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Addressing Work Zone Traffic Safety Issues in Arizona

Arizona Department of Transportation Research Center

ADOT

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SPR-720
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16. Abstract

The occurrence of work zone crashes is expected to increase in Arizona with the Arizona Department of Transportation's (ADOT's) shifted emphasis from constructing new roadways to preserving existing facilities. Identifying factors that contribute to work zone crashes will lead to development of appropriate strategies to improve work zone traffic control design and management. This research effort included analysis of work zone crashes identified in the ADOT Accident Location Identification Surveillance System (ALISS) database to determine accuracy of data and to identify factors associated with work zone crashes. The research also compared information from work zone crash reports to the data in the ALISS database to identify inconsistencies. Recommendations were developed for improving the accuracy of crash investigation reporting and transcribing, and for improving work zone policies and procedures.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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List of Acronymns

ADOT	Arizona Department of Transportation
ALERT	Arizona Local Emergency Response Team
ALISS	Accident Location Identification Surveillance System
CCTV	closed circuit television
DMS	dynamic message sign
DOT	department of transportation
FHWA	Federal Highway Administration
HCRS	Highway Condition Reporting System
ITS	intelligent traffic systems
MSLT	Maintenance Servant Leadership Team
PVMS	portable variable message sign
SR	state route
TIM	traffic incident management
TMC	traffic management center
TMS	traffic management system
TDOT	Tennessee Department of Transportation
TSMO	transportations systems management and operation
TRACS	Transportation Accounting System
TTC	temporary traffic control

EXECUTIVE SUMMARY

A work zone is the area of a trafficway subject to construction, maintenance, or utility work. It extends from the first warning sign indicating a work area to the END ROAD WORK sign. The “Arizona Crash Report Forms Instruction Manual” defines a work zone crash as a traffic crash in which the first event occurs within the boundaries of a work zone or on an approach to or exit from a work zone, resulting from an activity, behavior or control related to the movement of the traffic units through the work zone. This would include crashes related to queues created by the work zone activities, even if the queue extended beyond the END ROAD WORK sign.

While work zone fatal crashes had decreased in recent years, they trended upward both nationally and in Arizona in 2014 and 2015. The Arizona Department of Transportation (ADOT) 5-year Construction Program has shifted emphasis from constructing new roadways to preserving existing facilities, which will mean more active work zones that must accommodate live traffic. The more live traffic going through work zones may result in an increase in work zone related crashes.

This research effort included analysis of work zone crashes identified in the ADOT Accident Location Identification Surveillance System (ALISS) database to determine accuracy of data. Research was also intended to include analysis of work zone traffic control plans to identify contributing factors associated with crashes. Having the consistent and complete documentation for the work zone traffic control plan would assist engineers in identifying field conditions that may contribute to the crash causation. During the course of this study, it was difficult to retroactively identify the work zone traffic control plan that was in place at the time a work zone crash occurred. Instead, the research focus changed to identifying contributing factors from police crash reports, as well as making recommendations for improving accuracy of crash data.

The research team initially queried 29,877 crashes that the ALISS database identified as occurring in work zones for the 10 years from 2004 through 2013. Approximately 11 percent of these crashes were misidentified as work zone crashes. Analysis indicated that certain errors were associated with changes in the Arizona police crash report form in 2009. Further database queries were refined to produce actual work zone crash data, which was analyzed in Chapter 3 of this report.

The research team also analyzed a three-year sample of 300 work zone crash reports to obtain certain details, including field conditions noted by investigating police officers. Review of the sample revealed that only 191 of the 300 crashes occurred in actual work zones, an error rate of 36 percent. Examining the 191 remaining reports identified crash patterns on two interstate locations:

- Nighttime road departure crashes associated with the use of temporary yellow reflective tabs (rather than permanent markings) for the left edge line (Interstate 10)
- Daytime rear-end crashes due to limited view of the work zone related to queues caused by horizontal and vertical curves (Interstate 15)

Some or all of the data inaccuracies observed can lead to misidentifying both high-crash locations and the type of work zone where the crashes occurred, making it difficult for engineers to develop appropriate countermeasures to reduce the crash potential of a work zone.

Changes made in 2009 to the Arizona police crash report form led to a significant decrease of 74 percent in the number of crashes flagged as work zone crashes in the ADOT ALISS database. This can create issues in conducting before and after safety evaluations that incorporate work zone crash data before and after 2009, which can lead to erroneous conclusions on the effectiveness of safety countermeasures in work zones.

It is currently difficult to identify the work zone set-up that was in place at the time a crash occurred within a work zone. Having the data for the work zone set-up would assist engineers in identifying field conditions that may contribute to the crash causation.

ADOT requires that a work zone review be performed when a work zone experiences a significant crash or a re-occurrence of vehicular crashes. However, discussions with ADOT personnel indicated that these reviews are not conducted on a regular basis, removing the opportunity to identify timely changes in the work zone traffic control to decrease the potential for additional crashes.

Of multiple recommendations offered in Chapter 5 for ADOT's consideration, the following key ones are generalized here:

- Improve the accuracy of crash reporting by revising the police crash report form.
- Standardize documentation of work zone traffic control information so as to verify field conditions at the time of a crash.
- Conduct work zone crash reviews and work zone safety reviews on construction projects.
- During temporary traffic control (TTC) training, stress adherence to ADOT's policy of installing permanent edge line markings before opening the far left lane on divided highways.
- In training, stress using various types of queue management to prevent daytime rear-end crashes.
- Expand the use of temporary intelligent transportation systems in work zones.
- Enhance traffic incident management planning for work zones.

CHAPTER 1. INTRODUCTION

The Arizona Department of Transportation (ADOT) defines a work zone in its "Arizona Crash Report Forms Instruction Manual" as an area of a trafficway with highway construction, maintenance, or utility work activities. A work zone is typically marked by signs, channelizing devices, barriers, pavement markings, and/or work vehicles. It extends from the first warning sign or flashing lights on a vehicle to the "End of Work" sign or the last traffic control device. A work zone may be for short or long durations and may include stationary or moving activities.

The "Arizona Crash Report Forms Instruction Manual" defines a work zone crash as a traffic crash in which the first event occurs within the boundaries of a work zone or on an approach to or exit from a work zone, resulting from an activity, behavior,r or control related to the movement of the traffic units through the work zone. This definition includes collision and non-collision crashes occurring within the signs or markings indicating a work zone or occurring on approach to, exiting from, or adjacent to work zones that are related to the work zone.

Work zones present conditions that can violate driver expectancy that can increase the risk of a traffic crash. NCHRP Report 500, Volume 17, A Guide for Reducing Work Zone Collisions (Antonucci et al 2005), provides the following work zone crash statistics from a national perspective:

- More than half of all fatal work zone crashes occurred during the day.
- Fatal work zone crashes occurred most often during the summer months.
- Almost 30 percent of fatal work zone crashes occurred on Interstate roadways.
- Almost 60 percent of fatal work zone crashes occurred on roads with a posted speed limit of 55 mph or greater.
- Single vehicle crashes accounted for over half of all fatal work zone crashes.
- Ten percent of all work zone fatalities were pedestrians and bicyclists.
- Heavy trucks were involved in more than 20 percent of fatal work zone crashes.
- Alcohol was involved in almost 40 percent of fatal work zone crashes.
- Rear-end fatal crashes were 2.7 times as common in work zones as in all fatal crashes.

Work zone crashes are typically associated with traffic queues caused by the work zone condition; for example, approximately 50 percent of total work zone crashes in Michigan are due to stopped or slowing traffic (Roelofs and Brookes 2014).

From the ADOT Accident Location Identification Surveillance System (ALISS) database, the most commonly quoted statistics for Arizona work zone crashes were that almost 30,000 crashes occurred in the 10 years ending in 2013. However, as discussed in Chapter 2, this study found an 11 percent error rate in those figures. Refined ALISS queries showed that work zone crashes in that 10-year period, 2004 through 2013, numbered closer to 27,000 crashes in Arizona work zones, as summarized in Table 1.

Table 1. Summary of Arizona Work Zone Crashes (2004-2013)

Year	Fatal Crashes	Incapacitating Injury Crashes	Total Crashes
2004	9	97	**3513**
2005	15	81	**3527**
2006	23	103	**4307**
2007	19	114	**4820**
2008	13	109	**4934**
2009	1	25	**1460**
2010	5	19	**1220**
2011	5	19	**1089**
2012	4	24	**795**
2013	8	21	**1006**
Total	**102**	**612**	**26671**

While work zone fatal crashes had decreased in recent years, they trended upward both nationally and in Arizona in 2014 and 2015. ADOT's 5-year Construction Program has shifted emphasis from constructing new roadways to preserving existing facilities, which will lead to more active work zones that must accommodate live traffic. This will lead to more road user exposure in work zones, which may lead to an increase in work zone related crashes. It is imperative to understand the contributing causes of work zone crashes to then be able to implement improvements to work zone traffic control design and management.

Recommendations for traffic safety improvements are frequently based on causes identified in police crash reports; therefore, it is important that crash reports reflect the actual contributing factors to the crash. However, current methods of reporting and recording crash data may fall short of this due to:

- Inaccurate or incomplete representation on the crash report of the crash characteristics due to:
    - Limited law enforcement expertise in accurate identification of contributing factors
    - Inconsistencies in crash reporting
    - Uncertainty about whether the crash occurred in a work zone
    - Lack of information about the work zone, including work zone limits
- Inaccurate or incomplete input of data from the crash report form into ADOT's ALISS crash database

Figure 1 illustrates the process of crash data from crash to input into the ALISS database.

Figure 1. Flow of Data from Crash Occurrence to ADOT's Crash Database

This research effort included analysis of crashes coded in the ALISS database as work zone crashes to determine accuracy of data and to identify contributing factors associated with work zone crashes. The research also compared information from work zone crash reports to the data in the ALISS database so as to identify inconsistencies.

CHAPTER 2. RESEARCH METHODOLOGY

The ADOT approach to work zone safety is defined in these core agency documents:

- Implementation Guidelines for Work Zone Safety & Mobility, Revised May 2009
- ENG 07-3, ADOT Work Zone Safety & Mobility Policy
- Arizona Supplement to the Manual on Uniform Control Devices, Revised January 2012
- Traffic Control Guidelines, Revised October 2011
- Construction Manual, January 2005

Crash data for the 10-year period from 2004 through 2013 were obtained from ADOT in Incident, Unit, and Person worksheets. The Incident worksheet was queried on the "WorkZoneRelatedFlag" field to identify crashes occurring in work zones. The Unit worksheet was queried on the "Road Condition" field to identify additional characteristics of the work zone, including:

- Lane closure
- Lane shift/closure
- Work on shoulder or median
- Intermittent or moving work
- Work zone other
- Workers present

The initial research plan included analyzing 100 work zone crash reports and comparing the crash data with the actual setup of the work zone at the time of each crash. It was anticipated that the Temporary Traffic Control (TTC) plans for the 100 crash locations would be readily available to identify contributing factors in work zone crashes. Other documentation might also be examined to determine the actual work zone layout at the time of the crashes:

- ***Work Zone Crash Reviews:*** When a work zone is the scene of a significant crash or repeated crashes, a work zone review is supposed to be performed by the resident engineer and/or the regional traffic engineer.
- ***Photographs:*** Pictures taken during the crash investigation, documenting the crash scene and of the work zone setup
- ***Videotapes:*** Videotapes of active work zones taken when inspected by construction operations traffic control coordinators
- ***Inspector Daily Diaries:*** Inspectors responsible for traffic control setup and monitoring make daily entries related to work zone setup, including notes regarding any crashes that occurred.

At the start of the data collection process, ADOT personnel indicated that district offices institutional knowledge would be required to identify roadwork projects and their Transportation Accounting System (TRACS) numbers to assist in locating TTC plans. Typically, these TTC plans are designed and implemented prior to road construction and maintenance activities and, due to field revisions, may not accurately reflect the traffic control in the field at the time of a crash.

Attempts were made to obtain work zone traffic control information (TTC plans, photos, reports from inspectors) for the locations of the crashes for which crash reports were obtained. ADOT Construction Operations personnel conducted electronic searches and met with ADOT Tucson District staff to obtain additional information on the work zones. Challenges in finding this information included:

- Many TTC plans examined didn't have ADOT TRACS numbers, making it difficult to match the plans to the project location.
- Only 5 out of 10 TTC plans reviewed had associated inspector diaries.
- Inspector diaries did not provide information on the crashes.
- Some TTC plans didn't reference the specific traffic control setup that was in place at the time of the crash.
- TTC plans change in the field on a frequent basis, making it difficult to accurately identify the conditions at the time of the crash.
- Work zone crash reviews are not conducted on a regular basis.
- Inconsistency exists among ADOT districts in documenting the field conditions in a work zone after a crash occurs.

Dealing with the difficulties in obtaining accurate traffic control plans moved the study in a different direction. It was determined that even if specific traffic control information could be obtained after much effort, the information would probably not accurately show field conditions at the time of each crash. The original research methodology — comparing 100 work zone crashes to the traffic control plans — was changed. The revised methodology would analyze 300 work zone police crash reports by relying more heavily on the reporting officer's narrative for information on the work zone setup. The research focus changed to:

- Improving accuracy of identifying crash locations and characteristics by analyzing crash reports and the ALISS database
- Identifying contributing factors from police crash reports

Crash reports were obtained from ADOT's Traffic Records Section for the following types of crashes flagged as occurring in work zones on ADOT facilities from 2011 through 2013:

- All fatal crashes (18 crashes)
- All incapacitating injury crashes (33 crashes)
- A mix of non-incapacitating injury and possible injury crashes, with an emphasis on selecting crash cluster locations (249 crashes)

CHAPTER 3. ANALYSIS FINDINGS

Preliminary Analysis of Flawed Data

ADOT ALISS crash data for 2004 through 2013 were queried for work zone-related crashes and analyzed. It was learned that approximately 11 percent of these 29,877 crashes were not work zone related, so the database queries were refined and re-analyzed.

Note that the initial queries that yielded the inaccurate data are the queries currently used for the ALISS database. Highlights of the initial crash data included:

- 29,877 work zone crashes (2.5 percent of all crashes in Arizona)
- 32 percent of work zone crashes occur on ADOT roads
- 131 fatal work zone crashes (1.5 percent of all fatal crashes)
- 49 percent of fatal work zone crashes occur on ADOT roads
- Young drivers over-represented – 26 percent of crashes (11 percent of licensed drivers)
- 58 percent decrease in work zone crashes after 2008
    - Average of 4,220 crashes/yr for 2004-2008
    - Average of 1,755 crashes/yr for 2009-2013

Reasons for this decrease in work zone crashes after 2008 may include:

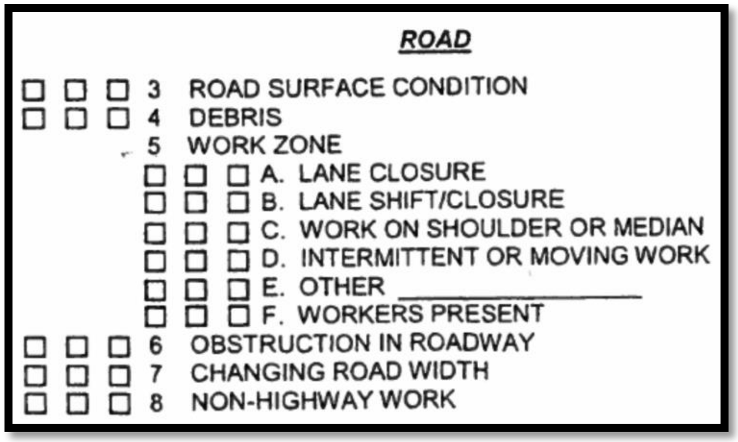
- Change in Crash Report Form on January 1, 2009 (old form listed “under construction” and “under repair” within the “Unusual Road Condition” section; new form lists “work zone” check boxes within the “Contributing Circumstances – Road” section
- Overall crash decrease due to impacts of recession on vehicle miles traveled
- Possible decrease in number of active work zones

Further Errors in Data

Review of the data from fatal and incapacitating injury work zone crash reports provided by ADOT showed that the majority of these crashes did not occur in work zones. The crashes were coded as “work zone related” in the ALISS database, but review of the original police crash reports indicated that:

- 12 of 18 fatal crashes were incorrectly flagged as work zone crashes
- 19 of 33 incapacitating injury crashes were incorrectly flagged as work zone crashes

This is an error rate of 61 percent. Review of the 31 crashes inaccurately coded as work zone crashes revealed that the errors occurred in the “Road Condition” field, which uses information from the “Contributing Circumstances – Road” section of the police crash report form shown in Figure 2.



ROAD

☐ ☐ ☐ 3 ROAD SURFACE CONDITION
☐ ☐ ☐ 4 DEBRIS
5 WORK ZONE
☐ ☐ ☐ A. LANE CLOSURE
☐ ☐ ☐ B. LANE SHIFT/CLOSURE
☐ ☐ ☐ C. WORK ON SHOULDER OR MEDIAN
☐ ☐ ☐ D. INTERMITTENT OR MOVING WORK
☐ ☐ ☐ E. OTHER ______________
☐ ☐ ☐ F. WORKERS PRESENT
☐ ☐ ☐ 6 OBSTRUCTION IN ROADWAY
☐ ☐ ☐ 7 CHANGING ROAD WIDTH
☐ ☐ ☐ 8 NON-HIGHWAY WORK

Figure 2. Arizona Police Crash Report Form - Contributing Circumstances

These errors included:

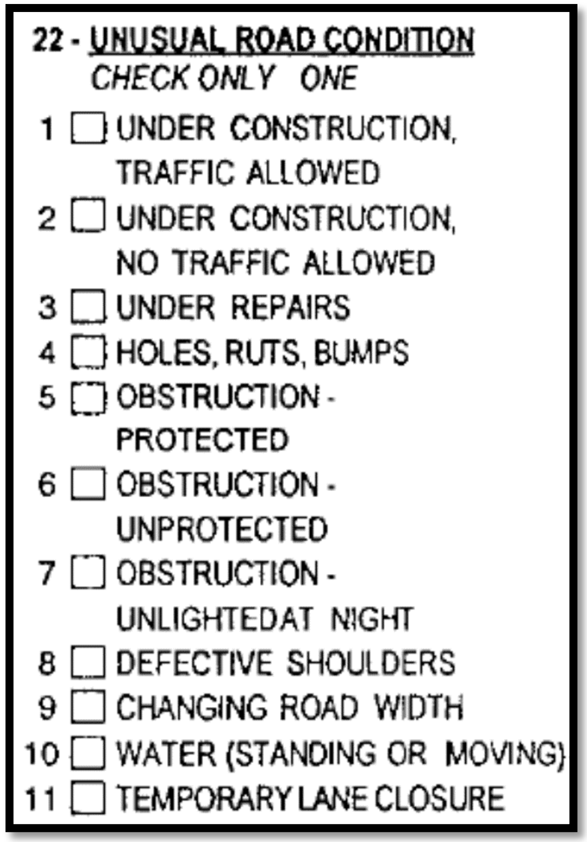
- 26 crashes coded as "obstruction in roadway" which included animal, downed motorcycle, pedestrian, abandoned vehicle, vehicle from prior crash, rock, and bicyclist
- 4 crashes coded as "other" under "work zone" which included 3 with water on the road and 1 weather-related
- 1 crash coded as "intermittent or moving work" which was actually a dust storm

This preliminary analysis of crash reports indicated that 84 percent of the coding error was due to the contributing circumstance of "obstruction in roadway" being flagged as work zone related. ADOT Traffic Records Section staff indicated that this specific error could be readily addressed within the ALISS crash database. Other errors may need to be addressed with a future revision to the crash report form.

After discovering these errors, a more detailed review of the ALISS database was conducted for the 29,877 crashes that were flagged as work zone crashes. Up to 14 percent of the 29,877 crashes may be incorrectly flagged as work zone crashes based on the following entries in the "Road Condition" field:

- 1,965 "obstruction in roadway"
- 1,436 "work zone other"
- 127 "road surface condition"
- 185 "debris"
- 72 "changing road width"
- 308 "no contributing circumstance"
- 222 "no data"

These entries do not appear in the database for crashes occurring prior to 2009, which is when the Arizona police crash report form was revised. Figure 3 shows the "Unusual Road Condition" section of the pre-2009 Arizona police crash report form.



22 - UNUSUAL ROAD CONDITION
CHECK ONLY ONE

1 ☐ UNDER CONSTRUCTION, TRAFFIC ALLOWED
2 ☐ UNDER CONSTRUCTION, NO TRAFFIC ALLOWED
3 ☐ UNDER REPAIRS
4 ☐ HOLES, RUTS, BUMPS
5 ☐ OBSTRUCTION - PROTECTED
6 ☐ OBSTRUCTION - UNPROTECTED
7 ☐ OBSTRUCTION - UNLIGHTEDAT NIGHT
8 ☐ DEFECTIVE SHOULDERS
9 ☐ CHANGING ROAD WIDTH
10 ☐ WATER (STANDING OR MOVING)
11 ☐ TEMPORARY LANE CLOSURE

Figure 3. Arizona Police Crash Report Form (Pre-2009) - Contributing Circumstances

Data from Refined ALISS Queries

To address the inaccurately flagged work zone crashes, the crash data in the ALISS database were filtered on the following "Road Condition1" and "Road Condition2" entries:

- Lane closure
- Lane shift/closure
- Work on shoulder or median
- Intermittent or moving work
- Workers present
- Work zone other

Since the "Work Zone Other" road condition was also shown to be in error, crashes with this code were further filtered on "Road Condition 2" equal to one of the first 5 bulleted items above or "Traffic Control Device" equal to "Warning Sign" or "Person." This filtering produced 26,671 work zone crashes, a decrease of 11 percent from the 29,877 crashes currently flagged in the "Work Zone Related" field.

This data shows that during the 10 years from 2004 through 2013 in Arizona, there were 26,671 work zone crashes (2.2 percent of all Arizona crashes) and 102 fatal work zone crashes (1.2 percent of all fatal

Arizona crashes). The frequency of crashes flagged as work zone crashes dropped beginning in 2009, after the Arizona police crash report form was revised. The annual work zone crash average dropped 74 percent after 2008: from an average of 4,220 crashes per year (2004-2008) to an average of 1,114 crashes per year (2009-2013).

The change in work zone crash frequency occurred over the 5-year period from 2009 through 2013; the filtered, or scrubbed, data did not impact the crash frequencies for 2004 through 2008. The overall decrease in work zone crash frequency for 2009 through 2013 (pre-scrubbed to post-scrubbed) is approximately 37 percent. This 5-year period is considered more accurate due to the additional scrubbing of data; the date shows that there were 5,570 work zone crashes (1.1 percent of all crashes) and 23 fatal crashes (0.6 percent of all fatal crashes) in work zones in Arizona. Crash analysis findings for the scrubbed data are shown in Tables 2 through 5 and Figures 4 through 9.

Table 2. Arizona Work Zone Crashes by Year and Injury Severity

Year	Fatal Crash	Incapacitating Injury Crash	Non- Incapacitating Injury Crash	Possible Injury Crash	No Injury Crash	Total Crashes
2004	9	97	384	592	2431	3513
2005	15	81	344	522	2565	3527
2006	23	103	420	716	3045	4307
2007	19	114	436	746	3505	4820
2008	13	109	478	737	3597	4934
2009	1	25	139	203	1092	1460
2010	5	19	104	163	929	1220
2011	5	19	133	173	759	1089
2012	4	24	79	104	584	795
2013	8	21	98	131	748	1006
Total	**102**	**612**	**2615**	**4087**	**19255**	**26671**

Table 3. Arizona Work Zone Crashes by Light Condition and Injury Severity (2004-2013)

Light Condition	Fatal Crash	Incapacitating Injury Crash	Non-Incapacitating Injury Crash	Possible Injury Crash	No Injury Crash	Total Crashes
Daylight	55	389	1714	3108	14455	19721
Dark	43	190	768	813	3934	5748
Dawn	4	32	117	152	773	1078
Dusk	0	1	12	12	69	94
Unknown	0	0	4	2	24	30
Total	**102**	**612**	**2615**	**4087**	**19255**	**26671**

Table 4. Arizona Work Zone Crashes by Route Type and Injury Severity (2004-2013)

Route Type	Fatal Crash	Serious Injury Crash	Minor/No Injury Crash	Total Crashes
US/State Route	24	121	4075	4220
Interstate	16	77	3667	3760
Non-ADOT	62	414	18215	18691
Total	102	612	25957	26671

Table 5. Arizona Work Zone Crashes by Crash Type and Injury Severity (2004-2013)

Crash Type	Fatal Crash	Incapacitating Injury Crash	Non-Incapacitating Injury Crash	Possible Injury Crash	No Injury Crash	Total Crashes
Rear End	17	178	982	2229	7649	11055
Sideswipe Same Direction	1	29	166	384	4313	4893
Single Vehicle	29	139	495	316	2652	3631
Angle	13	79	386	553	2449	3480
Left Turn	9	68	324	364	1076	1841
Other	9	18	60	50	427	564
Rear To Side	0	0	4	11	360	375
Head On	16	26	39	42	83	206
Sideswipe Opposite Direction	1	9	13	23	158	204
Pedestrian	6	43	78	50	18	195
Bicyclist	1	23	64	59	31	178
Unknown	0	0	3	2	24	29
Rear To Rear	0	0	1	4	15	20
Total	**102**	**612**	**2615**	**4087**	**19255**	**26671**

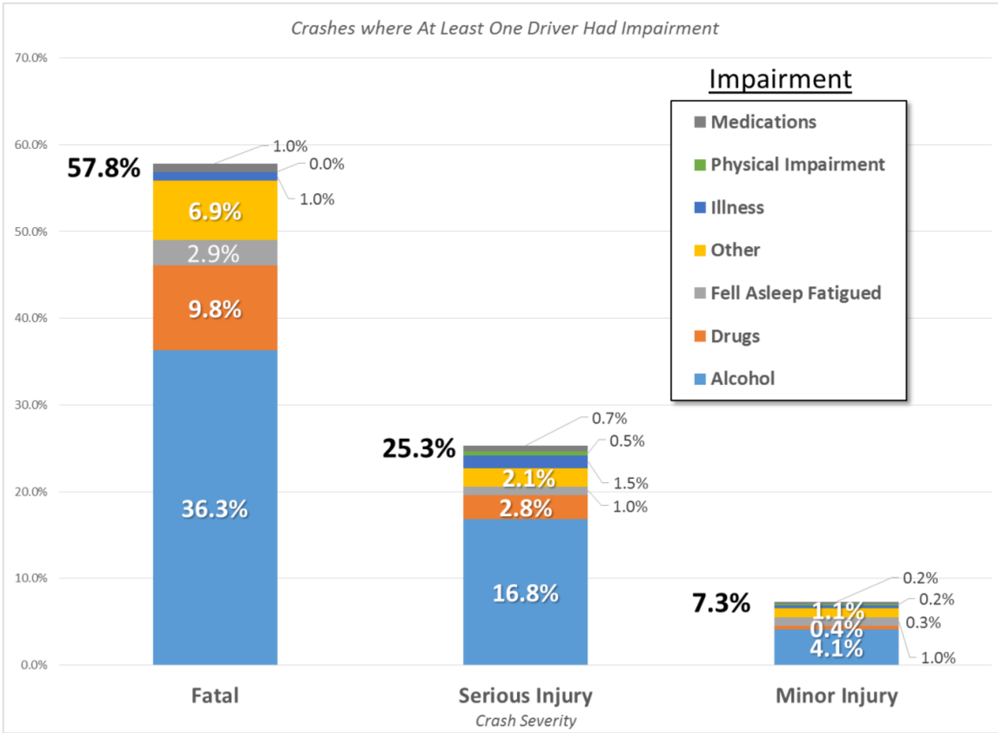


Figure 4. Arizona Work Zone Crashes Involving Driver Impairment (2004-2013)

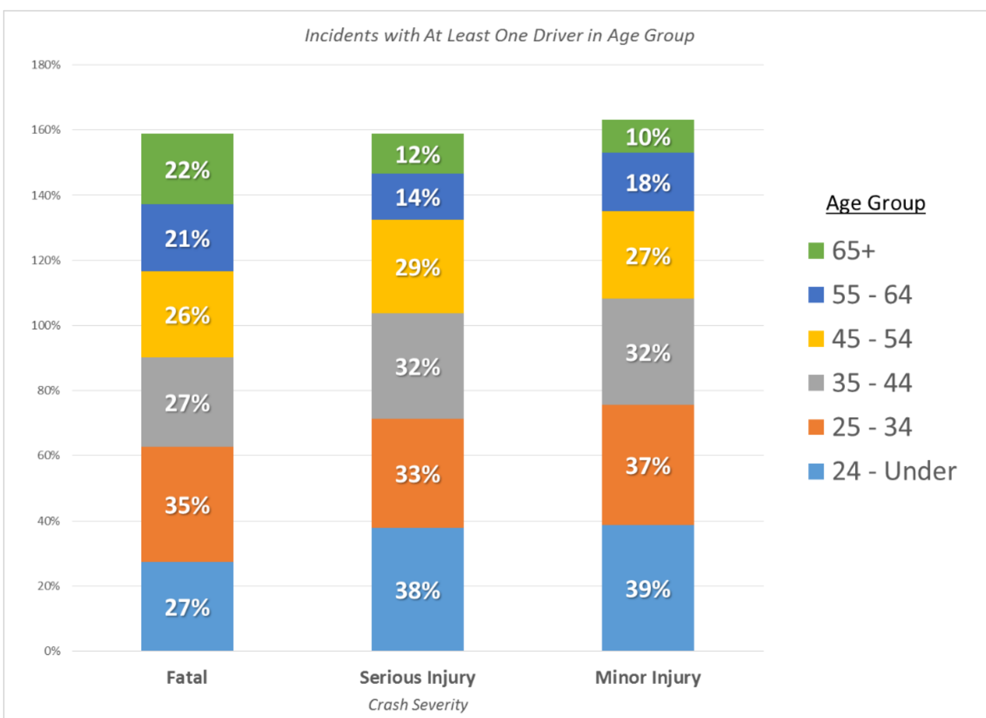


Figure 5. Arizona Work Zone Crashes by Age Group and Severity (2004-2013)

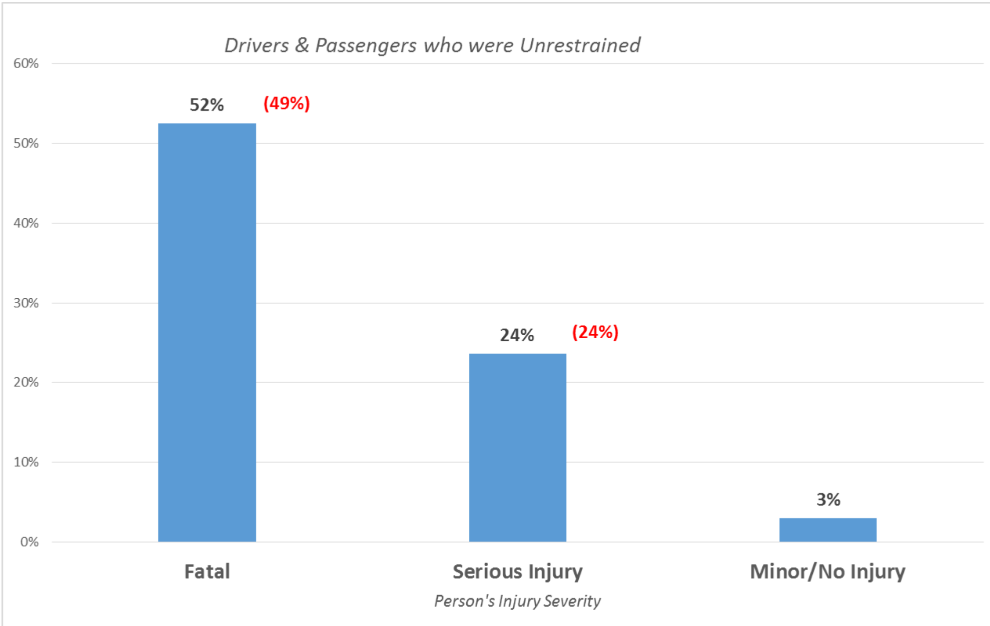


Figure 6. Arizona Work Zone Crashes Involving Lack of Restraint (2004-2013)

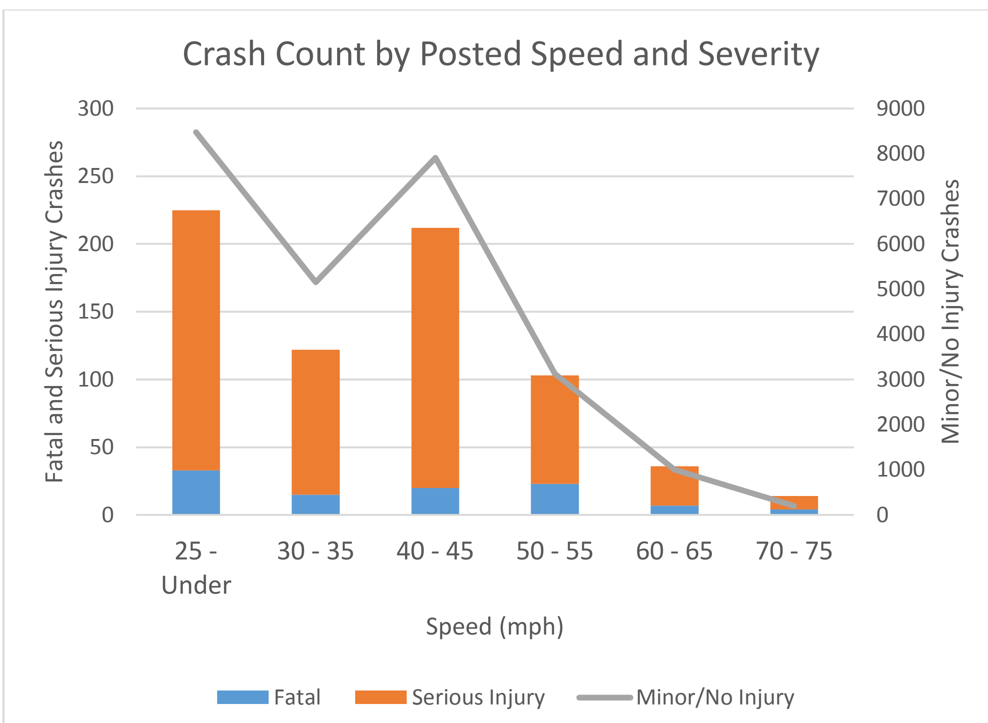


Figure 7. Arizona Work Zone Crashes by Posted Speed and Severity (2004-2013)

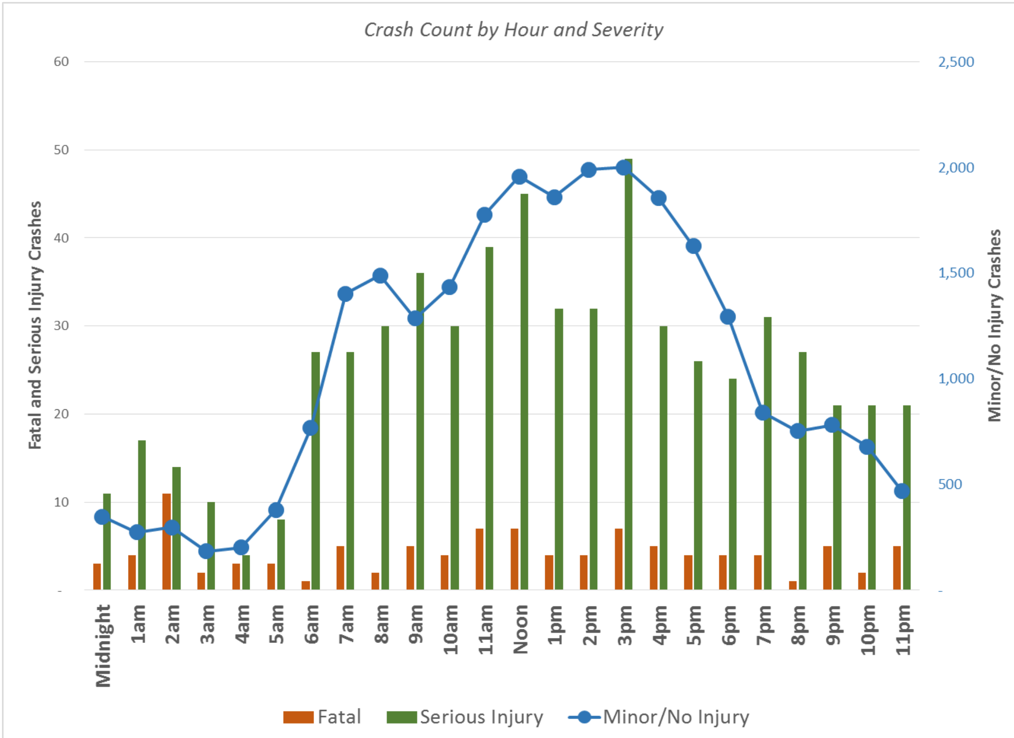


Figure 8. Arizona Work Zone Crashes by Hour and Severity (2004-2013)

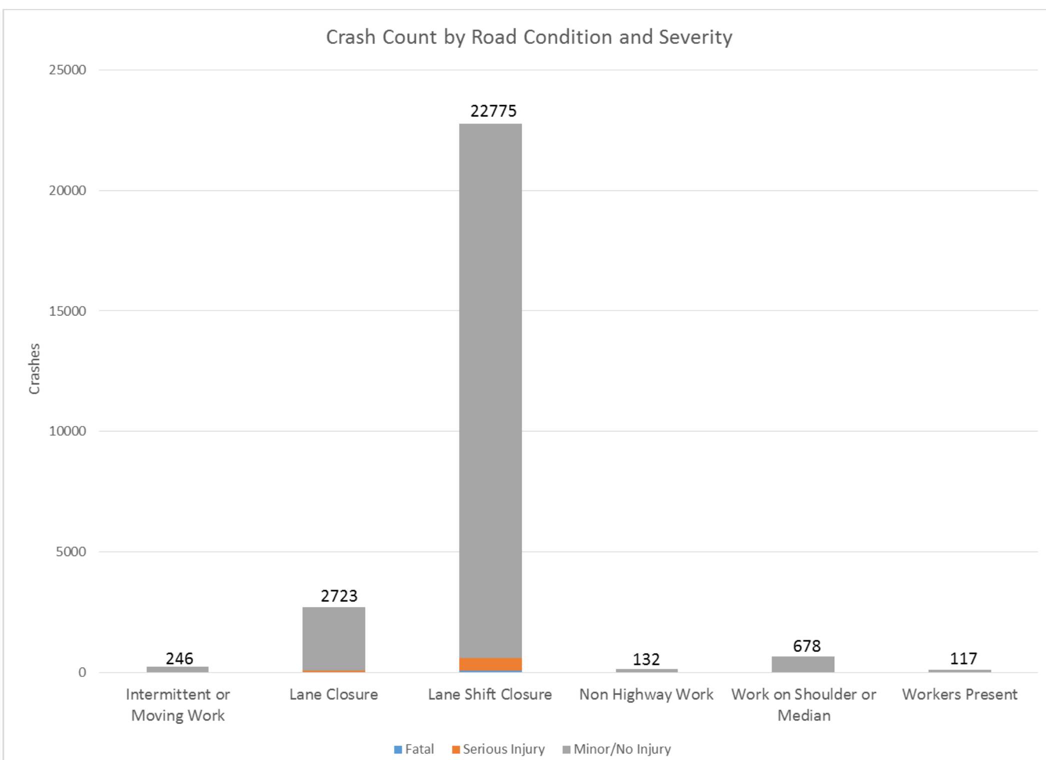


Figure 9. Arizona Work Zone Crashes by Road Condition and Severity (2004-2013)

Analysis of Crash Reports

To discover field condition details at the time of work zone-related crashes, the researchers wanted to examine the police reports filed for specific work zone crashes. This involved examining 300 crash reports obtained from ADOT's Traffic Records Section for the following work zone crashes occurring on ADOT facilities from 2011 through 2013:

- All fatal crashes (18 crashes)
- All incapacitating injury crashes (33 crashes)
- A mix of non-incapacitating injury and possible injury crashes, with an emphasis on selecting crash cluster locations (249 crashes)

Review of the 300 crash reports revealed that only 191 of the crashes occurred in actual work zones, an error rate of 36 percent that included these errors:

- Crashes coded as "obstruction in roadway" were not in work zones (64 crashes).
- Crashes coded as "work zone other" were not in work zones, including 7 secondary crashes due to queues from previous crashes (27 crashes).

The corrected sample of 191 crash reports for work zone crashes occurring on ADOT facilities from 2011 through 2013 showed that:

- The fatal work zone crashes numbered 6, not 18.
- The serious injury crashes in work zones numbered 14, not 33.
- The minor injury crashes in work zones numbered 171, not 249.

For those work zone crashes where an officer had listed the estimated driving speed for the at-fault vehicle, it was found that:

- 24 percent of the vehicles were estimated to be driving at the posted speed limit.
- 52 percent were estimated at under the posted speed limit (average 22 mph under).
- 24 percent were estimated at over the posted speed limit (average of 14 mph over).

Tables 6 through 8 and Figures 10 through 16 highlight the findings from the review of the three-year crash report sample.

Table 6. Sample Arizona Work Zone Crashes by Route and Severity (2011-2013)

Road Name	Fatal Crash	Serious Injury Crash	Minor Injury Crash	Total Crashes
Interstate 10	3	5	44	**52**
State Route 101	1	2	48	**51**
Interstate 17		1	10	**11**
State Route 202			10	**10**
US Highway 60			9	**9**
State Route 303			7	**7**
Interstate 8	1		5	**6**
State Route 95			5	**5**
Interstate 40			4	**4**
Interstate 15			3	**3**
State Route 260			2	**2**
State Route 389			2	**2**
State Route 51			2	**2**
State Route 69			2	**2**
State Route 86			2	**2**
State Route 92			2	**2**
US Highway 95			2	**2**
State Route 85		1	1	**2**
US Highway 160		1	1	**2**
US Highway 93		1	1	**2**
Interstate 19			1	**1**
State Alternate 89			1	**1**
State Route 177			1	**1**
State Route 64			1	**1**
State Route 77			1	**1**
State Route 80			1	**1**
State Route 87			1	**1**
State Route 90			1	**1**
US Highway 191			1	**1**
State Business 40		1		**1**
State Route 264	1			**1**
State Route 347		1		**1**
State Route 72		1		**1**
Total	**6**	**14**	**171**	**191**

Table 7. Sample Arizona Work Zone Crashes by Collision Manner and Severity (2011-2013)

Collision Manner	Fatal	Incapacitating Injury	Non Incapacitating Injury	Possible Injury	Total
Rear End	3	11	60	58	132
Single Vehicle	3	2	19	5	29
Sideswipe Same Direction		1	7	5	13
Angle			4	4	8
Other			2	1	3
Left Turn			1	1	2
Sideswipe Opposite Direction				2	2
Head On			1		1
Pedestrian			1		1
Total	**6**	**14**	**95**	**76**	**191**

Table 8. Sample Arizona Work Zone Crashes by Light Condition and Severity (2011-2013)

Light Condition	Fatal	Incapacitating Injury	Non Incapacitating Injury	Possible Injury	Total
Daylight	4	9	58	54	125
Dark	2	4	34	20	60
Dusk		1		2	3
Dawn			3		3
Total	**6**	**14**	**95**	**76**	**191**

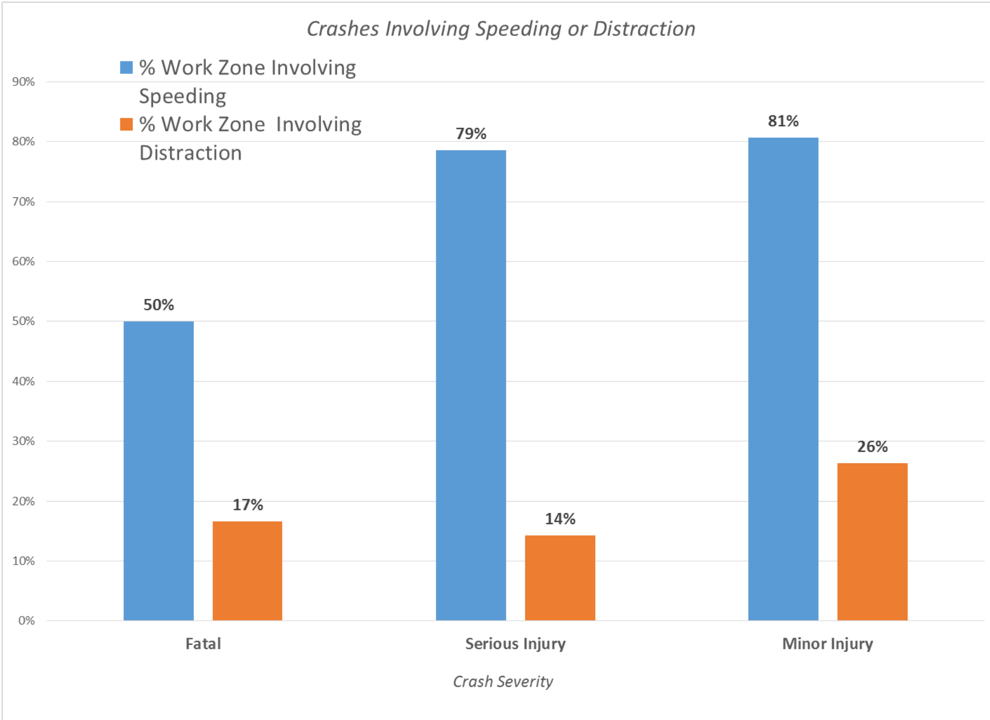


Figure 10. Sample Arizona Work Zone Crashes Involving Speeding or Distraction (2011-2013)

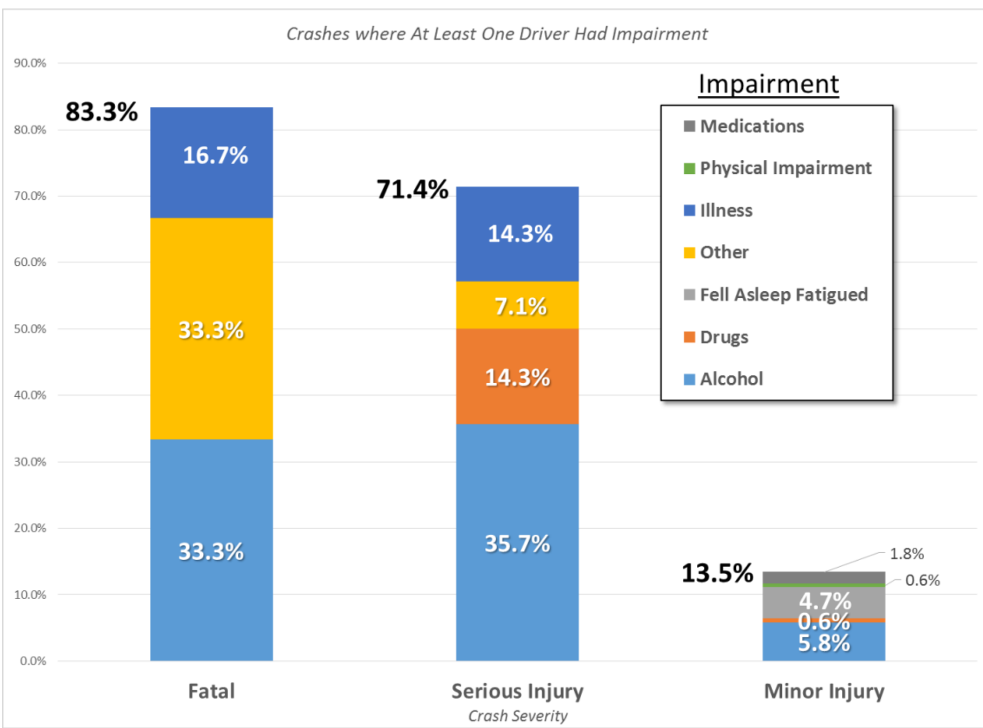


Figure 11. Sample Arizona Work Zone Crashes Involving Driver Impairment (2011-2013)

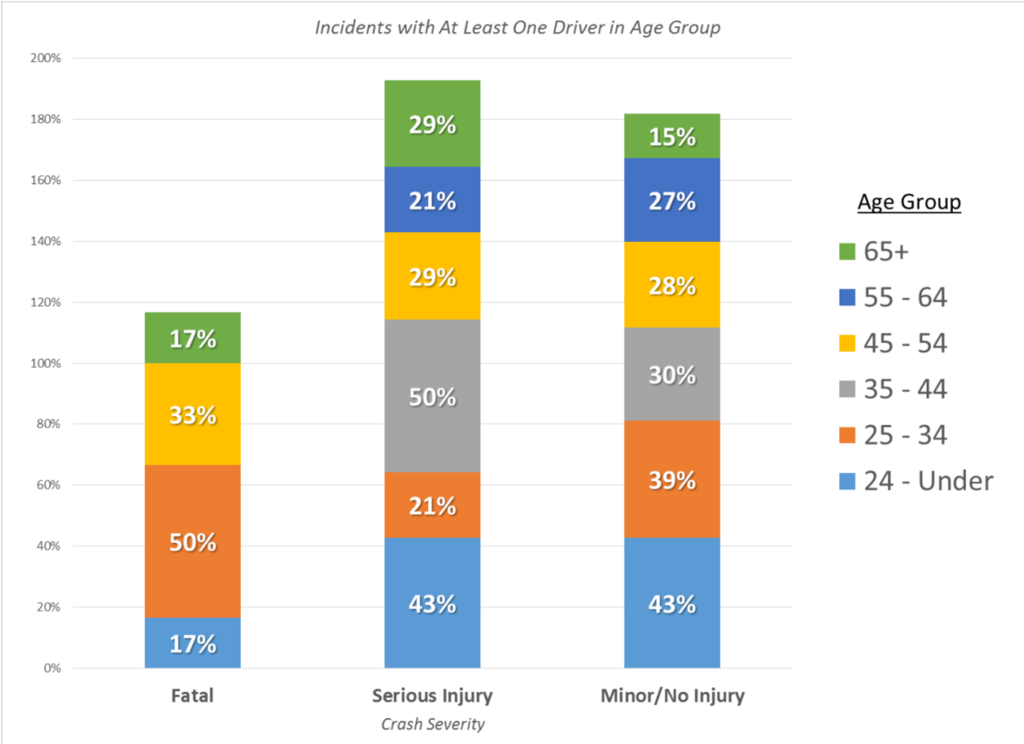


Figure 12. Sample Arizona Work Zone Crashes by Age Group (2011-2013)

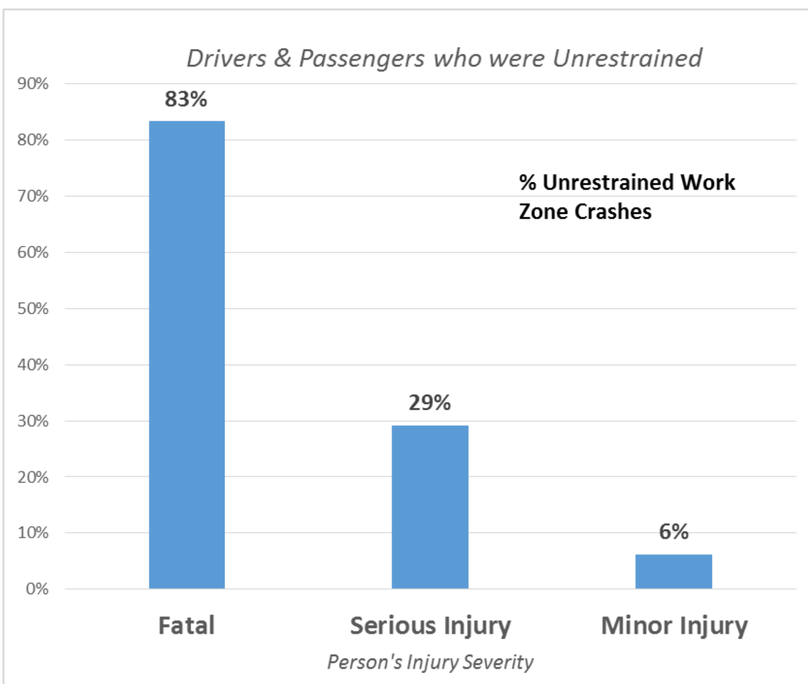


Figure 13. Sample Arizona Work Zone Crashes Involving Lack of Safety Restraint (2011-2013)

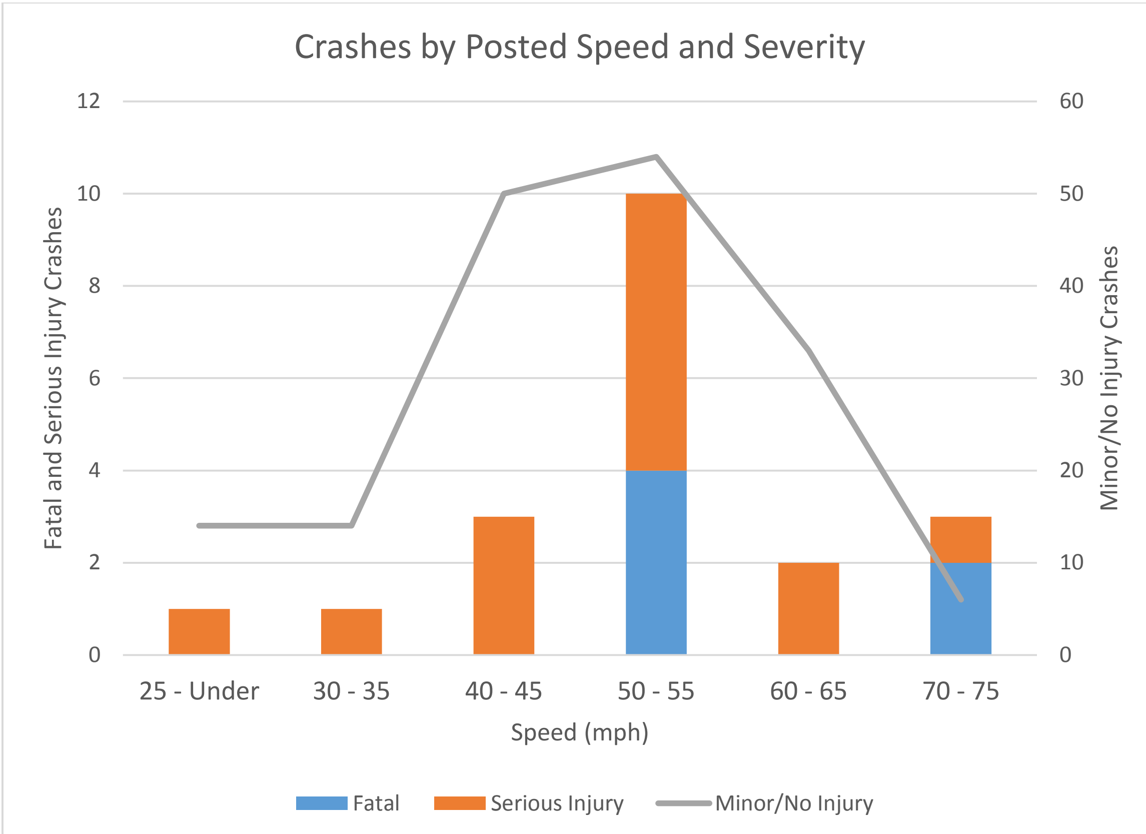


Figure 14. Sample Arizona Work Zone Crashes by Posted Speed and Severity (2011-2013)

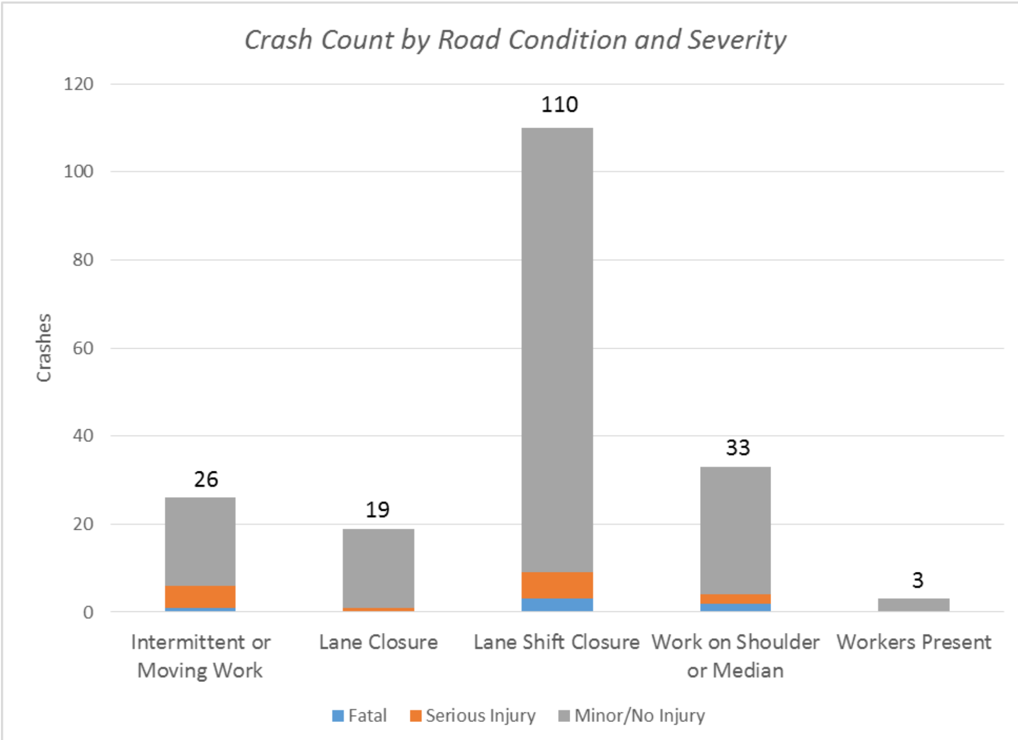


Figure 15. Sample Arizona Work Zone Crashes by Road Condition and Severity (2011-2013)

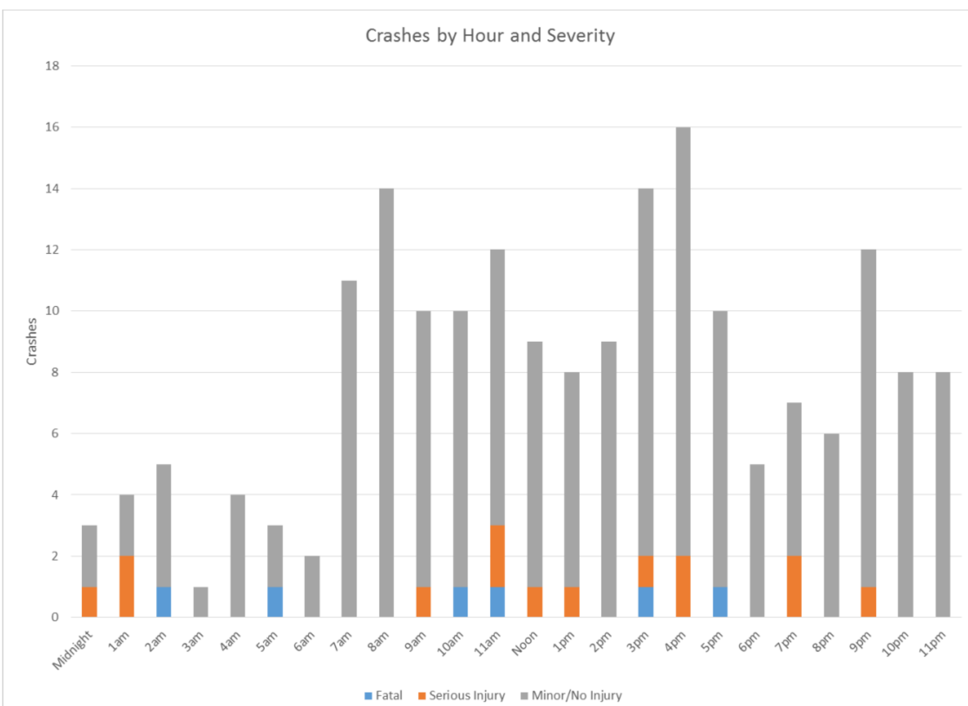


Figure 16. Sample Arizona Work Zone Crashes by Hour and Severity (2011-2013)

Location-Specific Crash Patterns

Further analysis of details in the sample police crash reports identified two work zone locations with a pattern of crashes. On Interstate 10 (I-10) between mileposts 199.7 and 203.9, from September 22 to October 22, 2011, there were three nighttime run-off-road left, rollover crashes with the following conditions and characteristics:

- Two lanes existed each direction, with an active construction project to widen to three lanes in each direction.
- Drivers indicated they were confused by the yellow reflective tabs along the left shoulder (there were no yellow edgeline markings) and directed their vehicles to the left thinking it was a lane.
- The posted speed limit was 65 mph, and the estimated vehicle speeds were 65 mph, 62 mph, and unknown.
- One vehicle vaulted the concrete barrier, landing in the opposite-direction lane.
- One driver was cited for speed too fast for conditions; the other two drivers were not cited.
- The crashes occurred in the same work zone, but each report noted a different road condition:
    - Intermittent or moving work
    - Work on shoulder or median
    - Other

The second location with a crash pattern was on Interstate 15 (I-15) between mileposts 21.1 and 25.5. There, between July 16 and September 30, 2012, three daytime rear-end crashes occurred with the following conditions and characteristics:

- One of the two travel lanes was closed.
- The drivers claimed they did not see the stopped traffic due to horizontal and vertical curves; the lane closure was on the far side of the curves.
- The posted speed limit was 45 mph, and estimated vehicle speeds were 60 mph, 45 mph, and unknown.
- One driver was cited for inattention.
- Two drivers were cited for inattention and speed too fast for conditions.
- Two crash reports listed road conditions as lane closure and workers present.
- One crash report noted lane closure and lane shift/closure.

A fourth similar daytime crash on I-15 occurred on July 28, 2013, at milepost 12.7. The crash had the following conditions and characteristics:

- A lane closure created 3-mile-long vehicle queues.
- The posted speed limit was 55 mph, and the estimated vehicle speed was 35 mph.
- The road condition was listed as “other.”

Review of Arizona Police Crash Report Form

Some of the errors in identifying work zone crashes may be related to the format of the Arizona police crash report form. The Arizona Crash Report Forms Instruction Manual defines a work zone crash as “A traffic crash in which the first event occurs within the boundaries of a work zone or on an approach to or exit from a work zone, resulting from an activity, behavior or control related to the movement of the traffic units through the work zone. Includes collision and non-collision crashes occurring within the signs or markings indicating a work zone or occurring on approach to, exiting from or adjacent to work zones that are related to the work zone.” Figure 17 shows an excerpt from the manual defining the Work Zone options to be listed on the crash report form.

A. Lane Closure - A reduction in the number of lanes but traffic is not diverted across median or onto shoulder.

B. Lane Shift/Crossover - There is no reduction in number of lanes but traffic is shifted or diverted into opposing traffic lanes, median or shoulder.

C. Work on Shoulder or Median - There is no reduction in roadway width but work is being performed immediately adjacent to the roadway.

D. Intermittent or Moving Work - Pothole patching, lane marking or other maintenance or non-fixed location work.

E. Other - If “Other” is used, list on the line provided or explain in the narrative.

F. Workers Present - Construction or maintenance workers physically present in the work zone at the time of the crash.

Figure 17. Work Zone Instructions for Arizona Crash Report Form

Item B, Lane Shift/Crossover, is erroneously listed as Lane Shift/Closure on the actual crash report form (Figure 18). Lane Shift/Closure is the most frequently cited work zone condition in the ALISS database; approximately 85 percent of the crashes flagged as work zone crashes showed this entry.

ROAD

☐ ☐ ☐ 3 ROAD SURFACE CONDITION
☐ ☐ ☐ 4 DEBRIS
5 WORK ZONE
☐ ☐ ☐ A. LANE CLOSURE
☐ ☐ ☐ B. LANE SHIFT/CLOSURE
☐ ☐ ☐ C. WORK ON SHOULDER OR MEDIAN
☐ ☐ ☐ D. INTERMITTENT OR MOVING WORK
☐ ☐ ☐ E. OTHER ____________
☐ ☐ ☐ F. WORKERS PRESENT
☐ ☐ ☐ 6 OBSTRUCTION IN ROADWAY
☐ ☐ ☐ 7 CHANGING ROAD WIDTH
☐ ☐ ☐ 8 NON-HIGHWAY WORK

Figure 18. Arizona Crash Report Form with Lane Shift/Closure Erroneous Listing

CHAPTER 4. PRACTICES IN OTHER STATES

Practices in other states demonstrate that opportunities exist to further enhance work zone safety.

Iowa's Integrated Temporary Intelligent Transportation Systems

The Iowa Department of Transportation (DOT) is a best practice state for work zone safety, especially as it pertains to monitoring traffic and responding to work zone crashes. Iowa has a standard construction specification that requires contractors to provide temporary intelligent transportation systems (ITS) capable of integration into the central operations software at the traffic management centers (TMCs). This allows the TMC to monitor traffic conditions in and around work zones. The use of temporary ITS monitoring of work zones can decrease the length of time to detect and verify incidents, thus contributing to quickly clearing crashes (Simodynes 2014).

Iowa DOT uses wireless connectivity and construction special specifications to help alert drivers to queues and to alert TMCs to emerging safety concerns. The figure below shows how the use of portable variable message signs (PVMS), portable detectors, and portable CCTV cameras proactively monitor traffic approaching a work zone.

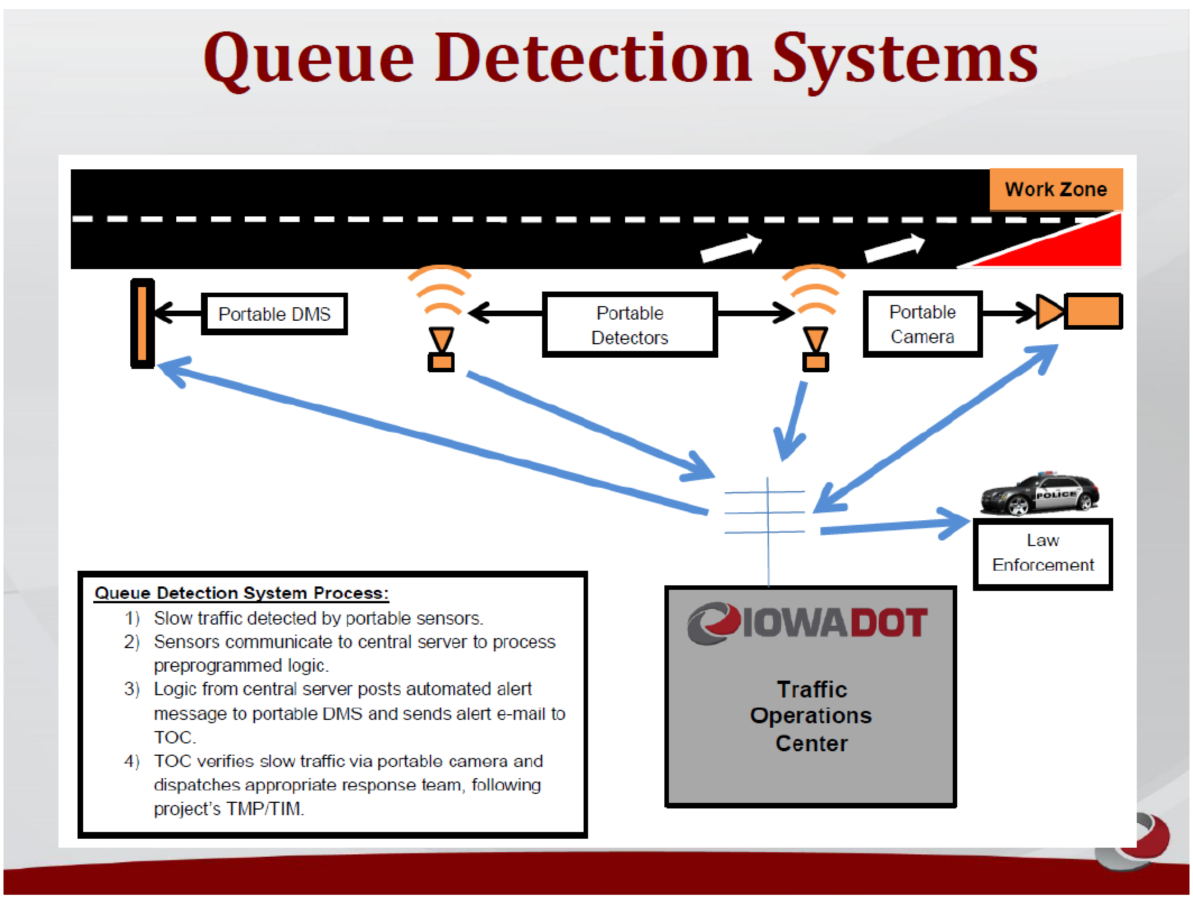


Figure 19. Iowa DOT Queue Detection Systems

This temporary ITS is not only important for real-time information gathering, but also gathers data that enables predictive operations in the future. Collecting queue information near work zones can lead to better predictions in the future.

Temporary ITS needs, such as queue detection, are captured as part of a stand-alone traffic incident management (TIM) report. The figure below shows how each plan sheet from the construction drawing set is overlaid with TIM and ITS information. The links at the bottom of each sheet provide links to:

- An overall map of the project
- Critical areas to monitor for diversion decision making
- Incident response options under moderate and low volume conditions
- Agency contacts
- DMS messages to be posted
- Traffic control options at adjacent intersections

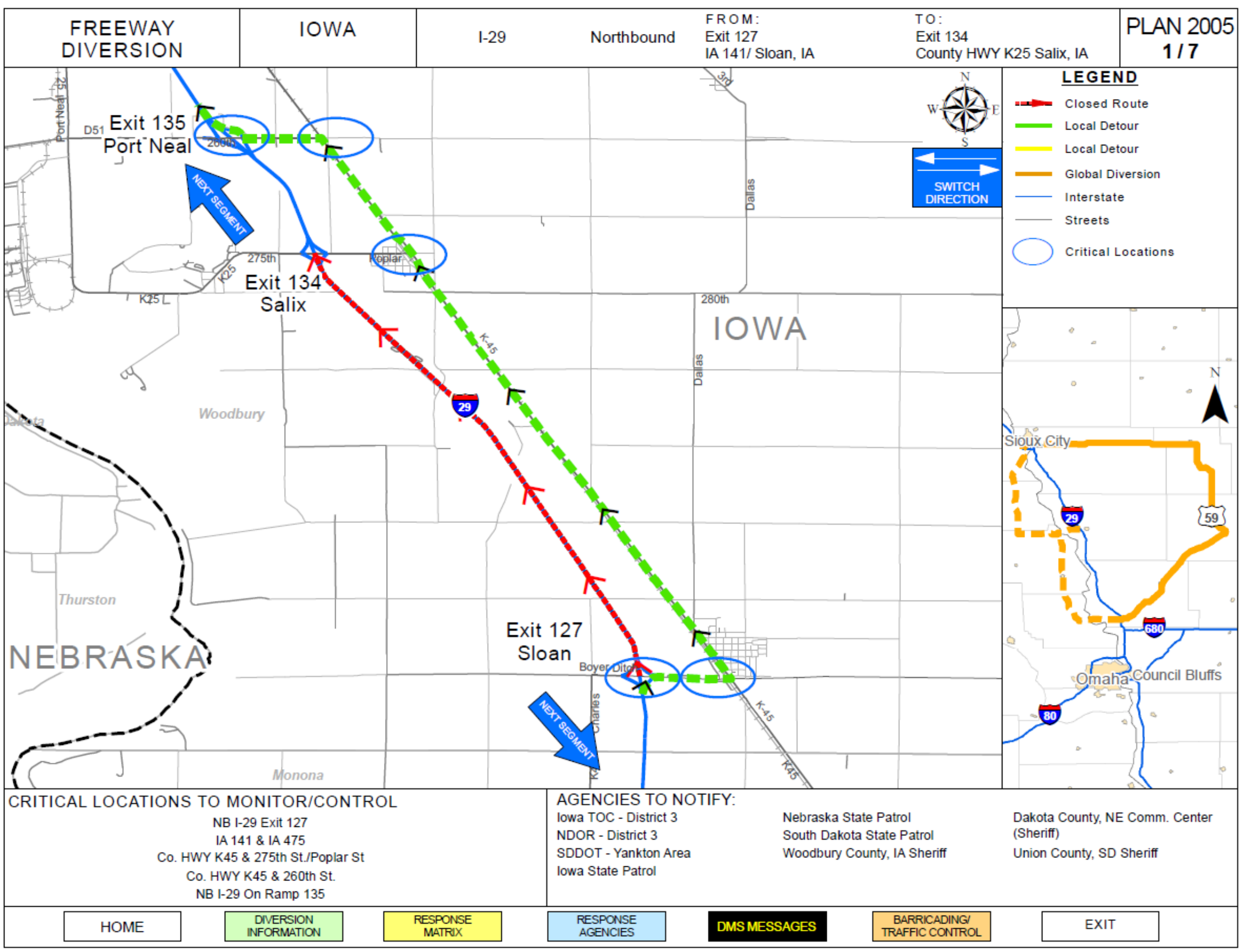


Figure 20. Iowa Traffic Critical Project Plan Overlay

Tennessee's Queue Management and Secondary Crashes

The Tennessee Department of Transportation (TDOT) uses a strategy called "Protect the Queue" to guard against secondary crashes. Secondary crashes are typically more lethal than initial crashes. TDOT regularly emphasizes to its employees and emergency partners the importance of protecting drivers in the queue through awareness/outreach and by providing training on effective queue management techniques. In addition, each of TDOT's 12 districts dispatch specially equipped "Protect the Queue" trucks when advised of non-recurring traffic queues caused by construction, maintenance, special events, or roadway incidents (FHWA 2015).

Florida's Transportation Systems Management and Operations

Transportation systems management and operations (TSMO) is a set of strategies to anticipate and manage traffic congestion, and minimize unpredictable causes of service disruption and delay, thus maintaining roadway capacity while improving reliability and safety. The Florida Department of Transportation (DOT) has developed a TSMO program over the years. The Florida DOT TSMO program focuses on work zone management, including:

- Automated speed enforcement
- Coordination with traffic management centers
- Focused training
- Peer exchanges

Florida uses the following diagram to present the concept during outreach efforts.

Figure 21. Florida DOT TSMO Outreach Graphic

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Work zone crashes in Arizona make up approximately 2 percent of all crashes and 1 percent of all fatal crashes in the state. Work zone crashes were identified as an Emphasis Area in the 2014 Arizona Strategic Highway Safety Plan. Accurate identification of work zone crashes, their locations, traffic control setup, and crash contributing factors are key to addressing work zone crash issues. The following conclusions and recommendations are based on analysis of ADOT's ALISS database, police crash reports, and available documentation of work zone traffic control plans.

Conclusions

It is currently difficult to identify the work zone set-up that was in place at the time a crash occurred within a work zone. This can create issues in identifying any field conditions that may contribute to the crash causation.

Current coding of work zone crashes in the ADOT ALISS database led to some inaccuracies in crashes being flagged as work zone crashes. There are also inaccuracies in the identification of the type of work zone that the crash occurred in. Some of these errors occur on the police crash report form, while other errors occur in the database management of the crash data. These inaccuracies can lead to misidentifying high crash locations and the type of work zone the crashes occurred in, making it difficult for engineers to develop appropriate countermeasures to decrease the crash potential of the work zone.

Changes made in 2009 to the Arizona police crash report form led to a decrease, after 2008, of 74 percent in the number of crashes flagged as work zone crashes in the ADOT ALISS database. This reporting variance can create issues in conducting before and after safety evaluations that incorporate work zone crash data before and after 2009, which can lead to erroneous conclusions on the effectiveness of safety countermeasures in work zones.

ADOT requires that a work zone review be performed when a work zone experiences a significant crash or a re-occurrence of vehicular crashes. However, discussions with ADOT personnel indicate that these reviews are not conducted on a regular basis, removing the opportunity to identify timely changes in the work zone traffic control to decrease the potential for additional crashes.

Review of crash reports identified two location-specific crash patterns on interstate facilities — one on Interstate 10 and one on Interstate 15:

- Nighttime road-departure crashes associated with the use of temporary yellow reflective tabs for the left edgeline (I-10)
- Daytime rear-end crashes due to limited visibility of the work zone related to queues caused by horizontal and vertical curves (I-15)

Recommendations

The following recommendations are offered for ADOT's consideration.

Revise the queries used for identifying work zone crashes in the ALISS database. When using the "Road Condition" field:

- Don't include "Obstruction in Roadway" as a work zone crash.
- Use "Other" in combination with "Road Condition" equal "Lane Closure" or "Lane Shift/Crossover" or "Work on Shoulder or Median" or "Intermittent or Moving Work" or "Workers Present."
- Use "Traffic Control Device" equal "Warning Sign" or "Person."

Improve the accuracy of crash reporting:

- Simplify the existing work zone section on the police crash report form to make it less susceptible to inaccurate reporting.
- Correct the "Lane Shift/Closure" check box on the police crash report form to read "Lane Shift/Crossover."
- Provide a "Queue" check box in the Work Zone Road Condition section of the crash report form.
- Provide cross-training to reporting officers and to ADOT Traffic Records staff on work zone crash reporting.
- Evaluate using ADOT's Highway Condition Reporting System (HCRS), which provides statewide highway closure and restriction information, for obtaining additional information on work zone locations to improve accuracy of locating crashes occurring within work zones.

Improve documentation of work zone traffic control information in ADOT Construction diaries, Construction Inspection Quantlists, Temporary Traffic Control (TTC) plans, and police crash reports, so that they include documentation of field conditions at the time of a crash. This will also help in defense of claims against ADOT. ADOT is moving toward making electronic copies of all TTC plans, which should make it easier to locate the plans. Improved documentation will provide a more accurate depiction of the traffic control setup at the time of a work zone crash. Use TTC training to emphasize the importance of the following items:

- Include TRACs numbers on the TTC plans
- Include date and time of initial set up and removal of TTC in Quantlists
- Include TTC changes made in the field in Quantlists
- Include TTC plan page numbers in the Quantlists

Conduct work zone crash reviews as required by ADOT Guidelines for Work Zone Safety & Mobility. This crash review includes a site visit, review of police crash reports, interviews with construction staff and contractor, and collaboration with the design engineer of record, district staff, and/or the regional traffic engineer. When the review is complete, a report containing any recommended changes is sent to the district engineer for a review to implement changes as necessary. As part of these reviews:

- Establish the protocol for law enforcement to contact ADOT District personnel when a crash occurs in a work zone.
- Develop criteria for conducting these crash reviews.
- Update standard specifications to require contractors to report crashes in work zones.

In addition to conducting work zone crash reviews, which are triggered by crashes, a more proactive approach to identifying potential safety issues in work zones before crashes occur is to conduct Work Zone Safety Reviews. ADOT should consider initiating a Work Zone Safety Review process, to include developing criteria for conducting Work Zone Safety Reviews on construction projects such as:

- Size of project
- Stage(s) to conduct (e.g. during design of traffic control plans, after setup of traffic control devices)
- Who performs the review (consider including human factors, law enforcement, and risk management perspectives)

The benefits of Safety Reviews for work zones include:

- Identification of work zone traffic safety issues, most of which aren't identified until a crash occurs
- Proactive nature anticipates driver errors
- Focus on safety of all road users, including pedestrians and bicyclists, which oftentimes get overlooked in work zone traffic control
- Considers the 4 E's of traffic safety (engineering, education, enforcement, emergency services)
- Recommendations can be incorporated into planning and design
- Recommendations can be implemented immediately
- Develop safety strategies for specific work zone crash types

To address nighttime road departure crashes associated with the use of temporary yellow reflective tabs for the left edgeline on interstates, during TTC training stress the importance of adherence to ADOT's policy to install permanent edgeline markings before opening the far left lane on divided highways to help address driver confusion associated with the use of temporary yellow reflective tabs.

To address daytime rear-end crashes due to limited visibility of the work zone related to queues caused by horizontal and vertical curves, during TTC training stress the importance of the use of on-site law enforcement, variable speed limit systems, and queue detection with Portable Changeable Message Signs to address queue-related crashes.

Opportunities Developed from Other States' Practices

Evaluation of work zone management practices in other states identified the following opportunities for ADOT to consider.

Expand the Use of Temporary ITS

One of the critical parts of work zone management is queue monitoring. It is important for drivers and TMC operators to know where the back of the queue is for quick mitigation of emerging safety concerns. Portable changeable message signs (PCMS) are devices closest to the work zone that could provide real time benefits with the ability to update the message as conditions change, especially with queue length detection. An issue that may need to be addressed is the potential for hacking into the PCMS.

Enhance Traffic Incident Management Planning for Work Zones

Expanding the ADOT Guidelines for Work Zone Safety and Mobility to provide specific objectives associated with stakeholder outreach to emergency responders will help increase readiness to respond to crashes. For example, every significant project and certain non-significant projects should include delivery of the National Traffic Incident Management Responder training. Delivering the training creates a dynamic dialog based on real-world conditions while also helping to achieve the national goal of traffic incident management training. ADOT's Maintenance Servant Leadership Team (MSLT) and Arizona Local Emergency Response Team (ALERT) should be included in this TIM training.

A mixture of training and "game planning" for possible response scenarios in work zones will help improve incident clearance. The core concept of successful development of local TIM activities is a three-tier process:

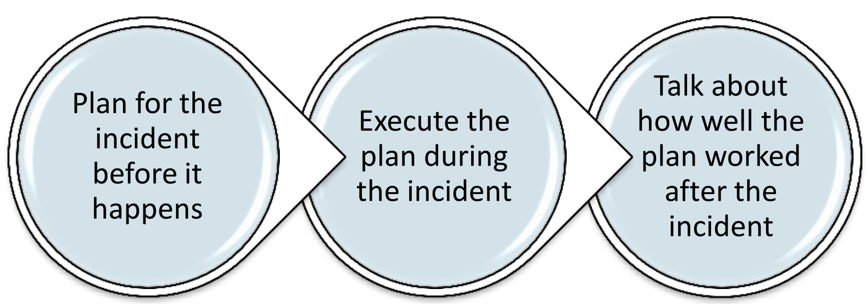


Figure 22. Process for TIM as Part of Work Zone Management

Plan for the Incident Before It Happens

as early in the process as possible, develop a TIM team that covers the planned construction limits. For example, establish a TIM team once ADOT decides to move forward with a project in the area so the team has plenty of time to gather and mature before their input is needed on the construction project. Comprise the TIM team membership from transportation, law enforcement, fire, emergency medical services, towing and recovery, hazardous materials, traffic media, and others that will have a stake in the project. During the formation of the TIM team, focus on making sure that the team:

- Stays engaged with regular meetings and changing agendas
- Focuses on institutionalizing informal agreements and locally understood response protocols
- Builds relationships and levels of trust

During the preliminary design process, meet with the TIM team to discuss design alternatives and how each alternative will impact operations. As the project nears the construction phase, work with the TIM team to develop emergency response plans. Once the plan has been developed, conduct National Traffic Incident Management Responder training and use the construction drawings as the basis for classroom exercises. In addition conduct Incident Command System - 300: Intermediate ICS for Expanding Incidents training for emergency responders in the area, responsible transportation agency representatives, and construction personnel. This training is designed to reinforce the principles of incident command and response scene management. Here is a checklist that summarizes the recommendation:

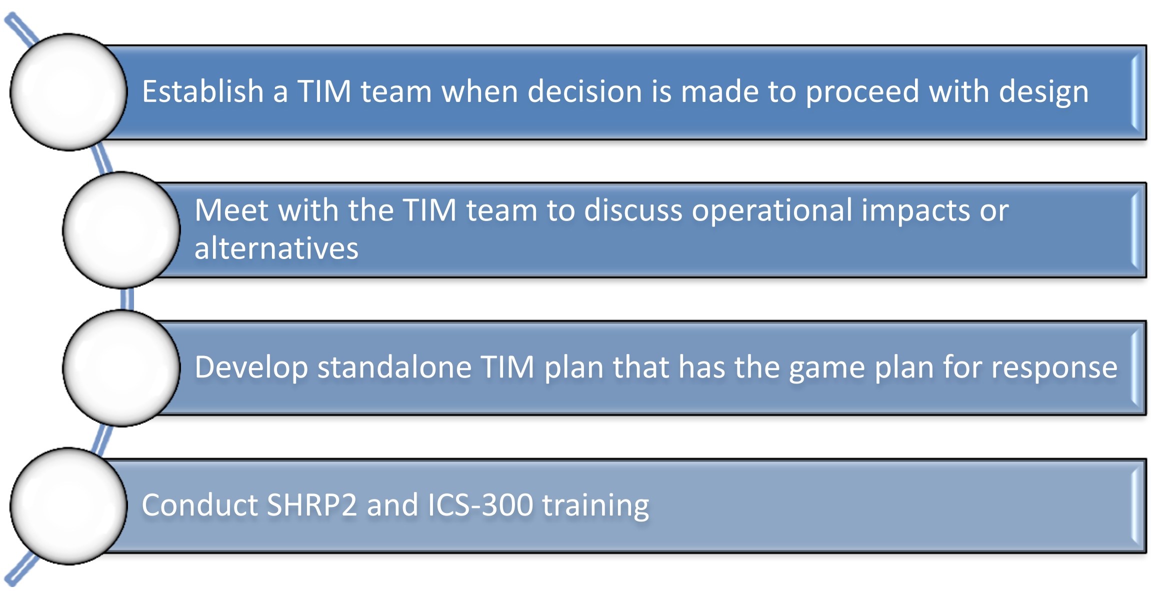


Figure 23. Checklist for Design Phase Work Zone Management using TIM Concepts

Execute the Plan During the Incident

During construction, conduct a briefing on the crash response game plan as part of the safety brief when there is a phase shift. If a crash occurs, execute the game plan as designed.

Discuss the Plan After the Incident

An important part of improvement is reviewing what was done to identify strengths and weaknesses. Conduct an after-action review within 48 hours after the incident. From a transportation agency standpoint, it will be important to gather data to support a positive and progressive conversation. Some examples of data will be screen shots from Google traffic taken during the incident by the TMC. Other information should be recordings from traffic cameras (where available), communication logs from each agency, and an initial assessment on how things went.

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