	1	Lane Reduction/Closure	5	1
204	3	17	One-Way Traffic with Flaggers	1	2
205	8	5	Lane Reduction/Closure	1	1
206	22	14	Lane Reduction/Closure	2	3
207	12	1	Intersection Restrictions	3	1
208	2	6	Lane Reduction/Closure	3	0
209	0	35	Lane Reduction/Closure	1	0
210	8	16	Lane Reduction/Closure	2	2
211	11	17	Lane Reduction/Closure	3	0
212	5	19	Lane Reduction/Closure	0	2
213	1	3	Lane Reduction/Closure	0	2
214	26	4	Lane Reduction/Closure	4	0
215	13	6	Lane Reduction/Closure	2	1
216	8	4	Lane Reduction/Closure	2	1
217	7	6	Lane Reduction/Closure	2	1
218	4	2	Lane Reduction/Closure	3	0
219	25	3	Lane Reduction/Closure	1	1
220	1	15	Lane Reduction/Closure	0	1
221	2	7	Lane Reduction/Closure	1	0
222	0	1	Lane Reduction/Closure	0	1
223	8	17	Lane Reduction/Closure	1	0
224	112	4	Lane Reduction/Closure	35	5
225	71	26	Lane Reduction/Closure	17	7

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
226	3	Other Principal Arterial	742	4.8141	4,550	1	55	45	1	4	17
227	3	Interstate	281	4.9877	17,200	1	70	55	2	5	15
228	3	Interstate	19	3.9888	22,300	1	70	55	1	1	1
229	3	Other Principal Arterial	174	0.2263	12,400	1	45	45	1	1	2
230	3	Other Principal Arterial	137	5.5640	4,950	1	55	45	1	2	3
231	3	Other Principal Arterial	938	2.3397	22,400	0	45	25	0	6	20
232	3	Other Principal Arterial	495	2.0481	27,500	1	45	45	0	2	12
233	3	Other Principal Arterial	731	2.3401	15,500	1	45	35	0	4	10
234	3	Interstate	92	5.9889	17,200	1	70	55	0	0	2
235	3	Other Principal Arterial	1,390	0.7029	18,100	1	35	35	0	0	3
236	3	Interstate	122	4.8249	32,900	1	70	55	0	0	1
237	3	Interstate	284	2.9784	34,100	1	70	45	0	0	1
238	3	Interstate	76	2.9683	29,200	1	65	55	0	1	1
239	4	Interstate	681	3.3158	54,300	1	70	45	0	3	18
240	4	Interstate	681	1.3461	23,200	1	65	45	0	2	5
241	4	Interstate	219	35.3903	37,400	1	70	55	0	0	8
242	4	Minor Arterial	124	8.4842	5,750	1	45	45	0	0	3
243	4	Interstate	512	7.7478	1,700	0	70	45	0	0	1
244	4	Interstate	681	1.5668	8,900	1	65	45	1	2	3
245	4	Interstate	166	11.7066	13,400	1	70	45	0	0	1
246	4	Interstate	213	8.2147	31,600	1	70	55	1	1	13
247	4	Interstate	151	7.0061	22,200	1	70	55	1	1	4
248	5	Interstate	109	10.9816	26,200	1	70	70	1	1	1
249	5	Interstate	213	8.2067	31,600	1	70	55	2	3	8
250	5	Interstate	2132.56	8.1771	31,600	1	70	55	2	3	8

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
226	33	5	One-Way Traffic with Flaggers	11	5
227	17	3	Lane Reduction/Closure	11	4
228	0	2	Lane Reduction/Closure	0	1
229	2	3	Lane Reduction/Closure	2	0
230	7	4	One-Way Traffic with Flaggers	2	1
231	66	8	Lane Reduction/Closure	17	1
232	75	6	Lane Reduction/Closure	9	3
233	66	7	Lane Reduction/Closure	7	3
234	3	6	Lane Reduction/Closure	1	1
235	121	4	Lane Reduction/Closure	1	2
236	1	3	Lane Reduction/Closure	0	1
237	8	3	Lane Reduction/Closure	0	1
238	6	6	Lane Reduction/Closure	1	0
239	30	9	Lane Reduction/Closure	6	10
240	5	6	Lane Reduction/Closure	5	0
241	28	24	One-Way Traffic with Flaggers	0	1
242	5	13	One-Way Traffic with Flaggers	0	1
243	13	8	Lane Reduction/Closure	0	1
244	5	2	Lane Reduction/Closure	0	3
245	2	12	Intermittent Roadwork	0	1
246	20	7	Lane Reduction/Closure	5	3
247	1	8	Lane Reduction/Closure	3	1
248	16	14	Lane Reduction/Closure	1	0
249	8	6	Lane Reduction/Closure	5	3
250	8	6	Lane Reduction/Closure	5	3

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
251	5	Interstate	213	8.1771	31,600	1	70	55	2	3	8
252	5	Major Collector	213	6.8386	4,000	1	55	55	1	1	3
253	5	Minor Arterial	138	2.2255	5,300	1	55	45	2	1	2
254	5	Interstate	212	10.9933	24,100	1	70	45	0	1	4
255	5	Interstate	213	9.9849	29,000	1	70	45	0	1	2
256	5	Other Principal Arterial	383	2.0120	10,250	1	55	35	0	0	2
257	5	Other Principal Arterial	129	4.5967	13,500	1	55	45	0	0	1
258	5	Other Principal Arterial	212	2.7594	19,000	1	45	35	0	0	1
259	5	Interstate	272	7.9390	23,100	1	70	70	0	0	13
260	5	Interstate	272	2.1011	36,100	1	70	55	1	2	5
261	5	Interstate	212	10.9584	26,200	1	70	55	1	3	15
262	5	Interstate	151	6.9600	22.200	1	70	55	1	2	6
263	5	Major Collector	35	2.0057	4,650	2	55	50	1	1	1
264	5	Interstate	127	5.9512	20,700	0	70	45	0	1	2
265	5	Minor Arterial	136	3.8525	11,000	1	55	55	0	1	1
266	5	Minor Arterial	141	4.7413	8,400	1	50	40	0	1	1
267	5	Interstate	272	12.9891	25,000	1	70	55	0	0	17
268	5	Interstate	272	12.9731	23,100	1	70	70	0	0	24
269	5	Interstate	127	5.9395	20,700	0	65	55	0	0	1
270	6	Interstate	716	17.9678	23,500	1	70	55	2	5	30
271	6	Interstate	790	10.4308	23,500	1	70	55	1	3	12
272	6	Minor Arterial	96	2.6136	7,700	1	55	55	1	1	2
273	6	Other Principal Arterial	114	4.5846	2,500	1	55	55	1	1	1
274	6	Interstate	201	13.2398	17,600	1	70	70	1	1	2
275	6	Minor Arterial	122	8.8673	2,300	1	55	55	1	1	1

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
251	8	6	Lane Reduction/Closure	5	3
252	6	13	Lane Reduction/Closure	0	3
253	3	6	One-Way Traffic with Flaggers	1	0
254	27	16	Lane Reduction/Closure	3	1
255	13	13	Lane Reduction/Closure	1	1
256	8	3	Lane Reduction/Closure	2	0
257	5	27	Lane Reduction/Closure	1	0
258	4	6	Lane Reduction/Closure	1	0
259	12	8	Lane Reduction/Closure	1	0
260	11	4	Lane Reduction/Closure	3	1
261	32	14	Lane Reduction/Closure	6	9
262	4	6	Lane Reduction/Closure	3	1
263	0	2	Road Closed	0	1
264	3	6	Lane Reduction/Closure	1	1
265	7	8	Lane Reduction/Closure	0	1
266	3	16	Lane Reduction/Closure	1	0
267	31	23	Lane Reduction/Closure	1	7
268	27	17	Lane Reduction/Closure	1	0
269	2	8	Lane Reduction/Closure	1	0
270	51	6	Lane Reduction/Closure	21	5
271	22	7	Lane Reduction/Closure	9	2
272	5	4	Lane Reduction/Closure	1	1
273	1	7	Lane Reduction/Closure	1	0
274	13	13	Lane Reduction/Closure	1	0
275	0	10	Lane Reduction/Closure	1	0

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
276	6	Interstate	150	5.5826	15,900	0	70	55	1	3	3
277	6	Interstate	209	1.0732	37,000	1	70	45	0	1	4
278	6	Interstate	177	3.3625	54,000	0	70	70	0	0	8
279	6	Interstate	76	3.9845	37,000	1	70	45	0	0	2
280	6	Interstate	27	30.5220	34,600	1	70	45	0	0	2
281	6	Interstate	165	5.3864	17,000	1	70	70	0	0	1
282	6	Interstate	71	38.9809	32,200	1	70	55	1	1	3
283	6	Other Principal Arterial	456	3.3716	18,000	1	35	35	0	0	2
284	6	Interstate	790	18.1401	23,500	1	70	45	0	0	19
285	6	Other Principal Arterial	746	0.3084	23,800	0	40	40	0	0	1
286	6	Interstate	201	13.2453	40,000	1	70	45	0	0	1
287	7	Interstate	233	8.5659	21,600	1	70	45	2	3	16
288	7	Interstate	103	36.9816	21,700	1	70	55	2	3	14
289	7	Interstate	260	8.9861	21,600	1	70	55	1	1	3
290	7	Minor Arterial	270	3.8547	6,250	1	55	45	1	1	2
291	7	Other Principal Arterial	113	8.3583	3,900	0	55	55	0	1	0
292	7	Interstate	844	4.0694	2,250	1	70	45	3	5	23
293	7	Interstate	576	4.9405	42,100	1	70	45	1	3	14
294	7	Interstate	173	3.9765	22,000	1	70	45	1	1	4
295	7	Minor Arterial	78	14.9044	4,300	1	55	55	1	1	1
296	7	Minor Arterial	418	0.0551	3,700	1	55	40	1	1	4
297	7	Interstate	260	8.9913	22,000	1	70	55	0	2	2
298	7	Interstate	577	9.9777	62,500	1	70	55	1	2	14
299	7	Interstate	258	8.9942	21,800	1	70	55	0	0	4
300	7	Interstate	283	4.9947	19,600	1	70	55	0	0	4

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
276	6	3	Lane Reduction/Closure	3	0
277	5	4	Lane Reduction/Closure	1	3
278	16	4	Lane Reduction/Closure	1	0
279	1	2	Lane Reduction/Closure	1	0
280	2	18	Lane Reduction/Closure	1	0
281	3	4	Lane Reduction/Closure	1	0
282	27	37	Lane Reduction/Closure	1	2
283	0	21	Lane Reduction/Closure	1	1
284	73	16	Intersection Restriction	1	0
285	4	6	Lane Reduction/Closure	1	0
286	7	13	Lane Reduction/Closure	0	1
287	11	8	Lane Reduction/Closure	9	4
288	27	34	Lane Reduction/Closure	7	5
289	10	7	Lane Reduction/Closure	2	1
290	15	12	Lane Reduction/Closure	0	2
291	3	12	Intermittent Roadwork	1	0
292	12	5	Lane Reduction/Closure	9	12
293	31	5	Lane Reduction/Closure	9	5
294	3	5	Lane Reduction/Closure	3	0
295	4	21	Lane Reduction/Closure	0	1
296	1	0	One-Way Traffic with Temporary Signals	1	0
297	3	8	Lane Reduction/Closure	1	1
298	31	12	Lane Reduction/Closure	9	2
299	8	9	Lane Reduction/Closure	4	0
300	7	4	Lane Reduction/Closure	3	0

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
301	7	Interstate	516	9.9765	36,000	1	70	45	0	0	3
302	7	Other Principal Arterial	105	1.0120	12,400	1	35	30	0	0	2
303	7	Interstate	214	2.1744	22,900	1	70	55	0	0	1
304	7	Interstate	435	8.9959	21,800	1	70	55	2	3	13
305	7	Interstate	103	36.9887	21,700	1	70	55	2	2	5
306	7	Interstate	173	7.9854	21,700	0	70	55	1	1	8
307	7	Interstate	258	8.9819	21,800	1	70	55	1	2	18
308	7	Interstate	270	7.9686	20,300	1	70	55	1	1	13
309	7	Interstate	173	7.9980	21,700	0	70	55	1	2	5
310	7	Interstate	275	2.9772	22,900	1	70	45	2	2	9
311	7	Interstate	270	8.0060	17,870	1	70	45	0	0	4
312	7	Interstate	844	3.9204	37,900	1	70	45	0	0	5
313	8	Interstate	1,149	7.9783	38,000	1	70	55	3	5	50
314	8	Interstate	979	7.9911	38,000	1	70	55	3	6	43
315	8	Interstate	228	10.9822	23,500	1	70	45	2	3	11
316	8	Other Principal Arterial	103	7.1164	3,600	1	55	55	1	1	2
317	8	Interstate	170	2.0474	49,300	2	50	50	1	1	10
318	8	Interstate	979	3.9838	38,000	1	70	55	1	1	16
319	8	Interstate	228	10.9840	23,500	1	70	55	3	5	17
320	8	Interstate	168	3.9758	71,300	1	65	55	1	3	9
321	8	Minor Arterial	176	16.1616	5,150	1	55	55	1	1	5
322	8	Interstate	168	3.9869	71,300	1	65	55	1	1	3
323	8	Interstate	329	7.5351	34,500	1	70	55	1	1	4
324	8	Interstate	114	10.0002	26,700	1	70	55	2	3	5
325	8	Interstate	18	7.5804	54,600	1	65	65	1	1	3

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
326	2	2	Lane Reduction/Closure	0	1
327	0	2	Lane Reduction/Closure	0	1
328	11	9	Lane Reduction/Closure	12	2
329	16	8	Lane Reduction/Closure	4	2
330	13	6	Lane Reduction/Closure	12	2
331	1	9	Lane Reduction/Closure	0	0
332	3	8	Lane Reduction/Closure	2	2
333	13	7	Lane Reduction/Closure	3	1
334	24	3	Lane Reduction/Closure	2	0
335	19	5	Lane Reduction/Closure	2	0
336	18	6	Lane Reduction/Closure	2	0
337	10	35	Lane Reduction/Closure	1	1
338	21	9	Lane Reduction/Closure	0	1
339	2	3	Lane Reduction/Closure	1	0
340	6	8	Lane Reduction/Closure	1	0
341	8	5	Lane Reduction/Closure	1	0
342	80	6	Lane Reduction/Closure	33	12
343	2	11	Lane Reduction/Closure	1	0
344	6	0	Lane Reduction/Closure	32	15
345	36	2	Lane Reduction/Closure	20	7
346	18	4	Lane Reduction/Closure	4	1
347	3	10	Lane Reduction/Closure	2	1
348	246	23	Lane Reduction/Closure	74	16
349	17	6	Lane Reduction/Closure	18	2
350	0	20	One-Way Traffic with Flaggers	1	0

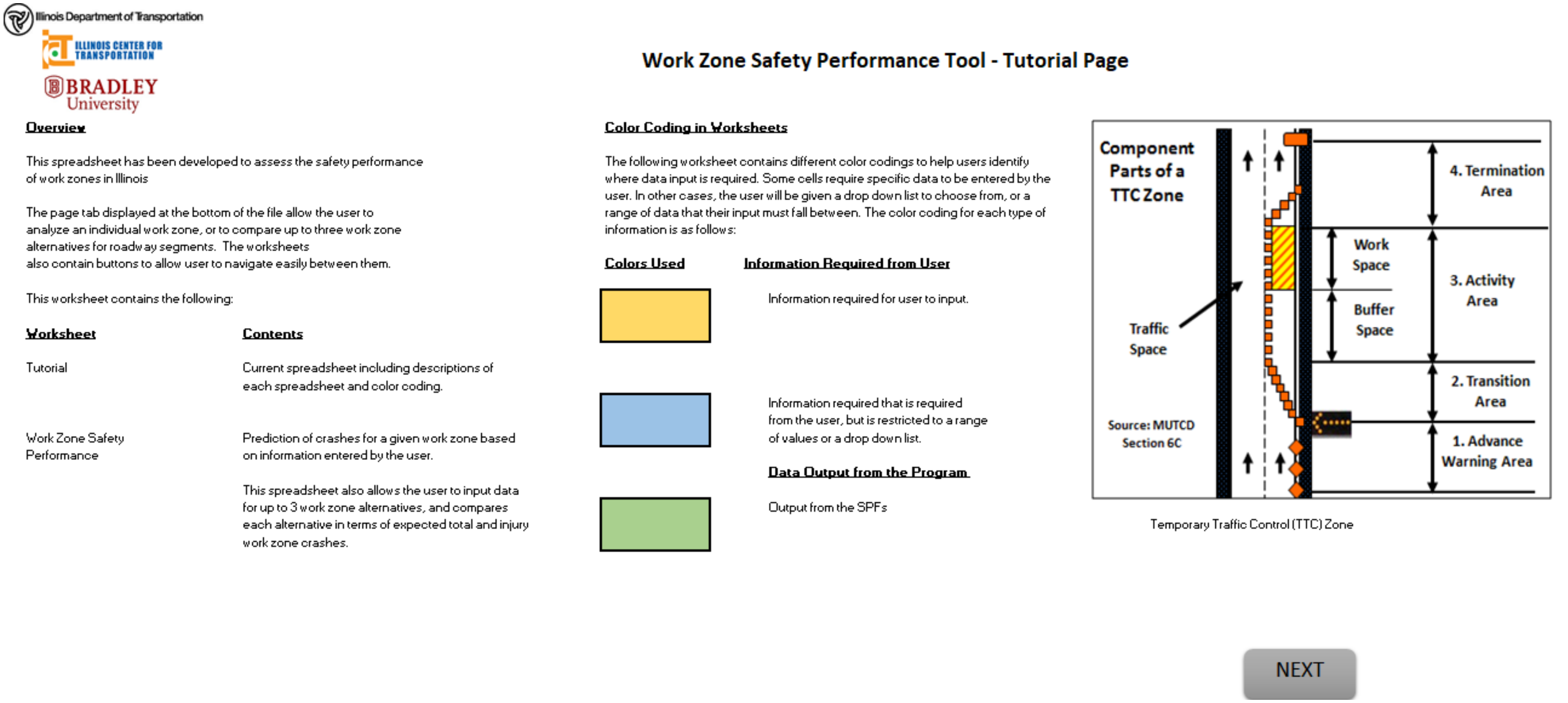
Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
351	8	Interstate	426	0.3482	3,500	0	65	55	1	1	1
352	8	Minor Arterial	254	0.5201	11,200	1	45	45	2	1	3
353	8	Other Principal Arterial	692	0.2495	550	0	55	55	1	2	2
354	8	Interstate	1,066	0.4714	20,108	1	55	45	1	1	7
355	8	Freeway and Expressway	96	5.5947	16,000	1	65	45	1	1	1
356	8	Other Principal	110	15.8023	5,081	1	55	55	0	1	1
357	8	Interstate	243	2.5157	95,298	1	50	45	0	0	16
358	8	Interstate	1,066	0.4620	50,108	1	55	45	0	0	8
359	8	Interstate	426	4.7591	36,000	0	65	55	0	0	8
360	8	Interstate	52	19.9653	26,512	1	65	45	0	0	3
361	8	Interstate	81	10.6419	22,600	1	65	55	0	0	2
362	8	Interstate	194	13.1566	34,105	1	70	45	0	0	2
363	8	Minor Arterial	127	4.5332	3,250	1	55	55	0	0	1
364	9	Interstate	172	10.4854	30,900	1	70	45	3	11	36
365	9	Other Principal Arterial	1,182	2.2435	20,200	1	55	45	2	3	21
366	9	Other Principal Arterial	59	4.0497	4,000	1	55	55	1	1	2
367	9	Interstate	165	4.8874	22,600	1	70	55	1	1	4
368	9	Minor Arterial	180	11.1759	1,550	1	55	55	1	1	2
369	9	Interstate	48	4.9226	30,900	1	70	45	1	1	10
370	9	Interstate	195	11.0368	11,900	1	70	55	1	1	5
371	9	Interstate	8	0.9732	39,100	0	70	55	1	1	2
372	9	Interstate	86	4.9867	38,500	1	70	45	0	1	3
373	9	Other Principal Arterial	1,182	2.2576	24,300	1	55	55	0	1	6
374	9	Interstate	540	2.2003	37,500	1	70	45	0	1	8
375	9	Interstate	225	9.6675	13,400	1	70	55	0	1	4

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
351	2	1	Lane Reduction/Closure	1	0
352	5	6	Lane Reduction/Closure	2	0
353	0	1	Ramp Closed	0	2
354	36	2	Lane Reduction/Closure	6	0
355	0	8	Lane Reduction/Closure	0	1
356	5	16	Lane Reduction/Closure	0	1
357	39	5	Lane Reduction/Closure	8	1
358	16	2	Lane Reduction/Closure	4	0
359	17	5	Lane Reduction/Closure	6	0
360	8	42	Lane Reduction/Closure	2	1
361	5	14	Lane Reduction/Closure	2	0
362	20	14	Lane Reduction/Closure	1	1
363	1	12	One-Way Traffic with Flaggers	0	1
364	16	9	Lane Reduction/Closure	17	16
365	34	4	Lane Reduction/Closure	18	3
366	2	3	Intermittent Roadwork	0	2
367	6	6	Lane Reduction/Closure	7	0
368	3	24	Intermittent Roadwork	0	2
369	1	3	Lane Reduction/Closure	4	6
370	4	13	Lane Reduction/Closure	3	2
371	0	1	Lane Reduction/Closure	2	0
372	4	3	Lane Reduction/Closure	1	2
373	32	5	Lane Reduction/Closure	2	0
374	14	7	Lane Reduction/Closure	4	1
375	6	11	Lane Reduction/Closure	1	2

Site No.	IDOT District No.	Functional Classification	Duration (days)	Length (miles)	Annual Average Daily Traffic (vehicles/day)	No. of Lanes Reduced	Speed Limit (mph)	Work Zone Speed Limit (mph)	Work Zone Crash Frequency by Severity per Work Zone Days (Confirmed, Likely, Probable)		
									KA Crashes	Injury Crashes (K, A, B, C)	Total Crashes
376	9	Interstate	618	1.9069	25,600	1	55	45	0	1	4
377	9	Interstate	43	0.2241	34,500	0	70	45	0	0	3
378	9	Interstate	618	2.9718	43,000	1	70	45	0	0	4
379	9	Interstate	144	7.0025	11,001	1	65	45	0	0	2
380	9	Other Principal Arterial	180	10.7344	5,100	1	55	55	1	2	3
381	9	Major Collector	334	2.9900	5,700	1	55	55	0	1	4
382	9	Interstate	75	2.2873	43,000	1	65	45	0	1	4
383	9	Other Principal Arterial	213	4.8540	12,500	1	55	45	0	1	3
384	9	Interstate	75	33.9710	6,550	1	70	55	1	0	23
385	9	Interstate	436	7.9407	10,500	1	70	45	0	0	4

Site No.	Pre-Construction Crash Frequency (Same Duration as WZ with No Overlap)	No. of Intersections/Ramps in Work Zone	Type of Road Closure	WZ Crash Frequency per WZ Days Workers Not Present	WZ Crash Frequency per WZ Days Workers Present
376	10	2	Lane Reduction/Closure	3	0
377	1	1	Ramp Closed	1	2
378	34	3	Lane Reduction/Closure	2	0
379	1	4	Lane Reduction/Closure	1	0
380	19	14	One-Way Traffic with Flaggers	1	0
381	14	4	One-Way Traffic with Flaggers	0	2
382	5	3	Lane Reduction/Closure	3	0
383	18	15	One-Way Traffic with Flaggers	0	1
384	27	8	Lane Reduction/Closure	3	0
385	12	7	Lane Reduction/Closure	1	0

APPENDIX D: SCREEN CAPTURES OF THE EXCEL TOOL



Illinois Department of Transportation
ILLINOIS CENTER FOR TRANSPORTATION
BRADLEY University

Work Zone Safety Performance Tool - Tutorial Page

Overview

This spreadsheet has been developed to assess the safety performance of work zones in Illinois

The page tab displayed at the bottom of the file allow the user to analyze an individual work zone, or to compare up to three work zone alternatives for roadway segments. The worksheets also contain buttons to allow user to navigate easily between them.

This worksheet contains the following:

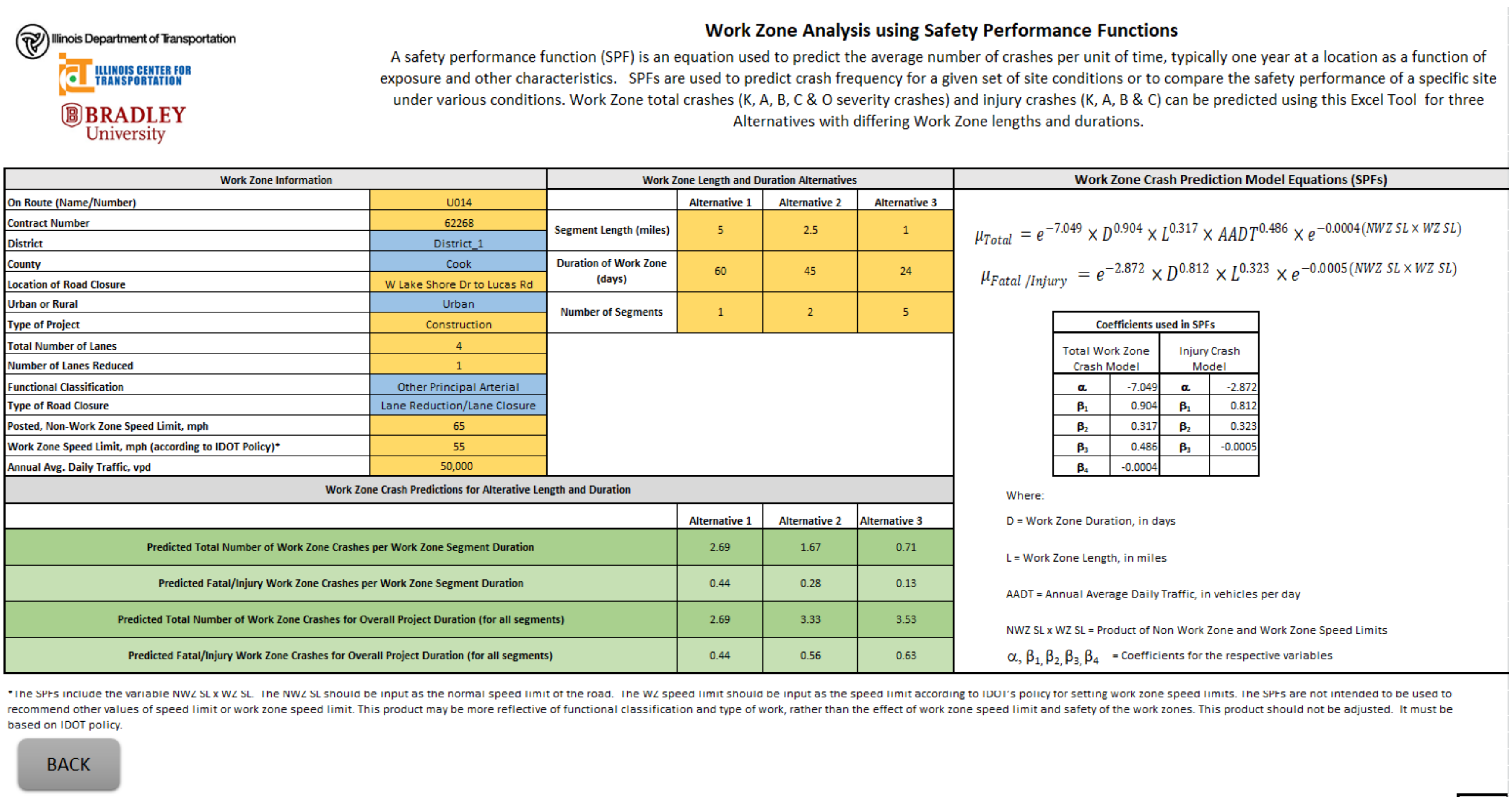
Worksheet	**Contents**
Tutorial	Current spreadsheet including descriptions of each spreadsheet and color coding.
Work Zone Safety Performance	Prediction of crashes for a given work zone based on information entered by the user. This spreadsheet also allows the user to input data for up to 3 work zone alternatives, and compares each alternative in terms of expected total and injury work zone crashes.

Color Coding in Worksheets

The following worksheet contains different color codings to help users identify where data input is required. Some cells require specific data to be entered by the user. In other cases, the user will be given a drop down list to choose from, or a range of data that their input must fall between. The color coding for each type of information is as follows:

Colors Used	**Information Required from User**
🟨	Information required for user to input.
🟦	Information required that is required from the user, but is restricted to a range of values or a drop down list.
	Data Output from the Program
🟩	Output from the SPFs

Temporary Traffic Control (TTC) Zone



Work Zone Analysis using Safety Performance Functions

A safety performance function (SPF) is an equation used to predict the average number of crashes per unit of time, typically one year at a location as a function of exposure and other characteristics. SPFs are used to predict crash frequency for a given set of site conditions or to compare the safety performance of a specific site under various conditions. Work Zone total crashes (K, A, B, C & O severity crashes) and injury crashes (K, A, B & C) can be predicted using this Excel Tool for three Alternatives with differing Work Zone lengths and durations.

Work Zone Information	
On Route (Name/Number)	U014
Contract Number	62268
District	District_1
County	Cook
Location of Road Closure	W Lake Shore Dr to Lucas Rd
Urban or Rural	Urban
Type of Project	Construction
Total Number of Lanes	4
Number of Lanes Reduced	1
Functional Classification	Other Principal Arterial
Type of Road Closure	Lane Reduction/Lane Closure
Posted, Non-Work Zone Speed Limit, mph	65
Work Zone Speed Limit, mph (according to IDOT Policy)*	55
Annual Avg. Daily Traffic, vpd	50,000

Work Zone Length and Duration Alternatives

	Alternative 1	Alternative 2	Alternative 3
Segment Length (miles)	5	2.5	1
Duration of Work Zone (days)	60	45	24
Number of Segments	1	2	5

Work Zone Crash Predictions for Alterative Length and Duration

	Alternative 1	Alternative 2	Alternative 3
Predicted Total Number of Work Zone Crashes per Work Zone Segment Duration	2.69	1.67	0.71
Predicted Fatal/Injury Work Zone Crashes per Work Zone Segment Duration	0.44	0.28	0.13
Predicted Total Number of Work Zone Crashes for Overall Project Duration (for all segments)	2.69	3.33	3.53
Predicted Fatal/Injury Work Zone Crashes for Overall Project Duration (for all segments)	0.44	0.56	0.63

Work Zone Crash Prediction Model Equations (SPFs)

$$\mu_{Total} = e^{-7.049} \times D^{0.904} \times L^{0.317} \times AADT^{0.486} \times e^{-0.0004(NWZ\ SL \times WZ\ SL)}$$

$$\mu_{Fatal\ /Injury} = e^{-2.872} \times D^{0.812} \times L^{0.323} \times e^{-0.0005(NWZ\ SL \times WZ\ SL)}$$

Coefficients used in SPFs

Total Work Zone Crash Model		Injury Crash Model	
α	-7.049	α	-2.872
β_1	0.904	β_1	0.812
β_2	0.317	β_2	0.323
β_3	0.486	β_3	-0.0005
β_4	-0.0004		

Where:

D = Work Zone Duration, in days

L = Work Zone Length, in miles

AADT = Annual Average Daily Traffic, in vehicles per day

NWZ SL x WZ SL = Product of Non Work Zone and Work Zone Speed Limits

$\alpha, \beta_1, \beta_2, \beta_3, \beta_4$ = Coefficients for the respective variables

*The SPFs include the variable NWZ SL x WZ SL. The NWZ SL should be input as the normal speed limit of the road. The WZ speed limit should be input as the speed limit according to IDOT's policy for setting work zone speed limits. The SPFs are not intended to be used to recommend other values of speed limit or work zone speed limit. This product may be more reflective of functional classification and type of work, rather than the effect of work zone speed limit and safety of the work zones. This product should not be adjusted. It must be based on IDOT policy.

APPENDIX E: IDOT’S ROAD RESTRICTION INFORMATION FORM OPER 2410

Illinois Department of Transportation

Road Restriction Information

Name: ______________________ Phone #: ________________ ☐ **Permanent** ☐ **Emergency**

Location Information: District: ________ County Name: ______________________________

Route Type: __________ Route Number or Street: ______________________________________

Near Town: _____________________________ Direction of Route: _______________ Bound

From Location or Mile: ______________________ To Location or Mile: ________________________

Road Restriction Information: **Start Date:** _____________ **Stop Date:** ______________

Contract #: ______________________ ☐ **New** ☐ **Revised** ☐ **Delete**

Contract Value: _______________ Contractor: _______________________________________

Type of Construction: ___________________________________ Lanes/Ramp Closed: __________

Suggestions to Motorists:

Traffic Alert (Special Comments):

Detour Route:

Oversize Vehicle Permit Restrictions:

Max Width:	Feet	Inches	**Max Length:**	Feet 000	Inches	Current Structure Number:	New Structure Number:	Crossing:

Crossover: ☐ Yes ☐ No

Web Address:

Send to: DOT.ROADINFO@Illinois.gov or in the Global Address Book under DOT.RoadInfo

OPER 2410: ROAD RESTRICTION INFORMATION FORM INSTRUCTIONS

(USE A SEPARATE FORM FOR EACH LOCATION)

Name: Please enter the name of person responsible for this restriction, who will answer all questions about restrictions.

Phone #: Please enter the phone number for the person responsible for this restriction.

Permanent or Emergency: Please mark box - Emergency - To report a restriction after informing Station 1, due to an *unplanned event*. Permanent - To identify a permanent roadway restriction not due to construction. Example: Max length 100 feet due to turning radius at intersection or 14 feet wide at a narrow structure. All narrow structures with actual openings of less than 17' 6" should be reported. For Permanent Restrictions you only need to fill out the location and Max Width or Length. This restriction will be placed on our Permanent Restriction List at:

Permanent Restriction List http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Specialty-Lists/Highways/Permits/Permanentrestrictedroads.pdf

Location Information:

District/ County Name: Please select District and identify County for construction location.

Route Type: Please select type of route at Construction Location. (Interstate, US Route, Illinois Route, Street, County Road, or other.)

Route Number or Street: Identify Route, e.g. 90 for Interstate 90 or roadway name. Do not use FAP, FAU, etc.

Near Town: Enter name of the town construction zone is in or nearest to.

Direction of Route: Use the official direction the route travels. Do not use cardinal direction. Example INT 55 travels south to north and INT 24 travels west to east. (North, South, North and South, East, West, East and West).

From / To Location or Mile: Always use mile posts or Exit Numbers for Interstate projects, e.g. MP 177 to 184 or MP 39 for a specific structure at MP 39. For all other roadways use intersecting streets, distance from state roadway, etc., e.g. "Elm St. to First Ave.," "2 miles south IL29 at BNSF RR," "Auburn Rd. to 5 miles north of Sydney." Do not use Station Numbers.

Road Restriction Information:

Start / Stop Dates: These should be the dates which will affect motorists and not necessarily the official contract starting and stopping dates. The start and stop dates are in mm/dd/yyyy format. **The Stop Date is the day the motoring public will stop being affected. If you are not sure of the Stop Date make it longer and revise at a later date. Construction zones will be removed on the Stop Date, if not revised prior to.** Projects not requiring roadway closures or dimensional restrictions on vehicles should be submitted within 7 days of start date. Projects requiring roadway/ramp closures or oversize vehicle permit dimensional restrictions (maximum width or length restrictions on vehicles) should submit restrictions 21 days prior to the actual start date the roadway will be closed or a dimensional restriction will be in place to give motorists and oversize overweight permit loads advance notice.
Stop dates should be revised or modified as necessary during the life of the project.

Contract #: Please enter contract number. If no contract number, specify reason like CN RR, Day Labor, Bridge Office, or Emergency. In those cases a contract number will be assigned.

New, Revised, Delete: Please mark box that describes what kind of temporary restriction you are submitting. **New** - Never submitted prior. **Revised** - For changing something submitted prior. **Delete** - To remove an active construction zone, prior to the Stop Date. (You do not have to submit a delete form when past the Stop Date. Restrictions will automatically be removed after the Stop Date.)

Contractor: Please provide name of contractor or entity doing the work.

Contract Value: Please provide value of work performed. (Some Districts use this form to provide data for Press Releases).

Type of Construction: Select what describes your construction zone the best. Use one of the following: Lane Reduction/Lane Closure, Intermittent Road Work, Intersection Restrictions, Temporary Changes, One Way Traffic with Temporary Signals, One Way Traffic with Flaggers, Shoulder Work, Road Closed, Bridge Closed, Shoulder Closed, Ramp Closed, Railroad Closure, Weight Station Closed, Rest Area Closed, or Closed Due to Flooding. This is a pull down box selection.

Lanes / Ramp Closed: Provide information on the number of lanes closed or if a ramp or shoulder is closed or restricted.

Suggestions to Motorists: Please enter information that would be helpful to motorists. Examples: Traffic restricted to one lane in each direction, Road closed to place beams expect 15 minute closures, Expect lane closures with narrow lanes, Traffic restricted to one lane directed by temporary traffic signals. Include general information on such things as delays, time of day or days of week, etc. This is an input text line.

Traffic Alert: Any special information, including special delays such as "Expect intermittent 20-minute delays on May 17," "INT 57 SB ramp to IL 17 EB ramp closed," etc. This is an input text line.

Detour Route: Enter detour route for standard vehicles and truck detour if needed. This is an input text line.

Current Structure Number: Enter the current structure number in the construction zone. Oversize vehicle permit restrictions will be placed on route specified at the structure only. If you need restrictions on the crossing roadway as well, please specify. Enter what the structure is crossing to right under Crossing. (Roadway, River, Creek, etc.)

New Structure Number: Enter the new structure number replacing the current structure in the construction zone.

Crossing: When working at a structure/specific feature, enter what the structure is crossing like Illinois River or Mudd Creek. Please enter the current structure number, not the new structure number in column to left.

Oversize Vehicle Permit Restrictions: This section is for submitting width or length restrictions placed on vehicles for construction zones. These restrictions are based on the limitations of the construction zone, not the dimensions of the Construction Zone. Max Width measurements shall be 1' 6" less than the actual opening, e.g. (If actual opening measures 13', width restriction should be reported as 11' 6" and signed as 11' 6"). Max Length restriction measurements shall be determined by the turning radius and traffic patterns in the construction zone. Note: Length restrictions are usually not submitted unless you identify long vehicles are using the route, e.g. a wind mill blade with overall length of vehicle at 205 feet. Max length is also used with permanent restrictions to report permanent turning radius issues.

The blank entry field below the max width and length fields is for additional info. Examples: Report start and stop dates for restrictions if different than general construction start and stop dates, identify additional structures/locations with width restrictions and dates of, Start and Stop dates for Stage 1 or 2. (STR # 013-4569 6/15/2013-12/1/14 (Useful when **From/To Location** for paving is 5 miles long with width restriction at structure) or Stage 1 10' 6" on 5/15 Stage II 9' 6" on 7/7/13-11/1/13.) **Do not** consider marked detours when reporting restrictions. Permit loads can't use detours. **If this will be a Permanent Restriction please mark the box in the upper right corner of the form and remind us in this field as well, so we will ignore the start and stop dates.**

Crossover: If a crossover is being utilized, mark the Yes box and provide a description below. The description should include where both crossovers are, especially in relation to vertical clearance issues, e.g. "East of Elm St. west of IC RR." The description must also include which direction the traffic is traveling on, e.g. "Traffic on NB lanes." Revise form 21 days prior to traffic moving to opposite direction of travel.

Web Address: Enter the address if you have a specific website established for the project.

Data Verification: Please verify the accuracy of the information posted for your area of the State on the Road Construction Map and Weekly Restriction List. Please bring all discrepancies to our attention by issuing a revised OPER 2410.

Road Construction Map	http://www.gettingaroundillinois.com/gai.htm?mt=cons
Weekly Restriction List	http://truckpermits.dot.illinois.gov/road/restrlst.rtf

Illinois Department of Transportation

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