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Data Needs for Tree Removal Crash Modification Factors on Arizona State Highways

Arizona Department of Transportation Research Center

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16. Abstract

The Arizona Department of Transportation (ADOT) Roadway Departure Safety Implementation Plan (RDSIP) has identified tree removal as a feasible countermeasure to reduce roadway departure crash frequency or severity. Previous ADOT work has identified locations for tree removal, and activities to conduct this work are underway. To test the safety effectiveness of removing the trees, ADOT intends to conduct statistically rigorous before-after safety effectiveness analysis to estimate state-specific crash modification factors (CMFs). This report provides a seven-step data collection process, identifies and describes data needs, and recommends analytical methods for estimating the CMFs. The data needed for the analysis relate to crash type and severity, roadway characteristics, traffic volume, and tree removal. To complete the analysis, ADOT will compile the data before and after tree removal as outlined in this report and subsequently conduct the statistical analysis. The study team estimates that compiling, organizing, and managing the before-after period database could be completed over the course of a month before and after tree removal has been completed. The statistical analyses may take approximately two months to conduct. This level of effort is an estimate and does not assume full-time activity. In addition, the project analysis will not be conducted until three years after the tree removal has been completed at all sites.

17. Key Words
Estimating crash modification factor, before after study for tree removal, CMF for tree removal

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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)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		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)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		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 ACRONYMS

AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
ADT	Average daily traffic
CMF	Crash modification factor
CPM	Crash prediction model
CRF	Crash reduction factor
DOT	Department of Transportation
EB	Empirical Bayes
FB	Full Bayes
FHWA	Federal Highway Administration
FIS	Feature Inventory System
FO	Fixed object
FY	Fiscal year
GIS	Geographic Information System
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
LIDAR	Light Detection and Ranging
MwRSF	Midwest Roadside Safety Facility
NCHRP	National Cooperative Highway Research Program
NYSDOT	New York State Department of Transportation
RDG	Roadside Design Guide
RDSIP	Roadway Departure Safety Implementation Plan
SD	Standard deviation
SPF	Safety performance function
TRB	Transportation Research Board
TRIS	Transportation Research Information Services
UNC	University of North Carolina
VHB	Vanasse Hangen Brustlin

EXECUTIVE SUMMARY

In recent years, the number of shrub- and tree-related crashes has increased in Arizona. In 2012, fatal crashes with trees and shrubs as the first harmful event made up more than 4 percent of all statewide fatal crashes. The Arizona Department of Transportation (ADOT) Roadway Departure Safety Implementation Plan (RDSIP) has identified tree removal as a feasible countermeasure to reduce roadway departure crash frequency or severity. For this reason, ADOT has started implementing projects to reduce the number of trees in the recovery area along state highways.

At the same time, states are placing more emphasis on measuring the effectiveness (i.e., change in crash frequency or crash severity) of safety investments. Safety effectiveness is measured in terms of crash modification factors (CMFs). A CMF is a multiplicative factor used to estimate the change in crash frequency or severity after a specific treatment is implemented at a specific site. CMFs are calculated using safety before-after studies. These studies use statistical methods to compare crash frequency, type, and severity three years before and three years after a project is implemented to identify:
1) whether crash frequency, type, or severity changes; and 2) how much of the change can be attributed to the project. This research project provides ADOT with a data collection plan for conducting a before-after study related to the tree removal and ultimately, if possible, estimating a CMF associated with tree removal in Arizona.

ADOT will need to develop a database with crash, tree removal, roadway characteristics, and traffic volume data at each tree removal site in the state in order to conduct the before-after analysis. Data will need to be collected at each site and compiled for three years before the trees are removed and again three years after the trees are removed. This report defines the data needs; outlines a seven-step framework for the data collection, compilation, and evaluation (Figure 7); provides a database template for organizing the data (Table 11); and discusses the likely statistical method for analysis (Chapter 3).

The data needed for the analysis relate to:

- **Crash type and severity** (e.g., number of crashes, number of crashes by severity, and crash type)
- **Roadway characteristics and traffic volume** (e.g., terrain, roadway functional classification, number and width of lanes, width and type of shoulders, presence of rumble strips/stripes, pavement edge type/condition, speed limit, and traffic volume)
- **Roadside characteristics** (e.g., guardrail presence and type, fences, walls, signs, and call boxes)
- **Tree removal** (e.g., date of tree removal, average tree density before and after removal, and actual recovery area distance before and after removal)

To complete this analysis, ADOT will need to compile the preceding data into a spreadsheet or database comparable to the template provided in this report. The crash, roadway, and traffic volume data are largely available from existing ADOT databases or Google Earth, if needed. These data can be compiled and organized at any time by ADOT staff members who are familiar with state databases and spreadsheets. As part of the tree removal projects, ADOT will need to collect a small amount of

information related to recovery area distances and tree density before and after removal. Chapter 4 includes a sample data collection form. The after-period crash, traffic volume, and roadway data will be compiled three years after the tree removal data are collected and recorded in the database. After all tree removal projects have been completed and data have been compiled in the database, ADOT will need staff or a consultant with statistical analysis expertise to conduct the before-after analyses. The study team estimates that compiling, organizing, and managing the before-after period database could be completed over the course of a month before and after tree removal has been completed. The statistical analyses may take approximately two months to conduct. This level of effort is an estimate and does not assume full-time activity. In addition, the project analysis will not be conducted until three years after the tree removal has been completed at all sites.

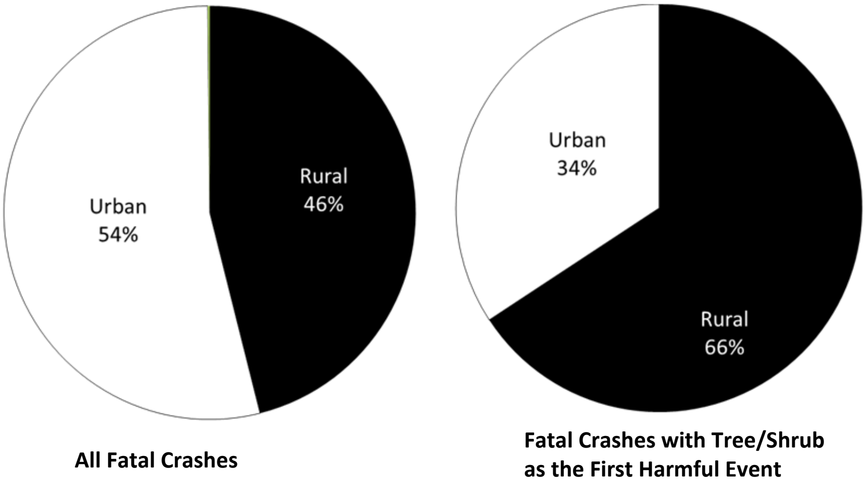
CHAPTER 1. INTRODUCTION

In recent years, the number of shrub- and tree-related crashes has increased in Arizona. As shown in Table 1, fatal crashes with trees and shrubs as the first harmful event made up approximately 2 to 4 percent of all fatal crashes in Arizona between 2008 and 2012. Although not tabulated in this research, the frequency of the crash type increases when severe injury crashes are also considered.

Table 1. Total Fatal Crashes and Fatal Crashes with Trees/Shrubs as First Harmful Event (2008 to 2012)

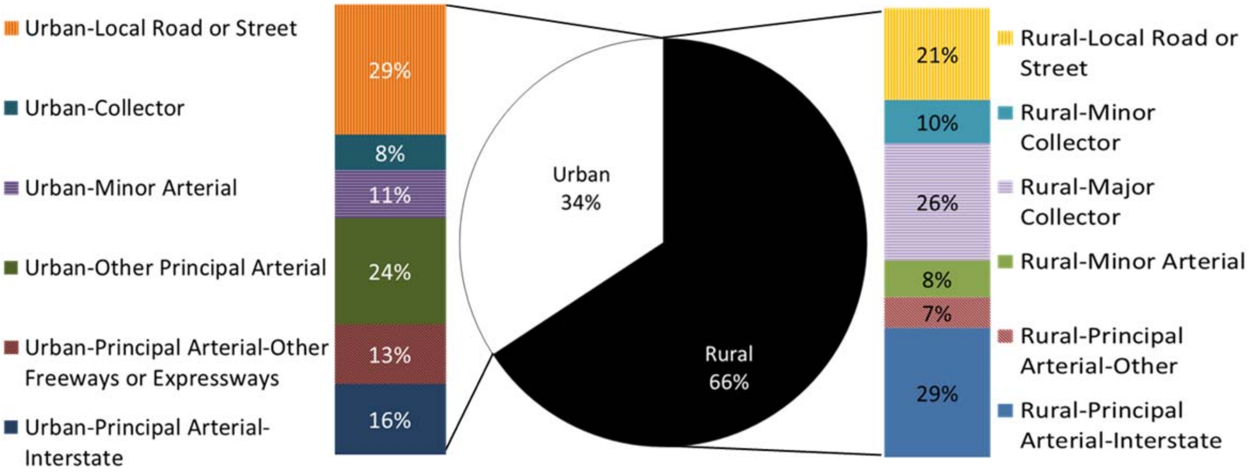
	2008	2009	2010	2011	2012
Trees/shrubs fatal crashes	15	14	22	28	32
All fatal crashes	843	709	695	755	742
Trees/shrubs fatal crashes as a percentage of all fatal crashes	1.8	2.0	3.2	3.7	4.3

As shown in Figure 1, rural roadways have a higher percentage of fatal crashes with trees and shrubs as the first harmful event compared to all fatal crashes on rural roadways. Between 2008 and 2012, 66 percent of fatal crashes with trees/shrubs as the first harmful event occurred on rural roadways. In contrast, 46 percent of all fatal crashes in Arizona occurred on rural roadways. Tree- and shrub-related crashes are concentrated on certain roadway functional classes. As shown in Figure 2, the two urban functional classifications with the greatest share of fatal crashes with trees/shrubs as the first harmful event are local road or street, and other principal arterials. The two rural functional classifications with the greatest share of fatal crashes with trees/shrubs as the first harmful event are principal arterial: interstate and major collector.



Source: National Highway Traffic Safety Administration, Fatality Analysis Reporting System, Arizona Crash Data, http://www.nhtsa.gov/FARS

Figure 1. Distribution of Fatal Arizona Crashes (2008–2012)



Source: National Highway Traffic Safety Administration, Fatality Analysis Reporting System, http://www.nhtsa.gov/FARS

Figure 2. Distribution, by Functional Class, of Fatal Crashes with Trees/Shrubs as First Harmful Event (2008–2012)

To address these issues, the Arizona Department of Transportation (ADOT) is executing a long-term roadside tree removal program as part of the ADOT Highway Safety Improvement Program (HSIP). This work is being conducted as part of the state Roadway Departure Safety Implementation Plan (RDSIP), in which tree removal was identified as a feasible countermeasure to reduce roadway departure crash frequency or severity.

Recognizing the importance of safety evaluation and the opportunity to estimate Arizona-specific crash modification factors (CMFs), ADOT initiated this project to develop data needs, a data collection plan, and optional analysis methods for developing CMFs based on the tree removal program. This report documents the anticipated safety effectiveness analysis methodology, data needs, and data collection framework. The study team expects that, after this research project has been completed, ADOT will compile the site and crash data along the tree removal segments before and after tree removal, and subsequently conduct the before-after analysis to estimate CMFs.

CHAPTER 2. A REVIEW OF EXISTING LITERATURE ON CMFS

This chapter presents a review of recent research and ADOT-specific documents that are relevant to estimating the safety effects of tree removal on Arizona state highways (i.e., tree removal CMFs). The results of this review inform the development of the data collection framework and safety analysis methodology for the ADOT tree removal program, as detailed in Chapters 3 and 4. This chapter has two components:

- A literature review of existing CMF research, with a focus on data needs for assessing the effectiveness of tree removal and CMF development methodologies
- A review of relevant ADOT materials, such as the Arizona RDSIP, documents relevant to ADOT policies on tree removal, ADOT's crash report form, and data already collected by ADOT

LITERATURE REVIEW SUMMARY

The research review provided the following key insights for identifying data needs and developing a data collection plan for ADOT:

- Few research efforts have been related to developing CMFs for tree removal.
- Projects that have identified CMFs have considered characteristics such as:
    - Lateral distance/clear zone to the fixed object (e.g., tree or utility pole)
    - Density of the fixed objects (e.g., utility poles) along the roadway
    - Traffic volume
    - Roadway functional classification and highway access
    - Roadway characteristics, including functional classification; posted speed; highway access; and shoulder width, alignment, and grade
- Peng et al. 2012 showed a small decrease in fatal and serious injury crashes as the lateral clearance increased. For instance, the analysis suggested that the probability of a fatal crash decreases from 6.9 percent to 4 percent with increasing lateral clearance from 10 feet to 40 feet.
- The 2011 American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide (RDG) identifies a fixed object as a tree (or a group of trees/shrubs) with an existing or mature diameter greater than 4 inches (AASHTO 2011).
- Typical ADOT procurement contracts for tree removal projects include assumptions about the density of trees/shrubs being removed. The categories of density are:
    - Low tree density is fewer than 16 trees per acre
    - Medium tree density is 17 to 32 trees per acre
    - High tree density is more than 32 trees per acre
- Arizona's crash report form includes crash type, location description, and severity information that will be useful for the analysis.
- It will likely be necessary to gather additional information, such as the characteristics (e.g., diameter and density) of the tree that was hit, and traffic volume from field data collection, other ADOT departments, or other data sources.

LITERATURE REVIEW

Resources

The project team acquired CMF literature from two sources: 1) the Federal Highway Administration (FHWA) listserv request; and 2) a list of relevant accident, clear zones, and treatment studies identified in a presentation by the Midwest Roadside Safety Facility (MwRSF) "Crash Risks, Location, and Treatment of Roadside Trees." (Ronald K. Faller, Ph.D., P.E., unpublished data, June 17, 2013).

In September 2013, the FHWA's Arizona Division Office sent out an information request about tree removal CMFs to a listserv of state highway engineers. These engineers provided relevant state-specific research projects, such as CMFs for tree removals to improve sight distance and CMFs associated with maintaining clear zone minimum requirements. Many CMFs from these projects also have been incorporated in the FHWA CMF Clearinghouse.

The studies within the MwRSF's presentation were identified by state highway engineers who had been contacted through the FHWA's information request. The MwRSF presentation's list of studies was cross-checked with the Transportation Research Information Services (TRIS) and online web searches to verify that it contained current, comprehensive information. These relevant reports and studies include the National Cooperative Highway Research Program (NCHRP) Report 500 series Volume 3: A Guide for Addressing Collisions with Trees in Hazardous Locations, and Volume 8: A Guide for Reducing Collisions with Utility Poles, CMFs from Australia and Europe on modifying clear zone widths, and the *NCHRP 17-54: Draft Interim Report Consideration of Roadside Features in the Highway Safety Manual* research report.

The literature review focused on the following questions:

- What CMFs related to tree removal are currently available?
- Is there evidence that tree removal projects change crash severity?
- Which data are used to estimate CMFs for tree removal?
- What methods are used to estimate CMFs?

Existing CMFs

The project team reviewed the published research to identify existing CMFs related to tree removal. The objective was to understand the methodologies used to estimate tree removal CMFs and document the range of CMF values and standard deviation (SD) currently estimated. The project team found very little research that specifically estimates CMFs for tree removal. The team identified only three recent studies: Hovey and Chowdhury (2005), New York State DOT (2012), and Pennsylvania Department of Transportation (DOT). The Pennsylvania DOT research is included in the NCHRP 500 Report, Volume 3. (Transportation Research Board 2003)

However, trees are not the only roadside object that vehicles can collide with. The literature review also identified CMFs for safety improvements comparable to removal: removing and relocating fixed objects (e.g., light poles, utility boxes, drainage structures, and sign posts); increasing clear zone width; and changing roadside fixed object density. Table 2 summarizes all of the countermeasures, CMFs, and sources identified in the project research. The research can be grouped into three main categories as follows.

Table 2. Existing CMFs Related to Tree Removal

	Countermeasure	Applicability			CMF (Standard Deviation)[a]	Star Quality Rating	Source
		Crash Type	Crash Severity	Roadway Description			
A	Remove or relocate fixed object (e.g., utility poles, trees, guardrails, sign supports, and fire hydrant)	All	All	Various roadway types (not specified)	0.62 (0.103)	Three out of five stars (per the CMF Clearinghouse)	(Hovey and Chowdhury 2005)
B	Increase distance to roadside features from: • 3.3 ft to 16.7 ft • 16.7 ft to 30 ft	All	All	Two-lane rural roadway	• 0.78 (0.01) • 0.56 (0.01)	Five out of five stars (per the CMF Clearinghouse)	(Elvik 2004). This CMF is also included in the Highway Safety Manual (HSM).
C	Change clear zone from: • ≤2 m (6.6 ft) to >8 m (26.2 ft) • Between 2 m (6.6 f) and 4 m (13.1 ft) to >8 m (26.2 ft) • Between 4 m (13.1 ft) and 8 m (26.2 ft) to ≥8 m (26.2 ft)	Run-off-road	Fatal, serious injury, minor injury	Rural	• 1. 0.46[b] (N/A) • 2. 0.63[b] (N/A) • 3. 0.79[b] (N/A)	Three out of five stars (per the CMF Clearinghouse)	(Jurewicz and Pyta 2010)
D	Increase lateral clearance from 10 to 40 ft: • On horizon curve sections • On tangent sections	Run-off-road, single vehicle	Fatal, serious injury, minor injury	Rural, two-lane undivided	• 0.68 (N/A) • 0.49 (N/A)	Three out of five stars (per the CMF Clearinghouse)	(Peng et al. 2012)
E	Clear the minimum clear zone (30 ft) of fixed objects	Fixed object (e.g., bridge, culvert, mailbox, pole, and tree)	All	Various (interstate, US primary, state primary, secondary, and county)	0.024 (0.1075)[c]	Two out of five stars (per the CMF Clearinghouse)	(Ogle et al. 2009)
F	Increase the clear zone by removing trees	Tree crashes	All	Not specified	Varies from 0.23 to 0.89, depending on before/after tree line (see Table 3 below)	Not specified	Transportation Research Board 2003 (Pennsylvania DOT Tree Crash Reduction Factors)
G	Remove or trim shrubs/ trees to improve sight distance (unspecified intersection vs. stopping)	All	All	• Average daily traffic (ADT) per lane <5000 • ADT per lane >5000	• 0.57[d] (N/A) • 0.68[d] (N/A)	The analysis showed these reductions as statistically significant.	New York State Department of Transportation 2012
H	Roadside fixed object density CMF	Utility pole collisions	All	Two-lane and multilane urban and suburban arterial roads	CMF varies by offset of fixed objects along roadway, fixed object spacing (density), and roadway type (see Equation 2 below).	Not specified	Zegeer and Cynecki 1984 (as referred to in HSM/NCHRP 17-54 Interim Report/ NCHRP 500, Volume 8)

a Unadjusted SD from original study. The CMF Clearinghouse also has an adjusted SD derived through the Highway Safety Manual (HSM) CMF inclusion process.

b Countermeasure reported in the CMF Clearinghouse as a decrease in clearance zone width. For comparison with other countermeasures, this evaluation inverted the CMF.

c This is based on an odds ratio calculation that the odds of a site having fixed object crashes are 42 times higher if minimum clear zone is not met.

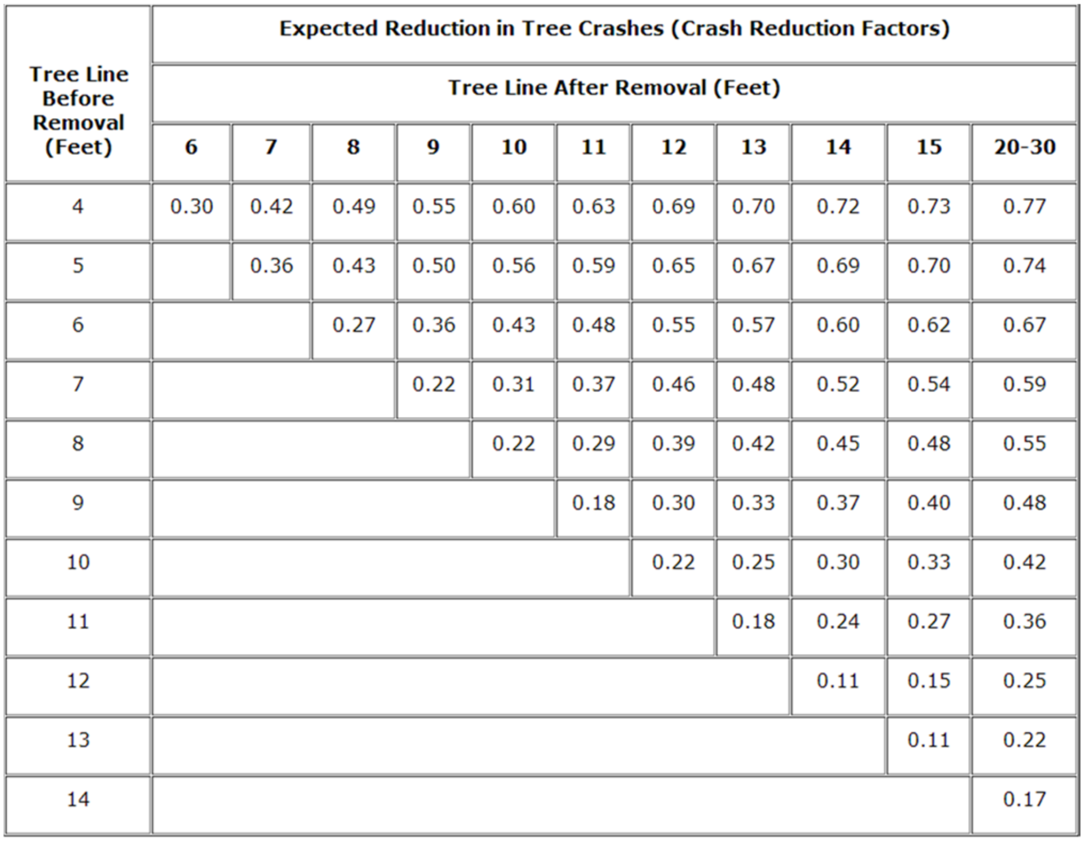
d Countermeasure reduction translated into CMF.

Increasing Clear Zone or Lateral Clearance

Clear zone or lateral clearance is the distance from the roadside to nearby obstructions and fixed objects, such as trees, utility poles, mailboxes, and culverts. Table 2 (Rows A, B, C, D, E, and F) shows that various studies have estimated CMFs or crash reduction pertaining to fixed object removal in the clear zone or clear zone expansion.

The NCHRP 500 Report, Volume 3 (Transportation Research Board 2003) provides a guide for addressing tree collisions in hazardous locations. This report refers to research completed by Pennsylvania Department of Transportation (PennDOT). PennDOT's research relates crash reduction to the tree line's distance from the traveled way as shown in Table 3. The PennDOT findings are reported in crash reduction factors (CRFs). A CRF is equal to one minus the CMF. Table 3 shows that a greater distance between the tree line and the traveled way before and after tree removal is related to greater crash reduction. Details related to study design, sample size, and years of data were not available in the NCHRP 500 report.

Table 3. Expected Reduction in Tree Crashes related to Tree Line (Crash Reduction Factors)[a]



Tree Line Before Removal (Feet)	Expected Reduction in Tree Crashes (Crash Reduction Factors)										
	Tree Line After Removal (Feet)										
	6	7	8	9	10	11	12	13	14	15	20-30
4	0.30	0.42	0.49	0.55	0.60	0.63	0.69	0.70	0.72	0.73	0.77
5		0.36	0.43	0.50	0.56	0.59	0.65	0.67	0.69	0.70	0.74
6			0.27	0.36	0.43	0.48	0.55	0.57	0.60	0.62	0.67
7				0.22	0.31	0.37	0.46	0.48	0.52	0.54	0.59
8					0.22	0.29	0.39	0.42	0.45	0.48	0.55
9						0.18	0.30	0.33	0.37	0.40	0.48
10							0.22	0.25	0.30	0.33	0.42
11								0.18	0.24	0.27	0.36
12									0.11	0.15	0.25
13										0.11	0.22
14											0.17

Source: NCHRP 500 Report, Volume 3, Appendix 8 (Transportation Research Board 2003) Transportation Resource Board (2003)

[a] Tree line means distance of tree from travelled way.

Other studies provide CMFs or CRFs for all fixed objects, and not just trees. Two studies identified in the FHWA CMF Clearinghouse—Hovey and Chowdhury (2005) (Table 2, Row A) and Elvik and Vaa (2004) (Table 2, Row B)—provide CMFs for all crash types that range from 0.56 to 0.78 based on increasing lateral clearance. The clear zone increase described in Elvik and Vaa (2004) has the highest research quality of all available CMFs. Although this CMF is based on European roadway safety data, it has a Clearinghouse quality rating of five out of five stars, which indicates the evaluation was statistically rigorous, with large samples, diverse sites, and a small standard error.

Three of the sources reviewed focused on two crash types: run-off-road and fixed object crashes. Two studies from the CMF Clearinghouse—Jurewicz and Pyta (2010) (Table 2, Row C) and Peng et al. (2012) (Table 2, Row D)—found CMFs for run-off-road crashes between 0.46 and 0.79 based on differences in lateral clearance. Both studies generated CMFs with FHWA Clearinghouse quality ratings of three out five stars. This rating indicates moderately rigorous study design with moderate sample size and limited site diversity. Both studies are based on rural roadways. Jurewicz and Pyta (2010), based on Australian driving conditions, found that larger changes in clear zone had greater safety benefits. For example, when the clear zone changed from fewer than 6.6 feet to greater than 26.2 feet, the CMF was estimated at 0.46; when the clear zone was changed from between 13.1 and 26.2 feet to greater than 26.2 feet, the CMF was estimated as 0.79. Ogle et al. (2009) also focused on fixed object crashes and estimated that implementing a minimum clear zone of 30 feet from the roadway yields a CMF for fixed object crashes of 0.024. Although this CMF is lower than the other CMFs shown in Table 2, it should be noted that the study has a lower Clearinghouse quality rating of two stars out of five stars.

Removing and Trimming Trees to Improve Sight Distance

New York State DOT (NYSDOT) calculated CRFs at state highway locations where trees were removed or trimmed based on identified accident patterns (Table 2, Row G). NYSDOT did not specify whether these locations were intersections or roadway segments. NYSDOT calculated the CRFs for different crash types, roadway characteristics, and driving conditions, as well as crash severity. The CRF for all crashes is 43 percent for roadways (CMF = 0.57) with annual average daily traffic (AADT) volumes lower than 5000 per lane. The CRF for all crashes on roadways with AADT greater than 5000 per lane is 32 percent (CMF = 0.68). NYSDOT determined these two reduction factors to be statistically significant based on a 99.9 percent level of confidence threshold.

NYSDOT's significance equation used to determine the maximum expected deviations is shown in Eq. 1 where RF = reduction factor, T = the threshold value required to gain significance expressed as a percent, and B = the adjusted number of before accidents by severity category.

$$T = (((232.6 * (SQRT(B - .16))) - 35)/B) \qquad \text{(Eq. 1)}$$

NYSDOT also estimated CRFs for removing and trimming trees to improve sight distance for a variety of crash types and severities. This information is summarized in Appendix A.

Roadside Fixed Object Density

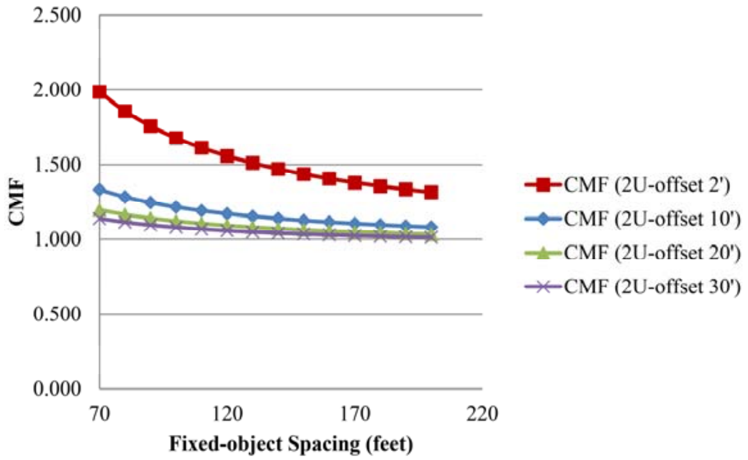
Zegeer and Cynecki (1984) evaluated utility pole collisions based on roadside fixed object density (Table 2, Row H). This study derived a CMF equation for urban and suburban arterial roadway segments with different numbers of lanes. This CMF equation is also included in the HSM and the NCHRP 17-54 draft interim report (TRB 2013). The equation has a base condition of no roadside fixed objects. The CMF is based on fixed object offset factors derived from offset distance to fixed objects (f_{offset}), fixed object density from both sides of the road (D_{FO}), and fixed object collisions as a proportion of total crashes (P_{FO}), as shown in Eq. 2.

$$CMF_{2r} = f_{offset} \text{ x } D_{FO} \text{ x } P_{FO} + (1.0 – P_{FO}) \qquad \text{(Eq. 2)}$$

According to the research, inputs for the CMF are:

- Point objects that are at least 4 inches in diameter and do not have a breakaway design.
- Continuous objects that are not obstructed by the point objects; these objects are counted as one point for every 70 feet of length.

Note that fixed objects in the medians of divided arterials are not considered in the CMF. To illustrate, Figure 3 shows the combined effect of the fixed object offset and density on two-lane, undivided urban and suburban arterials. The figure's X axis represents the distance between fixed objects in feet. The figure's legend indicates the various CMF trend lines based on offset to fixed objects (2, 10, 20, and 30 feet). Note that all trend lines assume the proportion of fixed object collisions for two-lane, undivided urban and suburban arterials to be 0.059. In general, the CMF is higher when objects are spaced closer together and when they are closer to the road.



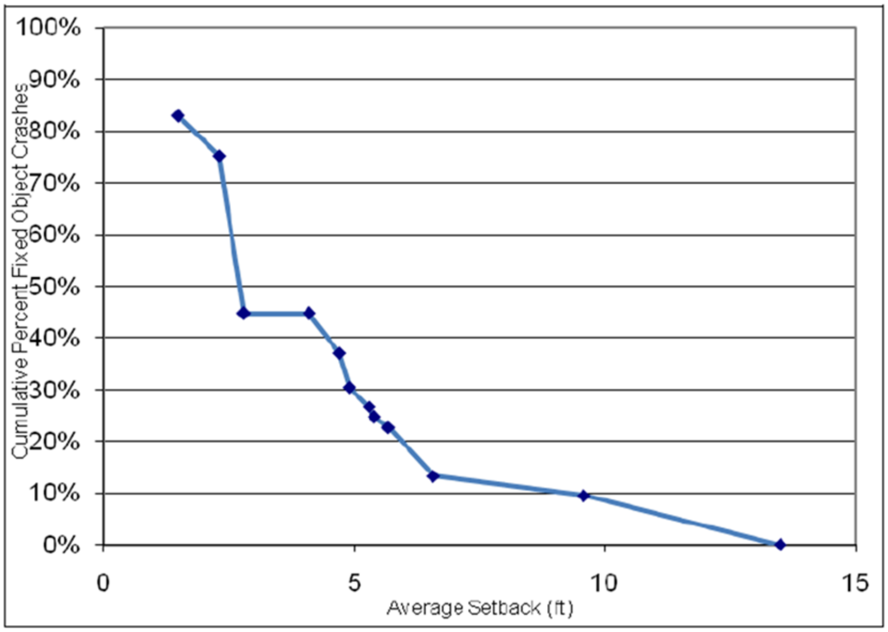
Source: NCHRP 17-54: Draft Interim Report (Transportation Research Board 2013)

Figure 3. Fixed Object CMF for Various Offsets and Spacing Along Two-Lane Urban and Suburban Arterials

Related CMFs

There are other CMFs related to roadside fixed objects. For example, numerous studies have evaluated before-after changes in CMFs pertaining to urban or suburban landscaping or road geometry improvements involving trees. Hallenbeck et al. (2013) examined before-after total, fatal, and tree crashes for five urban and suburban roadway segments that received landscape median treatments. The study showed that the presence of small trees in the median did not statistically increase crash rates, crash severity, or injury-crash rates. A 2006 before-after study on 10 Texas roadway segments with landscape improvements showed that only one of 10 sites experienced a significant reduction (83 percent) in tree collisions after landscape treatments (Mok et al. 2006). However, because the particular roadway segment also had multiple modifications and landscape treatments, it was difficult to conclude the source of the crash reduction.

Maze et al. (2008) also evaluated the benefits of providing a 10-foot clear zone along 11 urban curbed streets in Des Moines and Waterloo, Iowa. The study conducted a cumulative percent analysis to assess where the majority of the fixed object crashes occurred in relation to setback measurement. Figure 4 shows an example of the cumulative percent of fixed object crashes and their average setback for a speed limit of 30 miles per hour. The analysis suggested that in an urban setting, once the clear zone exceeds 5 feet, observed fixed object crashes are minimized. The cumulative percent analysis found that as the speed limit or ADT increased, the setback distance where 90 percent of fixed object crashes occur increased by only 1 or 2 feet, on average.



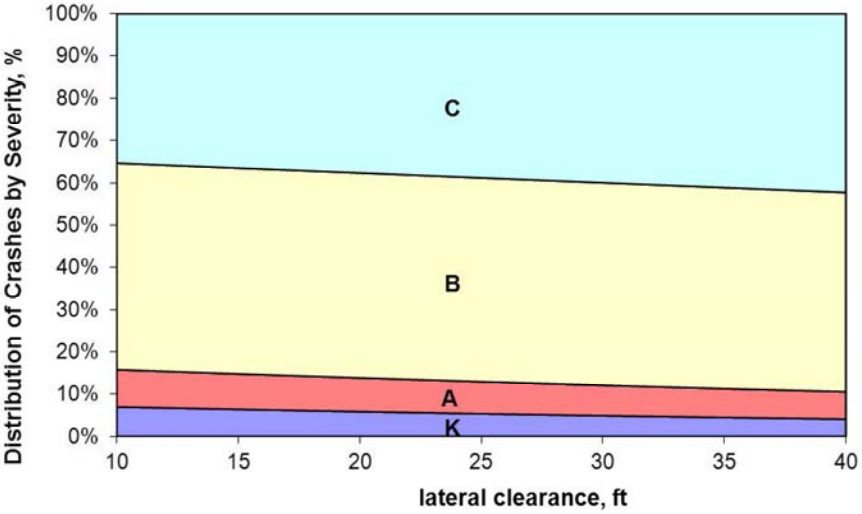
Source: Maze et al. (2008)

Figure 4. Cumulative Percent Average Setback in Segment Analysis at 30 Miles per Hour

Crash Severity Modification

Peng et al. (2012) performed a multinomial regression analysis to estimate the relationship between road departure crashes and lateral clearance, side slope condition, and driveway density on rural two-lane roads. The study used the KABCO scale for defining injuries, where K = fatal injury, A = incapacitating injury, B = nonincapacitating injury, C = possible injury, and O = no injury.

The researchers used a Light Detection and Ranging (LIDAR) gun to measure distances from the roadside to nearby obstructions and fixed objects, providing a record of lateral clearance. The distance measurement included the shoulder and is consistent with the AASHTO definition of roadside clearance. As shown in Figure 5, the analysis suggests that the probability of a fatal crash decreases from 6.9 percent to 4 percent, and the probability of an incapacitating injury crash decreases from 8.8 percent to 6.4 percent as lateral clearance increases from 10 feet to 40 feet, respectively.



Source: Peng et al (2012)

Figure 5. Expected Severity Distribution by Lateral Clearance

Geedipally et al. (2013) similarly developed severity distribution functions for freeway roadside crashes as a function of presence of inside and outside barriers, traffic volume, presence of inside and outside rumble strips, lane width, and segment length with curve. This methodology has been integrated into the freeway chapter of the AASHTO HSM (AASHTO 2010).

Data Needs

As part of the literature review, the study team examined the types of data used in the research to develop the CMFs or CRFs. Appendix B includes a full list and description of the data. Overall, data used in research can be grouped into five main categories: crash data, tree characteristics (e.g., diameter, density, and offset), traffic volume, highway functional classification and access type, and other roadway characteristics (e.g., roadway alignment and grade, shoulder type, and shoulder width). Not all data were used as inputs or factors for CMF functions. Some studies used these data as categories for site comparisons, and then conducted evaluations of crash outcomes. Other studies used these data as dependent and independent variables in the crash estimation models. The study team also reviewed the AASHTO RDG (AASHTO 2011) to understand national guidance about clear zone guidance.

Crash Data

All studies in this review used crash type data, such as the total number of crashes and run-off-road crashes, as a dependent variable that is affected by various factors (see Table 4). For instance, NYSDOT's CRFs calculation evaluated how trimming and removing bushes and trees would reduce the number of total crashes, overtaking, right angle, fixed object (tree/hydrant/other), and run-off-road crashes (NYSDOT 2012). NYSDOT found the number of all these crash types to be significantly reduced by bush and tree trimming/removing on high-volume roads (an ADT greater than 5000 vehicles per lane). For lower-volume roads (fewer than 5000 vehicles per day per lane), only the number of all crash types and right-angle crashes was significantly reduced by tree trimming and removal.

Table 4. Crash Type Considered in Tree Removal CMF Estimates

Crash Type	Study
1) Total crashes; and 2) run-off-road casualty crashes	Dependent variable for most studies
Overtaking, right-angle, fixed object (tree/hydrant/other), all fixed object, and run-off-road crashes	New York State DOT 2012
Type of fixed object crashes (trees, poles, culvert, mail box, bridge, guard rail, and other)	Ogle et al. 2009

Some studies also specified crash severity as a dependent variable of different factors. Typically, these studies broke severity into the following categories: fatal, injuries, and property damage only. Some studies focused on one type of crash severity. For instance, Jurewicz and Pyta (2010) examined how clear zone widths affect run-off-road fatal and injury crashes. Other studies, such as Peng et al. (2012), organized crash data into the five KABCO categories: fatal, incapacitating injury, nonincapacitating injury, possible injury, and property damage only.

Crash data precision issues, such as accuracy of crash locations or reported crash severity, were not discussed in the reviewed literature.

Tree Characteristics (Diameter, Density, Number of Trees, and Offset from Roadways)

The 2011 AASHTO RDG identifies trees with an existing or expected mature diameter greater than 4 inches as potential fixed objects (AASHTO 2011). A number of trees or shrubs within close proximity to each other also may be considered to have the same effect as a tree with a diameter greater than 4 inches. The RDG specifies that large trees and shrubs should be removed from the clear zone. The width of this clear zone is a function of highway speeds, traffic volume, and roadside slopes.

Traffic Volume

Much of the literature also used ADT or AADT data for traffic volume exposure. The traffic volume ranges and studies, shown in Table 5, have different categorical breakdowns by ADT. For instance, New York State DOT (2012) compared state highway locations with AADT of greater than 5000 vehicles per lane to those with AADT of fewer than 5000 vehicles per lane. In the Hovey and Chowdhury (2005) CRF development study, the authors applied the empirical Bayes (EB) method to estimate total crashes using total ADT and truck ADT as variables, and they estimated fatal and injury crashes based on total ADT.

Table 5. Ranges of Traffic Volume Considered in Tree Removal CMF Estimates

Traffic Volume Range	Study
AADT: 1500 to 6000 and 6000+	Maze et al. 2008
One-way AADT: <1200 and >1200	Jurewicz and Pyta 2010
AADT >5000 vs. AADT <5000	New York State DOT 2012
Average daily total and truck volumes as variables in the CRF functions	Hovey and Chowdhury 2005

Roadway Functional Classification/Highway Access Type

Hovey and Chowdhury (2005) also used functional class as a parameter to forecast total crashes and fatal and injury crashes. The variable coefficients differ between 12 roadway functional classes (six urban and six rural functional classes). The study also included a variable for highway access type that has different coefficients for three access types: no access control, limited access control, and full access control.

Other Roadway Characteristics

Studies in this category also compare crash reduction to other roadway characteristics (see Table 6). Hovey and Chowdhury (2005) included shoulder widths as a variable influencing total crashes and fatal and injury crashes. Jurewicz and Pyta (2010) also considered crash likelihood in different traffic lanes and with paved shoulder widths. The study found that road sections with fewer than 3.5 meters (11.5 feet) each way (or 7 meters [23 feet] across) have a run-off-road crash likelihood 1.2 times higher than roads with seal width of more than 7 meters (23 feet) across, although this relationship was found to be statistically insignificant.

Table 6. General Characteristics Considered in Tree Removal CMF Estimates

Characteristic	Study
Shoulder widths as variables in the CRF functions	Hovey and Chowdhury 2005
• Curve radius as a part of a run-off-road crash prediction model: <600 meters (1969 feet), 600 to 1500 meters (1969 to 4921 feet), and >1500 meters (4921 feet) • Grade (%) as part of a run-off-road crash prediction model: negative, positive, or zero • Traffic lane plus paved shoulder width as part of a run-off-road crash prediction model: <3.5 meters (11.5 feet) and >3.5 meters (11.5 feet)	Jurewicz and Pyta 2010
• Straight roadway level, grade, and hillcrest • Curve roadway level, grade, and hillcrest	CMF Clearinghouse (Ogle et al., 2009)
Speed limit: At 30, 35, and 40 miles per hour	Maze et al. 2008

Two of the review's studies also looked at road alignment and grades. Jurewicz and Pyta (2010) looked at curve radius as part of a run-off-road crash prediction model. Curve radii were divided into three categories: less than 600 meters (1969 feet), 600 to 1500 meters (1969 to 4921 feet), and greater than 1500 meters (4921 feet). The study found that crash likelihood is 2.4 times higher on curves with a radius less than or equal to 600 meters (1969 feet) than on curves with a radius of more than 1500 meters (4921 feet or relatively straight). Similarly, for straight and curved roads, the study further recorded whether the roadway is at a level, a grade, or a hillcrest. The study compared run-off-road predictions between negative grade roadways and positive or zero grade roadways. The study found that roadway sections with a downhill grade have a crash likelihood 1.3 times higher than road sections with an uphill grade or no grade.

Maze et al. (2008) also evaluated how the setback distance, where 90 percent of fixed object crashes occur, would differ under different speed limits. However, the study only tested three speed limits (30, 35, and 40 miles per hour), and the relationship between the number of fixed-object crashes per year to the speed limit was inconclusive.

Driving conditions (i.e., environmental characteristics) could also affect the relationship between safety improvements and crash reduction. NYSDOT documented crash conditions to evaluate whether trimming and removing trees reduced crashes on dry, wet, and snow/ice/slush roads (NYSDOT 2012). Based on the study's available data, trimming and removing trees significantly reduced the number of crashes in all three driving conditions for roads with AADT greater than 5000 vehicles per lane, while the crash reduction in all three driving conditions was not statistically significant for roads with AADT greater than 5000 vehicles per lane.

REVIEW OF RELEVANT ADOT MATERIALS

ADOT provided background information, which was reviewed to develop a deeper understanding of:

- The existing tree removal program
- Typical data likely to be available from the state crash report form
- Typical tree removal project procurement materials and the data likely to be developed for or during a tree removal project

ADOT HSIP-Funded Tree Removal Project H8206 and Arizona Roadway Departure Safety Implementation Plan, FHWA Office of Safety

On June 15, 2010, ADOT received a determination of eligibility to use HSIP funding for systemic tree removal, with an eligibility amount of $9.7 million. In June 2012, the FHWA Office of Safety completed the Arizona RDSIP, which included tree removal as one of the countermeasures. The RDSIP identified additional roadway segments for tree removal. On October 16, 2012, the FHWA Arizona Division granted HSIP eligibility to add the RDSIP identified segments to the June 15, 2010, approved list. The revised total HSIP funding for tree removal is $13 million, which covers approximately 700 roadway miles of tree removal.

ADOT has retained a contractor to prepare scoping documents and cost estimates based on recently completed field sampling of tree density (number of trees per acre) on I-19, SR 87, and I-8. The final steps are determination of environmental requirements and development of the implementation schedule for final plans and construction based on input from the ADOT Environmental Planning Group.

Some of the tree removal projects may be executed as standalone projects; others will be executed as part of other programmed projects (e.g., pavement preservation projects). The first standalone project is programmed at $2 million for construction in fiscal year (FY) 16. It is anticipated that a second standalone project will be designed and programmed at $4 million for construction in FY17, and a third at $4 million in FY18.

ADOT Crash Report Form

The existing ADOT Crash Report Form (Appendix C) was reviewed to understand the typical data available in a crash record. It is desirable that limited unusual or additional data be required as part of the process to estimate a CMF. The crash report provides the following information that may be useful:

- Location, including roadway name, site specific location, and urban or rural designation
- Injuries per crash and severity
- First harmful event, identifying collision with a tree, bush, or stump
- Light, weather, road surface, and road grade condition
- Manner of crash impact, including single vehicle, angle, left turn, rear end, head on, sideswipe (same and opposite direction), rear to side, and rear to rear collision

- Traffic unit maneuver/action, which includes an item for negotiating a curve
- Roadway alignment, including straight, curve left, curve right, and unknown
- Sequence of events, such as run-off-road (left or right) and collision with fixed object, including a tree, brush, or stump

The following information may be needed, but is not included in the crash reports:

- Roadway offset distance to the fixed object crash – This information may be included in the sketch or description provided by the reporting officer.
- Characteristics (diameter and density) of the tree or shrub that was hit.
- Roadway characteristics, which could include number of lanes, posted speed, shoulder type and width, and side slope. This information could possibly be gathered from other ADOT data sources.
- Traffic volume – These data are also likely available through other ADOT data sources.

Sample Tree Removal Project Procurement Materials – Lake Mary Road

ADOT provided the project team with sample ADOT tree-cutting project procurement materials, which the team reviewed in order to understand typical project descriptions and activities and typical tree removal pricing. In the sample project, the pricing for tree removal is set at a price per acre as a function of low, medium, and high tree density:

- Low tree density is fewer than 16 trees per acre.
- Medium tree density is 17 to 32 trees per acre.
- High tree density is more than 32 trees per acre.

In a typical tree removal project, ADOT specifies the recovery area for its contractors. The recovery area on Lake Mary Road is 30 feet from the adjacent shoulder stripe (or 42 feet from the roadway centerline if no shoulder stripe exists). The Lake Mary project also included a thinning zone between 30 feet and 100 feet (in different situations) from the shoulder stripe or right-of-way limits. In the thinning zone, trees are specified on an item-by-item basis for removal by ADOT. The ADOT materials also provide information on how the remaining tree stumps are treated as a function of diameter and slope roadside.

CHAPTER 3. PROPOSED METHOD OF DATA AND NEEDS ANALYSIS

This chapter presents an overview of various analysis methods for developing CMFs based on the tree removal program. Based on a series of criteria developed in the FHWA's A *Guide to Developing Quality Crash Modification Factors* (Gross et al. 2010), it is anticipated that the most appropriate analysis method will be the EB method's before-after analysis. However, this will need to be confirmed once data are collected and evaluated. The anticipated analysis method informs the development of the recommended data collection framework for the ADOT tree removal program, as detailed in Chapter 4.

This chapter has two components:

- An overview of safety analysis methods for developing CMFs
- An evaluation to select the appropriate analysis method

OVERVIEW OF ANALYSIS METHODS

One of the most comprehensive sources of methods for safety effectiveness evaluation is *Recommended Protocols for Developing Crash Modification Factors* (Carter et al. 2012). This document was produced by the University of North Carolina's (UNC) Highway Safety Research Center and Vanasse Hangen Brustlin, Inc. (VHB) for the FHWA CMF Clearinghouse. The methodologies for estimating crash modification factors can be divided into two broad categories: before-after studies and cross-sectional studies.

Before-After Studies

CMFs derived from before-after studies are based on the change in safety due to treatment implementation. Examples of before-after study designs are:

- Naïve before-after study – This simple before and after comparison of a treatment's safety effect compares the crash frequency in the after period with the crash frequency in the before period. A variation of this methodology compares crash rates (per vehicle miles traveled) between the before and after periods.
- Before-after study with comparison group – An untreated comparison group that is similar to the treatment group is identified to account for temporal effects or changes in traffic volumes from the before to after treatment period. The comparison group is used to calculate a comparison ratio; that is, the ratio of observed frequency in the after period to that in the before period. The observed crash frequency in the before period at the treatment sites is multiplied by this comparison ratio to estimate the expected number of crashes in the after period, had the treatment not occurred. The expected number of crashes in the after period (had the treatment not occurred) is then compared with the actual number of crashes in the after period to determine the safety impact of the treatment. Another approach is to develop safety performance functions (SPFs) using data from the untreated comparison group that relate crash frequency with site characteristics, including AADT. The SPF would account for the effect of traffic volume changes from the before period to the after period.

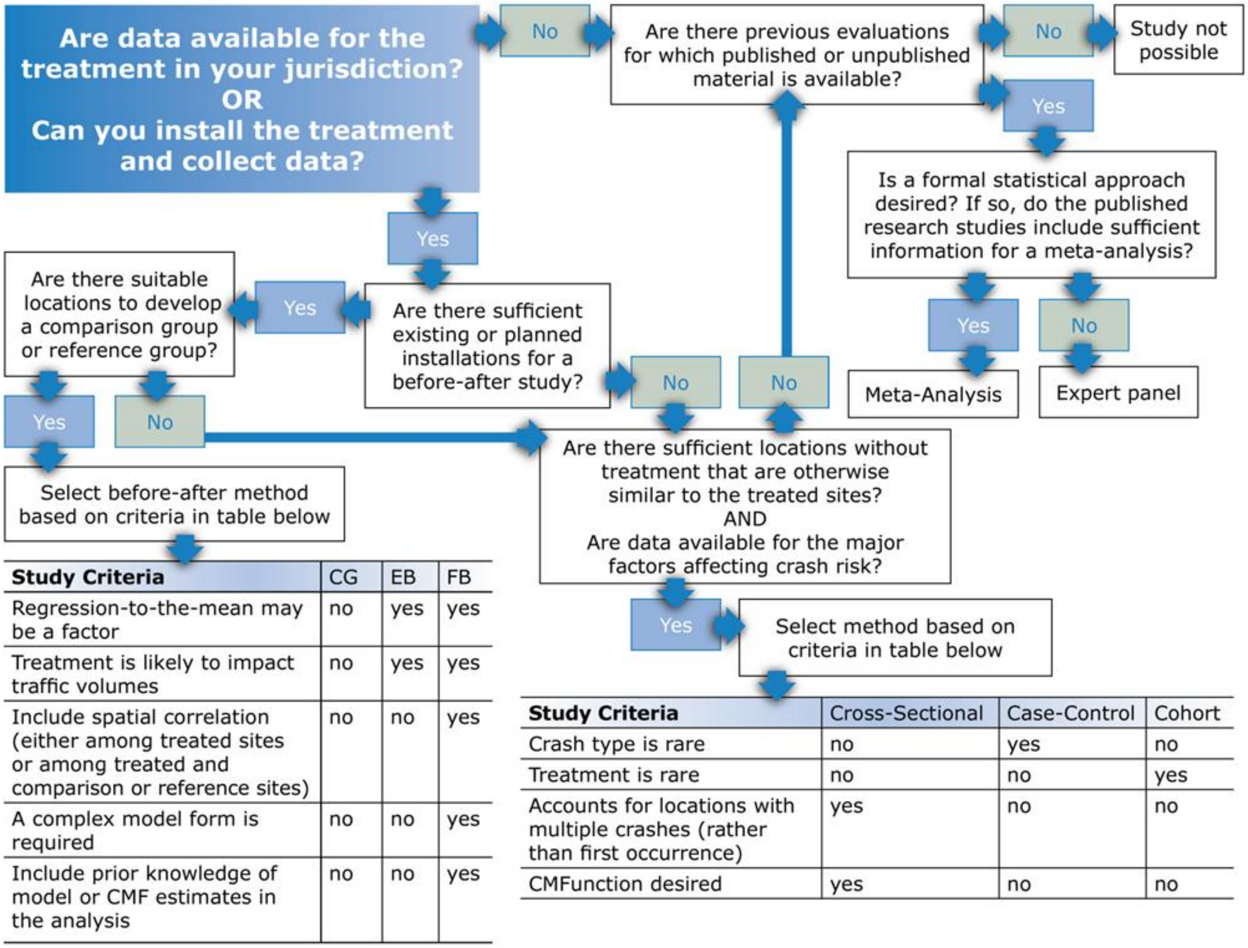
- EB before-after study – This type of study identifies a reference group of sites that have not had treatment, but are similar to the treatment sites in terms of crash risk factors (i.e., volume, roadway characteristics, and surrounding land use conditions). The method then estimates SPFs that relate crashes to independent variables, such as traffic volume and other site characteristics using the reference sites' data. The method also calculates annual SPF multipliers that account for the temporal effects. Using the SPFs, annual SPF multipliers, and traffic volume data, the method estimates the number of crashes that would be expected for the before period in each site. For each treatment site, the method then estimates the expected number of crashes that would have occurred in the after period, had there been no treatment. The expected number of crashes in the after period without the treatment, along with the variance of this parameter and the number of reported crashes after the treatment, is used to estimate the index of effectiveness, which also is referred to as the CMF (i.e., crash modification factor) and the variance of the CMF.
- Full or hierarchical Bayes before-after study – Similar to the EB methods, a reference group is used to estimate the expected crash frequency from an SPF. The full or hierarchical Bayes approach uses the distribution of likely values from the reference group instead of the point estimate. The method combines these estimates with the observed crash frequency in the before period of the treatment group to estimate the long-term expected crash frequency without the treatment.

Cross-Sectional Studies

CMFs from cross-sectional studies are derived by comparing the safety of a group of sites with a safety improvement to the safety of a group of sites without the safety improvement. Typically, this is a comparison of average crash frequency. Because finding sites with similar characteristics for comparison is difficult, the method uses SPFs or crash prediction models (CPMs) that relate crash frequency to site characteristics. The coefficients of the variables from these SPFs or CPMs are used to estimate the CMF associated with a treatment. Carter et al (2012) provides further explanation of confounding variables in cross-sectional studies.

EVALUATION TO SELECT THE APPROPRIATE ANALYSIS METHOD

Figure 6 provides a framework for identifying the most appropriate safety effectiveness analysis methodology given the conditions available to the researcher. Based on this flow chart, the EB method of before-after analysis will likely be the appropriate analysis methodology when ADOT staff undertake the safety effectiveness evaluation.



Study Criteria	CG	EB	FB
Regression-to-the-mean may be a factor	no	yes	yes
Treatment is likely to impact traffic volumes	no	yes	yes
Include spatial correlation (either among treated sites or among treated and comparison or reference sites)	no	no	yes
A complex model form is required	no	no	yes
Include prior knowledge of model or CMF estimates in the analysis	no	no	yes

Study Criteria	Cross-Sectional	Case-Control	Cohort
Crash type is rare	no	yes	no
Treatment is rare	no	no	yes
Accounts for locations with multiple crashes (rather than first occurrence)	yes	no	no
CMFunction desired	yes	no	no

Source: Gross et al. (2010)

Figure 6. Flow Chart for Study Design Selection

As shown in Figure 6, four key decisions lead to this conclusion:

- *Are data available for the treatment in your jurisdiction or can you install the treatment and collect data?*
  Yes. Assuming the data collection efforts specified in this report move forward, data for the analysis will be available.
- *Are there sufficient existing or planned installations for a before-after study?*
  Yes. This is essentially a question of sample size. The number of sites (or miles of roadway) with tree removals should be sufficient to develop a robust before-after study evaluation plan. The determination of sample size *a priori* is difficult because it depends on a number of factors, including average crash frequency, the level of statistical significance desired in the model, and the expected effect of the treatment. At the time of the before-after analysis, the researcher can explore the suitability of the identified sample in more detail. In general, quantification of statistically significant effects that are small (i.e., less than 10 percent of crash reductions) requires larger samples. Assessing the differences in safety effects based on the extent of tree

clearing activities (e.g., the clearing distance) and possibly changes in crash type or crash severity further complicate the sample size question. If the treated locations do not provide a sufficient sample size for evaluating effects of different recovery area lateral clearances, the data set could potentially be supplemented with sites such as those treated by routine maintenance. It should be noted that pursuing this option would reduce the clarity of the findings as they specifically relate to the benefits of removing trees for the purpose of reducing crash frequency or severity. If needed, another option for expanding the sample size would be to determine whether other states are deploying comparable projects, and if so, combine data sets. This would be possible if a state is considering a similar research question and collecting the same data as Arizona.

- *Are there suitable locations to develop a comparison group or reference group?*
  Yes. Because the treatment locations are not very unique (e.g., rural four-lane freeway and rural two-lane highway), a large suitable pool of similar locations from which to develop reference groups or comparison groups is likely. Development of SPFs specifically for evaluation of tree removal in Arizona (evaluation-level SPFs) is the preferred approach to conducting these analyses, as it would provide results specific to the situation and available data. A second option could be applying calibrated SPFs from the HSM (project-level SPFs). Finally, if available, calibrated SPFs from a full deployment of *SafetyAnalyst* (network screening-level SPFs) could be used if these models fit reasonably well. It should be noted, however, that this approach would provide the lowest degree of reliability in the results of the analysis, and in other states *SafetyAnalyst* SPFs have not fit well. The sites used to develop the models should not include the treated sites and will need to use data already collected in the ADOT data warehouse.
- *Select before-after study method.*
  The final element of Figure 6 provides criteria for selecting a study method. The criteria determine whether a comparison group, EB, or full Bayes (FB) evaluation is the most appropriate. In this study, the treated sites were selected primarily because of the high number of tree-related crashes. This selection introduces the regression-to-the-mean bias that cannot easily be controlled in the comparison group approach. The study criteria suggest that additional complexity of the FB approach does not have strong justification in this proposed study. Spatial correlation is possible between sites (i.e., some climates or geographies might make a certain area have larger and more dense trees), but the data collection plan recommends variables that should help properly account for these differences. Neither a complex model form nor inclusion of prior CMF knowledge is important in this study approach. Thus, the flow chart suggests an EB before-after methodological approach. It should be noted, however, at this point in the before-after safety evaluation (the data collection plan), the data requirements are nearly identical for the FB and EB studies, so the decision on analysis method can and should be re-evaluated after data collection.

Overview of Empirical Bayes Concepts and Methodology

In an EB before-after study, safety effectiveness is estimated by comparing the number of crashes in a given period after implementing a treatment to an estimate of the number of crashes in the same period, had the treatment not been implemented; for example, suppose enhanced signage was implemented along a group of horizontal curves in 2009. The safety effectiveness (CMF) of the treatment would be estimated by comparing the observed number of crashes at the curves from 2010 to 2013 with the treatment in place to an estimate of what would have been the number of crashes at the curves between 2010 and 2013 if the enhanced signage had not been installed.

In the EB method, safety performance functions, or SPFs, and observed crash data are used to estimate crash frequency in the after period had the treatment not been implemented. It typically is not a good idea to estimate these data by using observed crashes from the period before the treatment is installed. This is because other conditions (e.g., weather, traffic volume, and other road conditions) at the site might have changed in the after period and because of issues associated with regression-to-the-mean.

Seven basic steps are performed to complete a safety effectiveness evaluation using the EB method. Table 7 provides a tabular summary of the observed, predicted, and expected crash information used in the analysis. The steps to conduct the EB analysis are as follows:

1. Compile data, including crash data (A and B), SPFs, and any other data needed to estimate/use the SPFs (e.g., traffic volumes, geometric elements, and operational elements).
2. Apply SPFs to predict crashes at the treatment sites before the treatment was implemented (C) and after the treatment was implemented (D).
3. Apply the EB method to estimate expected crashes in the before period (E).
4. Calculate the ratio of predicted crash frequency in the after period with treatment to predicted crashes in the before period without treatment (D/C).
5. Estimate expected crash frequency in the after period, had the treatment not been in place (i.e., F = E*D/C).
6. Calculate safety effectiveness (or CMF) of the treatment by dividing observed crashes in the after period with the treatment in place by the estimate of safety in the after period, had the treatment not been implemented (B/F).
7. Calculate variance and standard deviation of the safety effectiveness.

Table 7. Summary of Time Period and Crash Data in EB Before-After Analysis

Time Period	Observed Crashes	Predicted Crashes (from SPFs)	Expected Crashes
Before	A	C	E
After without treatment – hypothetical scenario			F
After with treatment	B	D	

Role and Source of Safety Performance Functions

As part of the data collection and organization process, ADOT will categorize segments being treated with tree removal into different site types according to characteristics described in Chapter 4 of this report. SPFs and Arizona crash type distributions will be needed for each site type.

SPFs are used in the EB method for safety effectiveness evaluation to predict crash frequency before the treatment was in place at each site, predict crash frequency after the treatment is in place at each site, and to estimate expected crashes. The preferred approach is to develop and calibrate SPFs specifically for this evaluation (evaluation-level SPFs). There would be several different SPFs consistent with the site types (e.g., two-lane rural highways, rural multilane highways), crash severities (e.g., total crashes, or fatal and serious injury-only crashes), and crash type. SPFs from the HSM (project-level SPFs) also could be calibrated to site conditions, or network screening-level SPFs from a full *SafetyAnalyst* deployment could be used. Both of these options should be considered only if it is not possible to develop specific SPFs for this project.

FHWA has prepared two valuable documents related to calibrating or developing SPFs: *Safety Performance Function Development Guide: Developing Jurisdiction-Specific SPFs* (Srinivasan and Bauer 2013); and *How to Choose Between Calibrating SPFs from the HSM and Developing Jurisdiction-Specific SPFs* (Srinivasan et al. 2013). Note that, if ADOT plans to develop SPFs specifically for evaluation of tree removal, reference sites will also be needed. Reference sites are comparable to the sites receiving the before and after treatment conditions with the exception of the reference sites that do not have any tree removal activities (including tree removal maintenance activities).

CHAPTER 4. DATA NEEDS AND DATA COLLECTION FRAMEWORK

Based on the review of existing safety literature and relevant ADOT materials and the anticipated analysis method for developing CMFs (the EB method before-after analysis), this chapter presents the recommended data collection process and data needs. A summary list of data needs includes:

- Roadway segment data – Before and after tree removal
    - Site location (highway number, beginning and ending milepost)
    - Terrain (flat, rolling, mountainous)
    - Roadway functional classification
    - Posted speed
    - Number of lanes
    - Lane width
    - Shoulder width
    - Shoulder type
    - AADT (all years)
    - Side slope
    - Horizontal curve
    - Driveway density
- Tree removal data
    - Site location (highway number, beginning and ending milepost)
    - Removal location specification
    - Date and year of removal
    - Average density of trees before and after tree removal
    - Actual recovery area distance before and after tree removal
    - Tree density in thinned area before and after tree removal
- Crash data
    - Site location (highway number, beginning and ending milepost)
    - Total crashes
    - Fatal crashes
    - Incapacitating injury crashes
    - Nonincapacitating crashes
    - Possible injury crash
    - Property damage only

With the exception of the tree removal data, the majority of these data exist in ADOT databases. However, ADOT staff will need to assemble the data into a specific database for the safety effectiveness evaluation.

DATA COLLECTION FRAMEWORK

The study team recommends a seven-step framework for data collection, compilation, and evaluation. Figure 7 shows the seven-step flow chart.

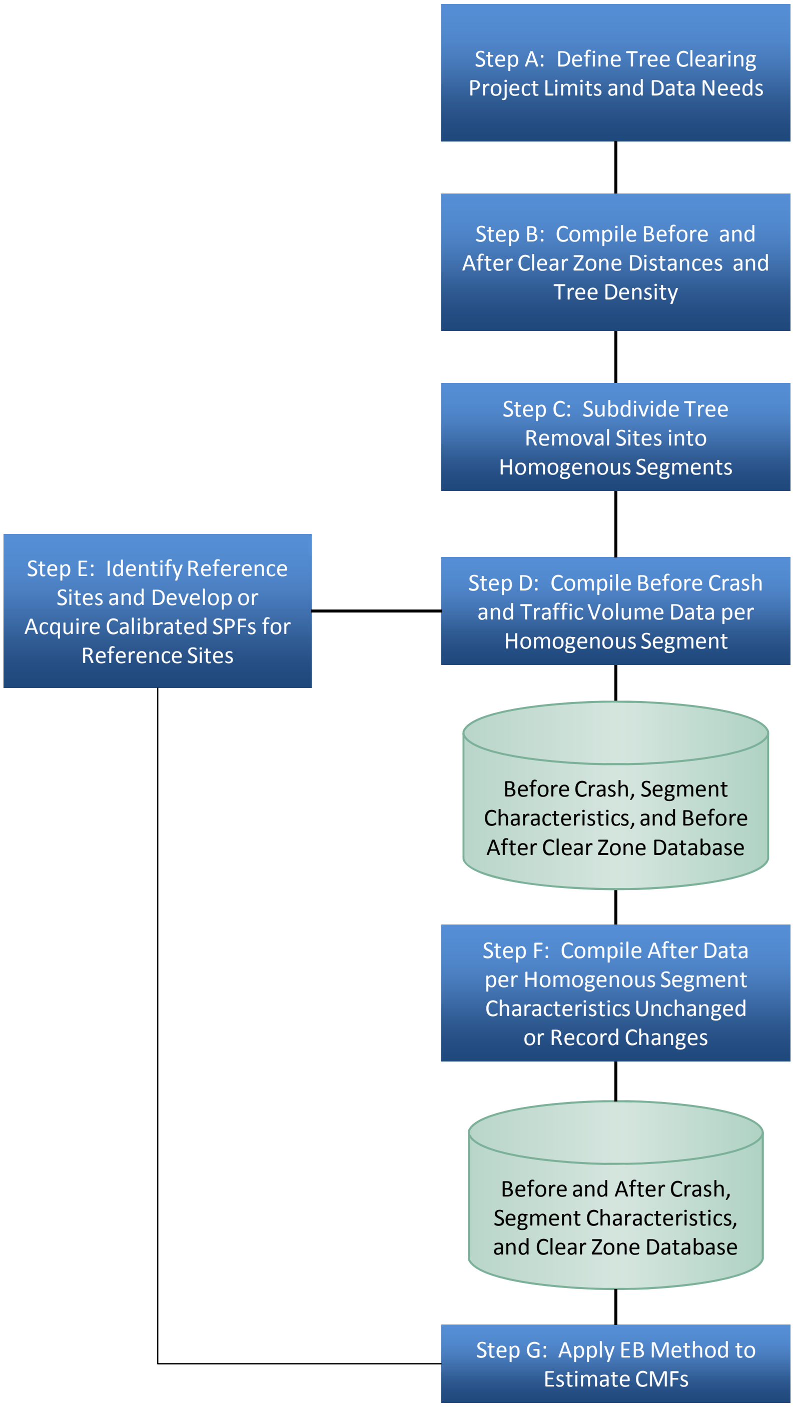


Figure 7. Data Collection Flow Chart

As outlined in Figure 7, the steps are:

- **Step A:** Define tree clearing project limits and data needs. ADOT begins by specifying tree removal projects and field data collection requirements. As appropriate, landscape architects should be included in the process. ADOT provides field data collection materials to contractors as appropriate. The project limits should be easily referenced so that tree density and recovery area can be easily converted to milepost measurements from the field measured distances (e.g., in feet or stations from project starting limit).
- **Step B:** ADOT compiles recovery area lateral distances and tree density before and after tree removal at each site. Tree density will be recorded as low (16 trees per acre), medium (17 to 32 trees per acre) and high (32 trees per acre). Recovery area lateral distances before and after tree removal will be recorded. If recovery area lateral distance along the road (before or after) changes by more than 5 feet, the beginning and ending milepost of these changes should be recorded. Photos before and after tree removal should also be taken. Finally, if tree density changes across the tree removal site, the beginning and ending milepost should be recorded.
- **Step C:** ADOT begins developing the analysis database by subdividing (as appropriate) tree removal sites into homogenous segments. Homogenous segments will be defined according to roadway characteristics, features, recovery area lateral distance, and tree density (depending on degree of variance). This information is compiled in a database to facilitate SPF development (if undertaken) and application of the EB method.
- **Step D:** ADOT compiles before-implementation crash and traffic volume data (three years before implementation) for the homogenous segments within each site (data developed in Steps A and B). The homogenous segments will be developed by roadway characteristics, traffic volume data, recovery area lateral distance, and tree density data. As such, the segmentation process will be iterative as field data (i.e., before and after recovery area lateral distances and before and after tree density information) are compiled.
- **Step E:** ADOT begins the CMF development process by identifying reference sites to the homogenous segments from Steps A through C. ADOT should then develop or acquire calibrated SPFs for these reference sites. One SPF will be needed for each type of homogenous segment.
- **Step F:** Three years after the tree removal implementation, ADOT compiles crash and traffic volume data for each homogenous segment. ADOT should record any changes to the study segment characteristics. This information is combined with the segment characteristics and crash data from Step C to form a database.

  Step G: ADOT applies the EB method with the calibrated SPFs from Step E and the combined crash and roadway characteristics database from Step F.

DATA NEEDS

Three categories of data are needed for this analysis:

- Site data that describe the location, context, traffic volume, and roadway characteristics of the site where ADOT implemented the tree removal (Steps A and B).
- Tree removal specifications that describe field data needs, such as longitudinal extent of tree removal, average horizontal distance to tree or group of trees removed, and average tree density before and after removal (Steps A and B).
- The number of crashes, crash type, and severity for three years before and three years after tree removal implementation (Steps C and D). Note that if crash frequency is low, in order to have a large enough sample size, it may be necessary to delay the study and compile two more years of data for a total of five years of after data. If this is the case, two additional years of data should be added to the before data set as well.

The site data specified below will support developing and conducting an EB analysis for estimating changes in crash frequency or severity that can be associated with tree removal in Arizona. If compiling all of these data is not possible, or data gaps remain, the analyst conducting the safety effectiveness evaluation will need to conduct exploratory and sensitivity analyses to understand the scope of analyses possible. Figure 7 can be a resource for these considerations.

Site Data

In Steps A and B of the process, ADOT will provide field contractors with field data needs per project site. Concurrently, for each tree removal site, ADOT will begin compiling data from existing ADOT databases or Google Earth as needed to segment sites and prepare for future analyses. The data needs and definitions follow. Note that some elements may vary by travel direction (indicated as "bidirectional" below).

- **Site:** A site is an HSIP tree removal project. If the site has trees removed from both sides of the roadway, each side of the roadway is considered a separate site. A site may have one or more homogenous segments on one or both sides of the roadway (depending on the tree removal project). The location is specified by the highway number and the beginning and ending mileposts of the site.
- **Homogenous segment**: A homogenous segment is a section of roadway with cross-sectional features, traffic volume, roadside features, and tree density that do not change more than as specified in the following bullets. A homogenous segment is a component of the site. Depending on roadway characteristics, a site may have different homogenous segments for each direction of travel. The location is specified by the highway number and the beginning and ending mileposts of the homogenous segment.
- **Terrain (bidirectional)**: Terrain could affect driver behaviors and vehicle performance. For instance, vehicles traveling downhill will have more momentum than vehicles traveling in the opposite direction. Terrain will be recorded by the field contractor as flat, rolling, or

mountainous. Assuming all other characteristics remain the same, a change from one terrain type to a different terrain type creates a new homogenous segment.

- **Roadway functional classification**: Functional classification indicates roadway and roadside characteristics and operating and posted speeds. ADOT has six functional classifications (interstate, freeway, principal arterial, minor arterial, major collector, and minor collector). These classifications are further divided by urban and rural area. ADOT has created FHWA-approved functional classification maps by counties, cities, towns, places, and tribes (ADOT 2016a). These maps can be used as references. Assuming all other characteristics remain the same, a change from one roadway functional classification to a different functional classification creates a new homogenous segment.
- **Posted speed limit**: ADOT establishes posted speed limits to be as near as practicable to the speed at or below which 85 percent of the drivers are traveling (ADOT 2016b). Posted speed can be revised downward based on factors such as crash experience, roadway geometrics, and adjacent development. The posted speed can be recorded in the field. A desirable option is for the consultant/ADOT designers to collect average vehicle traveling speed before and after tree removal to evaluate whether tree removal increases speed. If speed data are desired, a speed study would need to be conducted by ADOT. Assuming all other characteristics remain the same, a change from one posted speed limit to a different posted speed limit creates a new homogenous segment.
- **Number of lanes (bidirectional)**: Number of travel lanes (including turning lanes or passing lanes) at each site will be compiled from existing ADOT databases. Note that the number of travel lanes of a roadway segment may vary by travel direction. ADOT has this information in its annual state highway system log (ADOT 2016c). Assuming all other characteristics remain the same, a change in the number of lanes per direction creates a new homogenous segment.
- **Lane width:** Based on the AASHTO (2010) HSM, lane width is measured to 0.1 foot of precision. Table 8 recommends rounded lane widths to assist with segmentation. A change in lane width greater than 0.5 foot creates a new homogenous segment. These data will be compiled from existing ADOT databases or can be estimated from Google Earth if gaps exist.

Table 8. Rounded Lane Width for Roadway Segmentation

Measured Lane Width (Feet)	Rounded Lane Width (Feet)
9.2 or less	9 or less
9.3 to 9.7	9.5
9.8 to 10.2	10
10.3 to 10.7	10.5
10.8 to 11.2	11
11.3 to 11.7	11.5
11.8 or more	12 or more

Source: AASHTO (2010) HSM, Volume 2

- **Shoulder width (bidirectional):** Shoulder width is defined as the distance from the edge of the travel lane to the edge of the roadway. Based on the AASHTO (2010) HSM, shoulder width is measured to 0.1 foot of precision. Table 9 recommends rounded shoulder widths to assist with segmentation. A change in shoulder width greater than 1 foot creates a new homogenous segment. These data will be compiled from existing ADOT databases or can be estimated from Google Earth if gaps exist.

Table 9. Rounded Shoulder Width for Roadway Segmentation

Measured Shoulder Width (Feet)	Rounded Shoulder Width (Feet)
0.5 or less	0
0.6 to 1.5	1
1.6 to 2.5	2
2.6 to 3.5	3
3.6 to 4.5	4
4.6 to 5.5	5
5.6 to 6.5	6
6.6 to 7.5	7
7.6 or more	8 or more

Source: AASHTO (2010) HSM, Volume 2

- **Shoulder type (bidirectional)**: ADOT designers can extract shoulder type (e.g., asphalt, portland cement concrete, gravel, or dirt) from ADOT's highway system log. Optionally, the field contractor can collect/verify this information onsite. Assuming all other characteristics remain the same, a change in shoulder type per direction creates a new homogenous segment.
- **Side slopes (bidirectional)**: In some cases, a site might have a side slope, where the cross-section slopes down or up from the shoulder edge. Applying concepts from the HSM CMF for flattening side slopes, a change of side slope by more than either 1 foot of horizontal distance or 1 foot of vertical distance or both will create a new homogenous segment.
- **Horizontal curvature**: Horizontal curves are defined as gradual roadway transitions between two straight roadways. If the homogenous segment includes a horizontal curve, the curve should be identified as a separate homogenous segment. The length of curve and curve radius data should be recorded and can be requested from ADOT's Geographic Information System (GIS)/Multimodal Planning Division. The radius of the curve site should be available from as-built drawings or can be estimated from Google Earth.
- **AADT volume (bidirectional)**: Daily traffic volume is recorded on select mileposts on all Arizona state highways. The most recent AADT data collected by ADOT are for 2012 and are available online as AADT reports (ADOT 2016d). Note that a site may be located between two traffic volume collection mileposts. In this case, the daily traffic volume at the site should be the weighted average of the traffic volumes and distance between the recorded traffic volume sites. The AADT should be recorded each year for three years before and three years after tree removal. This information should include the truck factor or the percentage of the AADT volume generated by trucks or commercial vehicles. Truck factor is available from ADOT's AADT reports.

- **Presence of other roadside feature**: ADOT safety staff should compile and document the location and extent of other roadside features (e.g., guardrails (presence and type), fences, walls, and call boxes) at each project site. These features are available in ADOT's highway Feature Inventory System (FIS). The milepost and offset of features within the recovery area lateral distance should be recorded.
- **Presence of driveways and driveway density**: If driveways are present, the number of driveways per mile should be recorded. The HSM CMF for driveway density is more sensitive to changes in driveway density at lower traffic volumes. A change of driveway density greater than two driveways per mile would yield a new segment. A driveway providing access to a facility where only one or two trips per day are made (e.g., a farm or private residence) should not be included in this analysis.

The site elements described above may change over time. To evaluate before and after safety effectiveness as detailed in the next section, the data may need to be confirmed by ADOT safety staff during the after data collection period and prior to analyses (Step F).

Tree Removal Implementation Specifications

For the purposes of this analysis, a tree is defined as vegetation with trunk diameter greater than 4 inches (AASHTO and TRB 2016). Similarly, a group of trees or shrubs with a collective diameter greater than 4 inches also is considered a tree. The ADOT designer and field contractor need to record the following key specifications of the work conducted on a segment:

- **Date:** Date and year tree removal project is begun and completed.
- **Average density of trees along the roadway before and after tree removal**: The density of trees removed is defined as the number of trees per acre. The density before tree removal and after tree removal should be recorded. If field contractors conducted tree thinning beyond the recovery area, they should record the distance from the edge of the traveled way to the tree line, as well as the average density of trees in the area where thinning was conducted. This information will need to be converted to milepost to match other ADOT data. Based on specifications provided by ADOT, tree density should be recorded as low (16 trees per acre), medium (17 to 32 trees per acre) and high (32 trees per acre).
- **Recovery area lateral distance (bidirectional)**: In this project, recovery area lateral distance is the actual horizontal distance from the edge of the traveled way to the tree line and includes the shoulder. Field contractors will record this distance in feet. Note that the recovery area lateral distance can vary along different parts of a site. If this variation is within 5 feet, the recovery area lateral distance can be the average distance along the segment. Recovery area lateral distance variation greater than 5 feet would reflect a new segment. Again, beginning and ending milepost of the recovery area lateral distance would be recorded and integrated into the database. If appropriate, the recovery area for the median also should be recorded.

The field contractor also should collect before and after photos and videos, including the following:

- Photos (looking along the roadway and the roadside) before tree removal implementation
- Photos (looking along the roadway and the roadside) immediately after the tree removal has been completed
- If possible, a video log of the site before and after tree removal implementation

Crash Data

To evaluate safety effectiveness, ADOT will consider questions such as:

- Whether the site has seen a decrease in recorded crashes with trees, shrubs, or stumps as one of the crash events.
- Whether the site has experienced a change in crash type or severity, but not frequency. For instance, a site that previously experienced many overturn crashes with tree collisions could see only overturn crashes after tree removal.
- Whether the site has experienced a shift in crash severity. For example, a site might experience fewer severe crashes after tree removal because of a decrease in fixed object crashes.

As such, during the period before data collection, ADOT safety staff should record all crashes on the segments, as well as their crash type and severity (i.e., fatal, incapacitating, moderate, minor, and no injuries). The ADOT Crash Report Form Box 31 indicates the sequence of crash events and can be used to record crash type. ADOT safety staff should extract all crashes with trees, shrubs, or stumps in any of the sequence of events (Form Box 31). Note again that if crash frequency is low, it may be necessary to change the study period from three to five years. If so, two additional years of before crash and traffic volume data should be collected, as well as two additional years of after period data.

Data Collection Form and Organization

Table 10 is an example of a form for field contractors to use at the time of tree removal. The field contractor would collect the following information: the before and after recovery area lateral distance, the before and after average tree density and whether tree thinning beyond the clear zone was conducted, the distance from the traveled way to the tree line, and the average density of trees before and after thinning.

Table 10. Example Field Data Collection Form

Tree Removal Work Specifications

Date of field work:
Site location (highway number, beginning & ending mileposts): S 260, 5.2, 10.7
Segment location (highway number, beginning & ending mileposts): S 260, 7.2, 10.0

	Before	After
Clear zone distance (ft)		
Clear zone – average density of trees		

If thinning was conducted:
Distance from edge of travelled way to tree line (ft):
Average density of trees (trees/acre)

Table 11 shows how the information from the data collection process can be organized for the effectiveness analysis. This table provides two sample records. Note that each data record or row represents a homogenous roadway segment at a site. For the purpose of this example, only segment data variables with values that have changed after tree removal are shown in the after tree removal implementation columns.

Table 11. Data Organization Example

		Before Tree Removal Implementation – Segment Data														After Tree Removal Implementation – Segment Data				
Site location (highway number, beginning MP, ending MP)	Segment location (highway number, beginning MP, ending MP)	Terrain (categories: flat, rolling, or mountainous)	Roadway functional classification	Posted speed (miles per hour)	Number of lanes	Lane width	Shoulder width (in feet)	Shoulder type (description)	Clear zone distance (in feet)	Average annual daily traffic (AADT) volume - year 1	Average annual daily traffic (AADT) volume - year 2	Average annual daily traffic (AADT) volume - year 3	Side Slope (slope of angle)	Horizontal curve (radius in feet)	Driveway density	Shoulder width (in feet)	Clear zone distance (in feet)	Average Annual Daily Traffic (AADT) volume - year 1	Average Annual Daily Traffic (AADT) volume - year 2	Average Annual Daily Traffic (AADT) volume - year 3
S 260, 5.2, 10.7	S 260, 6.5, 7.8	Flat	Major collection	55	2	12	3	Asphalt	25	5500	6100	6000	None	None	No driveways	3	30	6100	6200	6200
S 260, 5.2, 10.7	S 260, 7.8, 9.2	Flat	Major collection	55	2	12	2	Asphalt	20	5600	6000	5900	None	None	No driveways	3	30	6000	6100	6200

		Tree Removal Specifications		
Site location (highway number, beginning MP, ending MP)	Segment location (highway number, beginning MP, ending MP)	Removal job specifications (highway number, beginning MP, ending MP)	Date and year of implementation	Average density of trees removed (trees per acre)
S 260, 5.2, 10.7	S 260, 6.5, 7.8	S 260, 6.6, 7.5	7/12/2015	15
S 260, 5.2, 10.7	S 260, 7.8, 9.2	S 260, 8.2, 9.0	7/12/2015	20

		Total Crashes with One of the Sequence of Events as Collision with Tree, Shrub, or Stump											
		Three-Year Period Before Tree Removal*						Three-Year Period After Tree Removal*					
Site location (highway number, beginning MP, ending MP)	Segment location (highway number, beginning MP, ending MP)	Total crashes	Fatal crashes	Severe injury crashes	Moderate injury crashes	Minor injury crashes	Property damage only crashes	Total crashes	Fatal crashes	Severe injury crashes	Moderate injury crashes	Minor injury crashes	Property damage only crashes
S 260, 5.2, 10.7	S 260, 6.5, 7.8	31	1	2	5	8	15	15	0	0	2	3	10
S 260, 5.2, 10.7	S 260, 7.8, 9.2	23	0	1	3	7	12	11	0	1	0	1	9

*Crash data would be recorded per year over the three-year period.

CHAPTER 5. CONCLUSION

Conducting a before-after safety effectiveness evaluation is a multiyear and multiphase process. To complete the evaluation, the before data are collected, the sites are treated, the after data are collected for three years, and the safety effectiveness analysis is made at the end of that period.

The research team anticipates that an EB analysis, as described in Chapter 3, would be the most appropriate method for estimating safety effectiveness. It would be necessary to have calibrated SPFs to complete this analysis.

The data needed to conduct the before-after analysis are detailed in Chapter 4, and the steps involved in the overall process are shown in Figure 7. In summary, the data relate to crash type and severity, roadway characteristics and traffic volume, and specifics related to tree removal. The majority of the data needed for these analyses are available in existing ADOT crash, roadway, and traffic volume databases; however a small amount of field data will need to be collected and transferred to the analysis database.

It is recommended that ADOT compile data for each tree removal site into a specific database or spreadsheet developed for this analysis. Note that the data for reference sites would also be included and analyzed in order to develop safety performance functions, as explained in Chapter 3. It would also be necessary for ADOT field staff or the contractor to collect before-and-after tree densities and recovery area lateral distances at each project site as part of the tree removal field work. Chapter 4 includes specifications for this data. After all of the tree removal projects are completed and the data are compiled, ADOT staff (or consultants with statistical analysis expertise) would conduct the analysis to estimate the CMF related to tree removal projects in Arizona.

A CMF related to tree removal in Arizona could be a valuable addition to safety research and literature. The CMF could support a cost-benefit analysis that would demonstrate the value of the tree removal project investments in Arizona. In addition, conducting state-specific CMF research would demonstrate to other states the feasibility and value of conducting such analyses.

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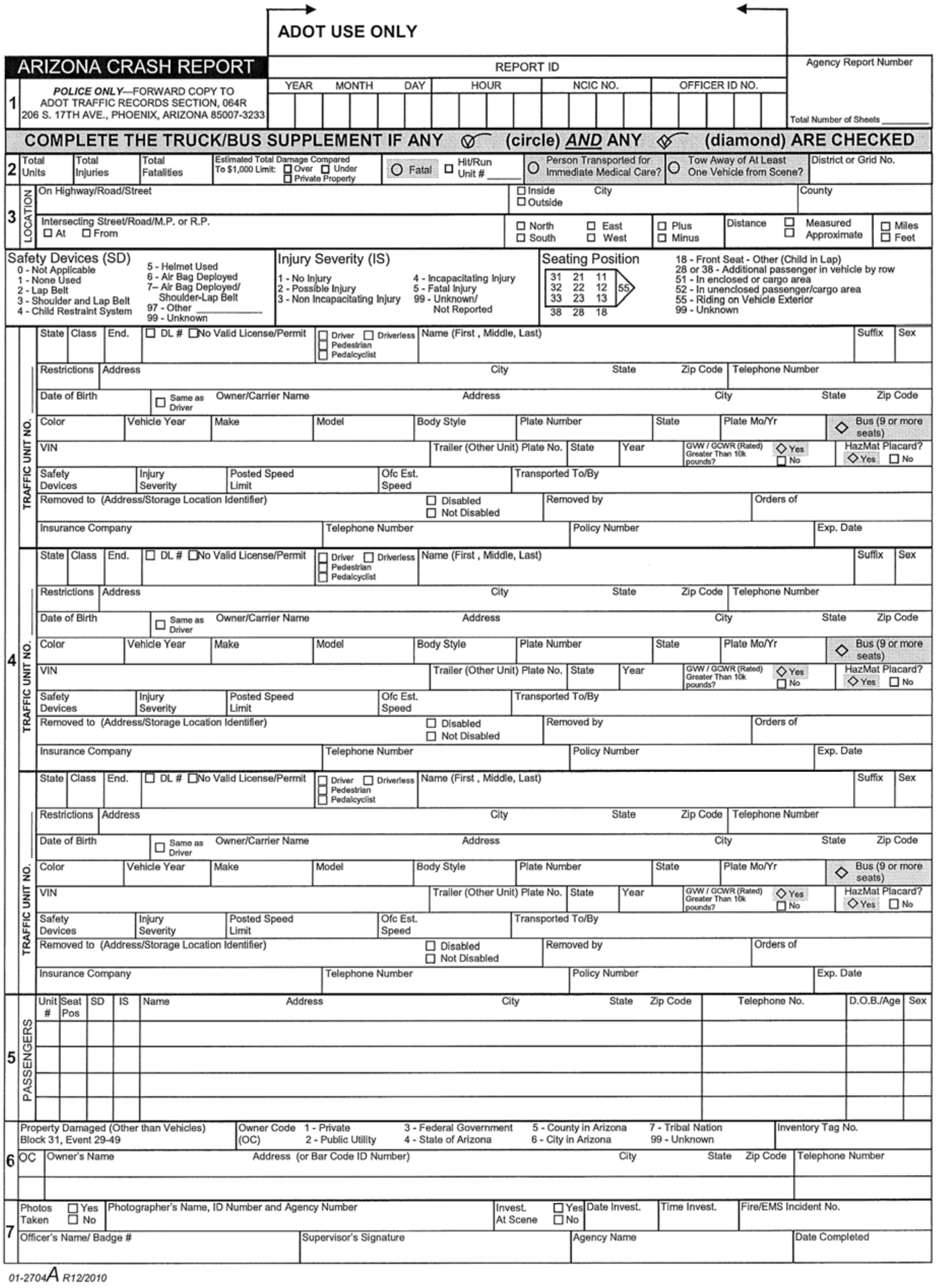
APPENDIX A. NEW YORK STATE DOT ACCIDENT REDUCTION FACTORS

Crash Type	Crash Severity	CMF 1. AADT per lane <5000 2. AADT per lane >5000	Statistical Significance
All	All	1. Reduced by 43% 2. Reduced by 32%	Yes
All	Injury	1. Reduced by 41% 2. Reduced by 19%	
All	Property damage only	1. Reduced by 35%	
Nonreportable	All	1. Reduced by 51%	
Dry road	All	2. Reduced by 16%	
Wet road	All	2. Reduced by 26%	
Snow/ice/slush road	All	2. Reduced by 31%	
Overtaking	All	2. Reduced by 64%	
Right angle	All	1. Reduced by 63% 2. Reduced by 60%	
Fixed object (tree, hydrant, and other)	All	2. Reduced by 45%	
All fixed object and run-off-road	All	2. Reduced by 28%	
Day	All	1. Reduced by 48% 2. Reduced by 20%	
Day and wet road	All	2. Reduced by 37%	
Night	All	2. Reduced by 22%	
Road	All	2. Reduced by 36%	
Dry road	All	1. Reduced by 16%	No
Wet road	All	1. Reduced by 24%	
Snow/ice/slush road	All	1. Reduced by 32%	
All fixed object and run-off-road	All	1. Reduced by 9%	

APPENDIX B. DATA USED IN ASSESSING EFFECTIVENESS OF TREE OR FIXED OBJECT REMOVAL PROJECTS

Data Type	Detailed Description	Study
Crash type	1. Total crashes 2. Run-off-road casualty crashes 3. Overtaking, right-angle, https://maps.gstatic.com/mapfiles/mapcontrols3d7.png fixed object (tree/hydrant/other), all fixed object, and run-off-road crashes 4. Type of fixed object crash (trees, poles, culvert, mail box, bridge, guard rail, and other)	1. and 2. Dependent variable for most studies 3. New York State DOT 2012 4. Ogle et al. 2009
Crash condition	1. Dry road, wet road, snow/ice/slush road, day and night	1. New York State DOT 2012
Crash severity	1. Injury, fatal, and property damage only crashes 2. All accidents, injury, and property damage only	1. Dependent variable for most studies 2. New York State DOT 2012
Tree offset from the roadway/clear zone	1. Minimum setback, average setback, and 15th percentile setback 2. Clear zone as a part of a run-off-road crash prediction model: <2 m, 2 to 4 m, 4 to 8 m, and > 8 m	1. Maze et al. 2008 2. Jurewicz and Pyta 2010
ADT volume	1. AADT: 1500 to 6000 and 6000+ 2. One-way AADT: <1200 vehicles and >1200 vehicles 3. AADT > 5000 vehicles per lane vs. AADT <5000 vehicles per lane 4. Average daily total and truck volumes as variables in the CRF functions	1. Maze et al. 2008 2. Jurewicz and Pyta 2010 3. New York State DOT 2012 4. Hovey and Chowdhury 2005
Highway access type	1. As a variable in the CRF function: no access control, limited access control, and full access control	1. Hovey and Chowdhury 2005
Roadway functional classification	1. Six urban and six rural functional classes as variables in the CRF functions 2. Interstate, US primary, state primary, secondary, county, and other roads	1. Hovey and Chowdhury 2005 2. Ogle et al., 2009
Other roadway characteristics	1. Shoulder width as a variable in the CRF functions 2. Curve radius as a part of a run-off-road crash prediction model: <600 m, 600 to 1500 m, and >1500 m 3. Grade (%) as a part of a run-off-road crash prediction model: negative, positive, or zero 4. Traffic lane plus sealed shoulder width as part of a run-off-road crash prediction model: <3.5 m and >3.5 m 5. Straight roadway level, grade, and hillcrest 6. Curve roadway level, grade, and hillcrest 7. Speed limit at 30, 35, and 40 miles per hour	1. Hovey and Chowdhury 2005 2., 3., 4. Jurewicz and Pyta 2010 5., 6. Ogle et al. 2009 7. Maze et al. 2008

APPENDIX C. ADOT CRASH REPORT FORM



ADOT USE ONLY

ARIZONA CRASH REPORT

REPORT ID

Agency Report Number

1

POLICE ONLY—FORWARD COPY TO
ADOT TRAFFIC RECORDS SECTION, 064R
206 S. 17TH AVE., PHOENIX, ARIZONA 85007-3233

YEAR | MONTH | DAY | HOUR | NCIC NO. | OFFICER ID NO.

Total Number of Sheets ____

COMPLETE THE TRUCK/BUS SUPPLEMENT IF ANY ○✓ (circle) *AND* ANY ◇✓ (diamond) ARE CHECKED

2

Total Units | Total Injuries | Total Fatalities | Estimated Total Damage Compared To $1,000 Limit: ☐ Over ☐ Under ☐ Private Property | ○ Fatal | ☐ Hit/Run Unit # ____ | ○ Person Transported for Immediate Medical Care? | ○ Tow Away of At Least One Vehicle from Scene? | District or Grid No.

3 LOCATION

On Highway/Road/Street | ☐ Inside ☐ Outside | City | County

Intersecting Street/Road/M.P. or R.P. ☐ At ☐ From | ☐ North ☐ South | ☐ East ☐ West | ☐ Plus ☐ Minus | Distance ☐ Measured ☐ Approximate | ☐ Miles ☐ Feet

Safety Devices (SD)
0 - Not Applicable
1 - None Used
2 - Lap Belt
3 - Shoulder and Lap Belt
4 - Child Restraint System
5 - Helmet Used
6 - Air Bag Deployed
7– Air Bag Deployed/ Shoulder-Lap Belt
97 - Other ____________
99 - Unknown

Injury Severity (IS)
1 - No Injury
2 - Possible Injury
3 - Non Incapacitating Injury
4 - Incapacitating Injury
5 - Fatal Injury
99 - Unknown/ Not Reported

Seating Position

31	21	11	55
32	22	12	
33	23	13	
38	28	18	

18 - Front Seat - Other (Child in Lap)
28 or 38 - Additional passenger in vehicle by row
51 - In enclosed or cargo area
52 - In unenclosed passenger/cargo area
55 - Riding on Vehicle Exterior
99 - Unknown

TRAFFIC UNIT NO.

State | Class | End. | ☐ DL # ☐ No Valid License/Permit | ☐ Driver ☐ Driverless ☐ Pedestrian ☐ Pedalcyclist | Name (First , Middle, Last) | Suffix | Sex
Restrictions | Address | City | State | Zip Code | Telephone Number
Date of Birth | ☐ Same as Driver | Owner/Carrier Name | Address | City | State | Zip Code
Color | Vehicle Year | Make | Model | Body Style | Plate Number | State | Plate Mo/Yr | ◇ Bus (9 or more seats)
VIN | Trailer (Other Unit) Plate No. | State | Year | GVW / GCWR (Rated) Greater Than 10k pounds? ◇ Yes ☐ No | HazMat Placard? ◇ Yes ☐ No
Safety Devices | Injury Severity | Posted Speed Limit | Ofc Est. Speed | Transported To/By
Removed to (Address/Storage Location Identifier) | ☐ Disabled ☐ Not Disabled | Removed by | Orders of
Insurance Company | Telephone Number | Policy Number | Exp. Date

4 TRAFFIC UNIT NO.

State | Class | End. | ☐ DL # ☐ No Valid License/Permit | ☐ Driver ☐ Driverless ☐ Pedestrian ☐ Pedalcyclist | Name (First , Middle, Last) | Suffix | Sex
Restrictions | Address | City | State | Zip Code | Telephone Number
Date of Birth | ☐ Same as Driver | Owner/Carrier Name | Address | City | State | Zip Code
Color | Vehicle Year | Make | Model | Body Style | Plate Number | State | Plate Mo/Yr | ◇ Bus (9 or more seats)
VIN | Trailer (Other Unit) Plate No. | State | Year | GVW / GCWR (Rated) Greater Than 10k pounds? ◇ Yes ☐ No | HazMat Placard? ◇ Yes ☐ No
Safety Devices | Injury Severity | Posted Speed Limit | Ofc Est. Speed | Transported To/By
Removed to (Address/Storage Location Identifier) | ☐ Disabled ☐ Not Disabled | Removed by | Orders of
Insurance Company | Telephone Number | Policy Number | Exp. Date

TRAFFIC UNIT NO.

State | Class | End. | ☐ DL # ☐ No Valid License/Permit | ☐ Driver ☐ Driverless ☐ Pedestrian ☐ Pedalcyclist | Name (First , Middle, Last) | Suffix | Sex
Restrictions | Address | City | State | Zip Code | Telephone Number
Date of Birth | ☐ Same as Driver | Owner/Carrier Name | Address | City | State | Zip Code
Color | Vehicle Year | Make | Model | Body Style | Plate Number | State | Plate Mo/Yr | ◇ Bus (9 or more seats)
VIN | Trailer (Other Unit) Plate No. | State | Year | GVW / GCWR (Rated) Greater Than 10k pounds? ◇ Yes ☐ No | HazMat Placard? ◇ Yes ☐ No
Safety Devices | Injury Severity | Posted Speed Limit | Ofc Est. Speed | Transported To/By
Removed to (Address/Storage Location Identifier) | ☐ Disabled ☐ Not Disabled | Removed by | Orders of
Insurance Company | Telephone Number | Policy Number | Exp. Date

5 PASSENGERS

Unit #	Seat Pos	SD	IS	Name	Address	City	State	Zip Code	Telephone No.	D.O.B./Age	Sex

6

Property Damaged (Other than Vehicles) Block 31, Event 29-49 | Owner Code (OC) 1 - Private 2 - Public Utility 3 - Federal Government 4 - State of Arizona 5 - County in Arizona 6 - City in Arizona 7 - Tribal Nation 99 - Unknown | Inventory Tag No.

OC | Owner's Name | Address (or Bar Code ID Number) | City | State | Zip Code | Telephone Number

7

Photos Taken ☐ Yes ☐ No | Photographer's Name, ID Number and Agency Number | Invest. At Scene ☐ Yes ☐ No | Date Invest. | Time Invest. | Fire/EMS Incident No.
Officer's Name/ Badge # | Supervisor's Signature | Agency Name | Date Completed

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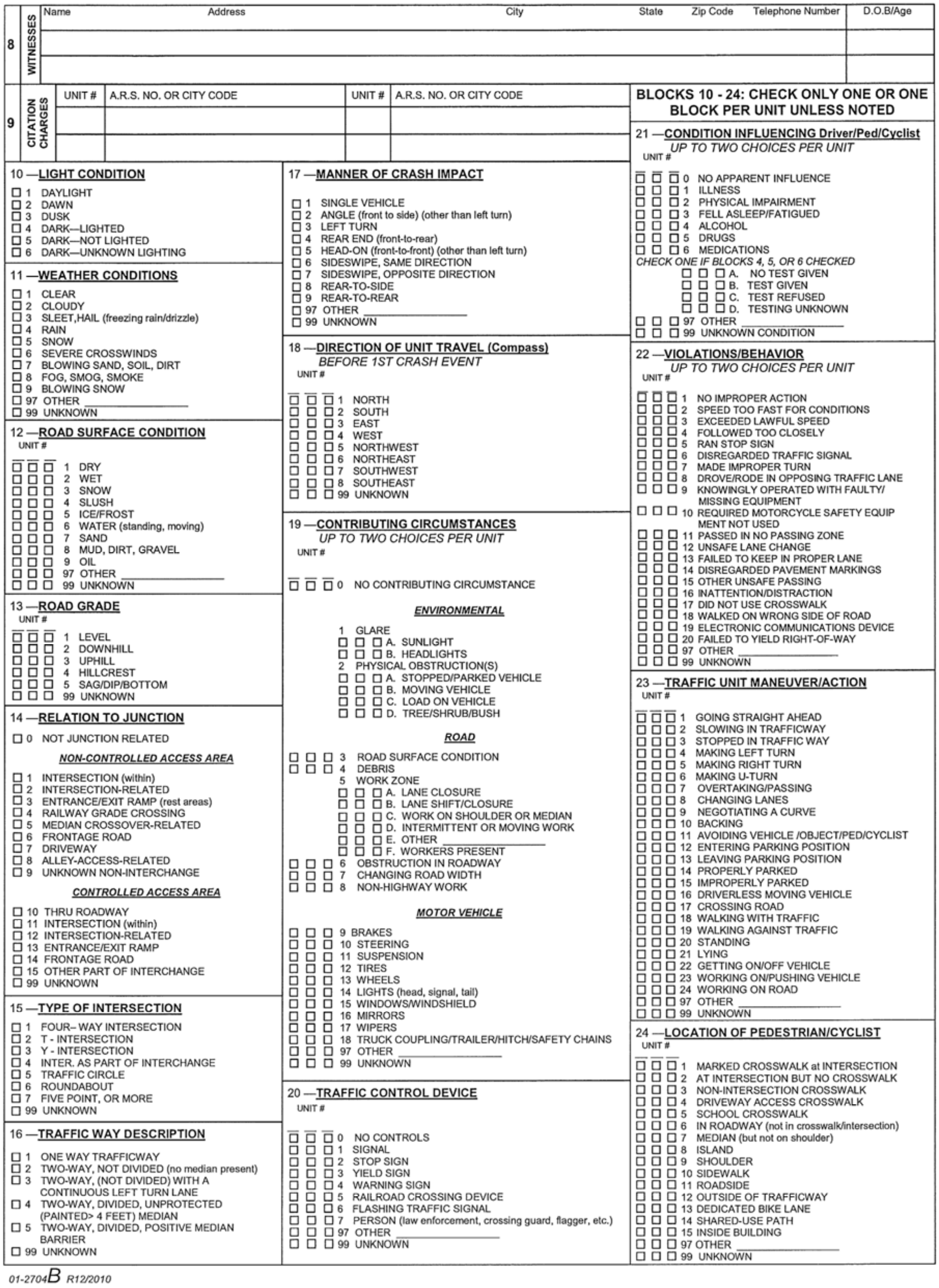


8 WITNESSES

Name	Address	City	State	Zip Code	Telephone Number	D.O.B/Age

9 CITATION CHARGES

UNIT #	A.R.S. NO. OR CITY CODE	UNIT #	A.R.S. NO. OR CITY CODE

10 —**LIGHT CONDITION**

☐ 1 DAYLIGHT
☐ 2 DAWN
☐ 3 DUSK
☐ 4 DARK—LIGHTED
☐ 5 DARK—NOT LIGHTED
☐ 6 DARK—UNKNOWN LIGHTING

11 —**WEATHER CONDITIONS**

☐ 1 CLEAR
☐ 2 CLOUDY
☐ 3 SLEET,HAIL (freezing rain/drizzle)
☐ 4 RAIN
☐ 5 SNOW
☐ 6 SEVERE CROSSWINDS
☐ 7 BLOWING SAND, SOIL, DIRT
☐ 8 FOG, SMOG, SMOKE
☐ 9 BLOWING SNOW
☐ 97 OTHER ______________
☐ 99 UNKNOWN

12 —**ROAD SURFACE CONDITION**

UNIT #

☐ ☐ ☐ 1 DRY
☐ ☐ ☐ 2 WET
☐ ☐ ☐ 3 SNOW
☐ ☐ ☐ 4 SLUSH
☐ ☐ ☐ 5 ICE/FROST
☐ ☐ ☐ 6 WATER (standing, moving)
☐ ☐ ☐ 7 SAND
☐ ☐ ☐ 8 MUD, DIRT, GRAVEL
☐ ☐ ☐ 9 OIL
☐ ☐ ☐ 97 OTHER ______________
☐ ☐ ☐ 99 UNKNOWN

13 —**ROAD GRADE**

UNIT #

☐ ☐ ☐ 1 LEVEL
☐ ☐ ☐ 2 DOWNHILL
☐ ☐ ☐ 3 UPHILL
☐ ☐ ☐ 4 HILLCREST
☐ ☐ ☐ 5 SAG/DIP/BOTTOM
☐ ☐ ☐ 99 UNKNOWN

14 —**RELATION TO JUNCTION**

☐ 0 NOT JUNCTION RELATED

NON-CONTROLLED ACCESS AREA

☐ 1 INTERSECTION (within)
☐ 2 INTERSECTION-RELATED
☐ 3 ENTRANCE/EXIT RAMP (rest areas)
☐ 4 RAILWAY GRADE CROSSING
☐ 5 MEDIAN CROSSOVER-RELATED
☐ 6 FRONTAGE ROAD
☐ 7 DRIVEWAY
☐ 8 ALLEY-ACCESS-RELATED
☐ 9 UNKNOWN NON-INTERCHANGE

CONTROLLED ACCESS AREA

☐ 10 THRU ROADWAY
☐ 11 INTERSECTION (within)
☐ 12 INTERSECTION-RELATED
☐ 13 ENTRANCE/EXIT RAMP
☐ 14 FRONTAGE ROAD
☐ 15 OTHER PART OF INTERCHANGE
☐ 99 UNKNOWN

15 —**TYPE OF INTERSECTION**

☐ 1 FOUR- WAY INTERSECTION
☐ 2 T - INTERSECTION
☐ 3 Y - INTERSECTION
☐ 4 INTER. AS PART OF INTERCHANGE
☐ 5 TRAFFIC CIRCLE
☐ 6 ROUNDABOUT
☐ 7 FIVE POINT, OR MORE
☐ 99 UNKNOWN

16 —**TRAFFIC WAY DESCRIPTION**

☐ 1 ONE WAY TRAFFICWAY
☐ 2 TWO-WAY, NOT DIVIDED (no median present)
☐ 3 TWO-WAY, (NOT DIVIDED) WITH A CONTINUOUS LEFT TURN LANE
☐ 4 TWO-WAY, DIVIDED, UNPROTECTED (PAINTED> 4 FEET) MEDIAN
☐ 5 TWO-WAY, DIVIDED, POSITIVE MEDIAN BARRIER
☐ 99 UNKNOWN

17 —**MANNER OF CRASH IMPACT**

☐ 1 SINGLE VEHICLE
☐ 2 ANGLE (front to side) (other than left turn)
☐ 3 LEFT TURN
☐ 4 REAR END (front-to-rear)
☐ 5 HEAD-ON (front-to-front) (other than left turn)
☐ 6 SIDESWIPE, SAME DIRECTION
☐ 7 SIDESWIPE, OPPOSITE DIRECTION
☐ 8 REAR-TO-SIDE
☐ 9 REAR-TO-REAR
☐ 97 OTHER ______________
☐ 99 UNKNOWN

18 —**DIRECTION OF UNIT TRAVEL (Compass)**
BEFORE 1ST CRASH EVENT

UNIT #

☐ ☐ ☐ 1 NORTH
☐ ☐ ☐ 2 SOUTH
☐ ☐ ☐ 3 EAST
☐ ☐ ☐ 4 WEST
☐ ☐ ☐ 5 NORTHWEST
☐ ☐ ☐ 6 NORTHEAST
☐ ☐ ☐ 7 SOUTHWEST
☐ ☐ ☐ 8 SOUTHEAST
☐ ☐ ☐ 99 UNKNOWN

19 —**CONTRIBUTING CIRCUMSTANCES**
UP TO TWO CHOICES PER UNIT

UNIT #

☐ ☐ ☐ 0 NO CONTRIBUTING CIRCUMSTANCE

ENVIRONMENTAL

1 GLARE
☐ ☐ ☐ A. SUNLIGHT
☐ ☐ ☐ B. HEADLIGHTS
2 PHYSICAL OBSTRUCTION(S)
☐ ☐ ☐ A. STOPPED/PARKED VEHICLE
☐ ☐ ☐ B. MOVING VEHICLE
☐ ☐ ☐ C. LOAD ON VEHICLE
☐ ☐ ☐ D. TREE/SHRUB/BUSH

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

MOTOR VEHICLE

☐ ☐ ☐ 9 BRAKES
☐ ☐ ☐ 10 STEERING
☐ ☐ ☐ 11 SUSPENSION
☐ ☐ ☐ 12 TIRES
☐ ☐ ☐ 13 WHEELS
☐ ☐ ☐ 14 LIGHTS (head, signal, tail)
☐ ☐ ☐ 15 WINDOWS/WINDSHIELD
☐ ☐ ☐ 16 MIRRORS
☐ ☐ ☐ 17 WIPERS
☐ ☐ ☐ 18 TRUCK COUPLING/TRAILER/HITCH/SAFETY CHAINS
☐ ☐ ☐ 97 OTHER ______________
☐ ☐ ☐ 99 UNKNOWN

20 —**TRAFFIC CONTROL DEVICE**

UNIT #

☐ ☐ ☐ 0 NO CONTROLS
☐ ☐ ☐ 1 SIGNAL
☐ ☐ ☐ 2 STOP SIGN
☐ ☐ ☐ 3 YIELD SIGN
☐ ☐ ☐ 4 WARNING SIGN
☐ ☐ ☐ 5 RAILROAD CROSSING DEVICE
☐ ☐ ☐ 6 FLASHING TRAFFIC SIGNAL
☐ ☐ ☐ 7 PERSON (law enforcement, crossing guard, flagger, etc.)
☐ ☐ ☐ 97 OTHER ______________
☐ ☐ ☐ 99 UNKNOWN

BLOCKS 10 - 24: CHECK ONLY ONE OR ONE BLOCK PER UNIT UNLESS NOTED

21 —**CONDITION INFLUENCING Driver/Ped/Cyclist**
UP TO TWO CHOICES PER UNIT

UNIT #

☐ ☐ ☐ 0 NO APPARENT INFLUENCE
☐ ☐ ☐ 1 ILLNESS
☐ ☐ ☐ 2 PHYSICAL IMPAIRMENT
☐ ☐ ☐ 3 FELL ASLEEP/FATIGUED
☐ ☐ ☐ 4 ALCOHOL
☐ ☐ ☐ 5 DRUGS
☐ ☐ ☐ 6 MEDICATIONS
CHECK ONE IF BLOCKS 4, 5, OR 6 CHECKED
☐ ☐ ☐ A. NO TEST GIVEN
☐ ☐ ☐ B. TEST GIVEN
☐ ☐ ☐ C. TEST REFUSED
☐ ☐ ☐ D. TESTING UNKNOWN
☐ ☐ ☐ 97 OTHER ______________
☐ ☐ ☐ 99 UNKNOWN CONDITION

22 —**VIOLATIONS/BEHAVIOR**
UP TO TWO CHOICES PER UNIT

UNIT #

☐ ☐ ☐ 1 NO IMPROPER ACTION
☐ ☐ ☐ 2 SPEED TOO FAST FOR CONDITIONS
☐ ☐ ☐ 3 EXCEEDED LAWFUL SPEED
☐ ☐ ☐ 4 FOLLOWED TOO CLOSELY
☐ ☐ ☐ 5 RAN STOP SIGN
☐ ☐ ☐ 6 DISREGARDED TRAFFIC SIGNAL
☐ ☐ ☐ 7 MADE IMPROPER TURN
☐ ☐ ☐ 8 DROVE/RODE IN OPPOSING TRAFFIC LANE
☐ ☐ ☐ 9 KNOWINGLY OPERATED WITH FAULTY/ MISSING EQUIPMENT
☐ ☐ ☐ 10 REQUIRED MOTORCYCLE SAFETY EQUIPMENT NOT USED
☐ ☐ ☐ 11 PASSED IN NO PASSING ZONE
☐ ☐ ☐ 12 UNSAFE LANE CHANGE
☐ ☐ ☐ 13 FAILED TO KEEP IN PROPER LANE
☐ ☐ ☐ 14 DISREGARDED PAVEMENT MARKINGS
☐ ☐ ☐ 15 OTHER UNSAFE PASSING
☐ ☐ ☐ 16 INATTENTION/DISTRACTION
☐ ☐ ☐ 17 DID NOT USE CROSSWALK
☐ ☐ ☐ 18 WALKED ON WRONG SIDE OF ROAD
☐ ☐ ☐ 19 ELECTRONIC COMMUNICATIONS DEVICE
☐ ☐ ☐ 20 FAILED TO YIELD RIGHT-OF-WAY
☐ ☐ ☐ 97 OTHER ______________
☐ ☐ ☐ 99 UNKNOWN

23 —**TRAFFIC UNIT MANEUVER/ACTION**

UNIT #

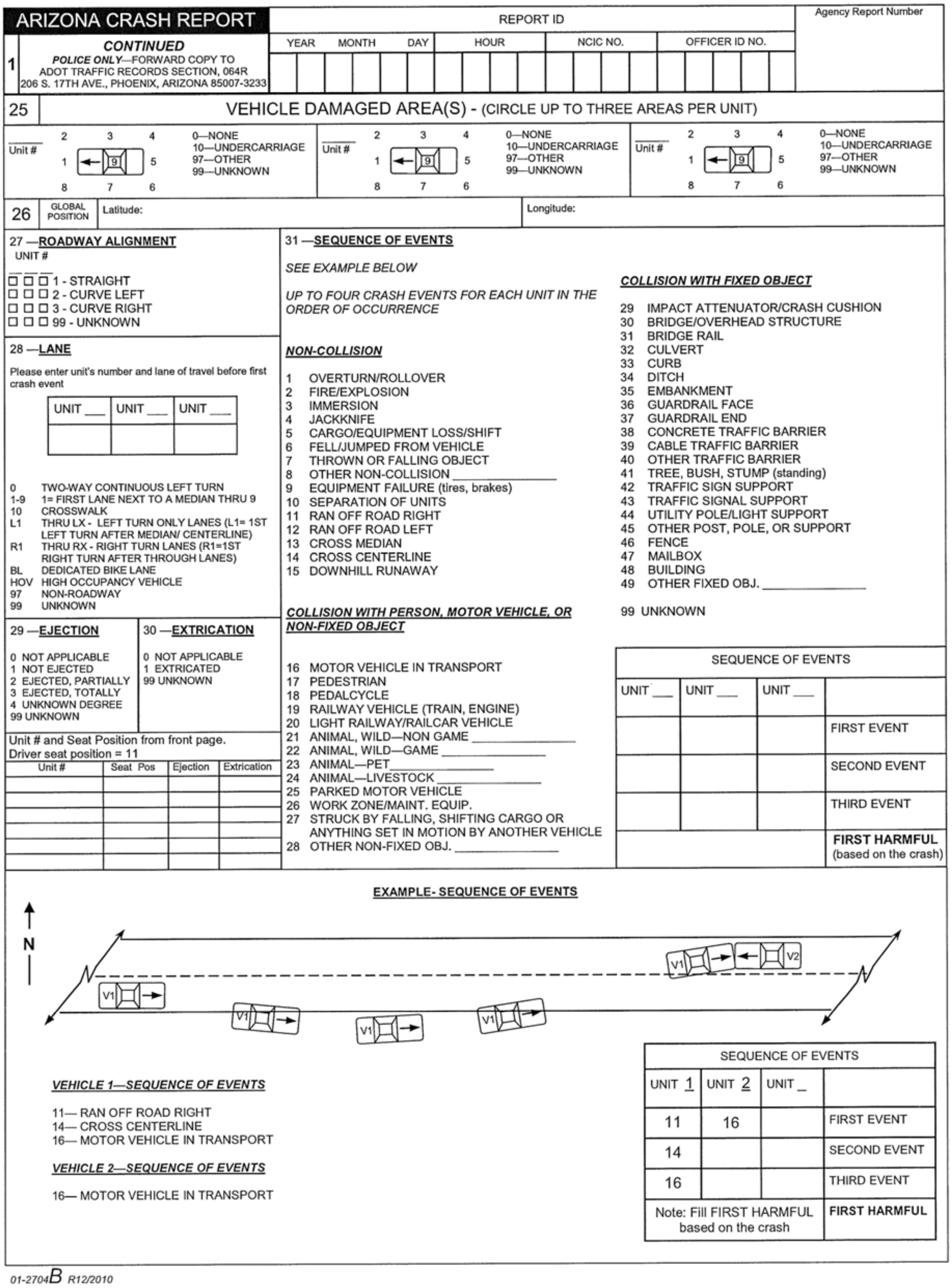
☐ ☐ ☐ 1 GOING STRAIGHT AHEAD
☐ ☐ ☐ 2 SLOWING IN TRAFFICWAY
☐ ☐ ☐ 3 STOPPED IN TRAFFIC WAY
☐ ☐ ☐ 4 MAKING LEFT TURN
☐ ☐ ☐ 5 MAKING RIGHT TURN
☐ ☐ ☐ 6 MAKING U-TURN
☐ ☐ ☐ 7 OVERTAKING/PASSING
☐ ☐ ☐ 8 CHANGING LANES
☐ ☐ ☐ 9 NEGOTIATING A CURVE
☐ ☐ ☐ 10 BACKING
☐ ☐ ☐ 11 AVOIDING VEHICLE /OBJECT/PED/CYCLIST
☐ ☐ ☐ 12 ENTERING PARKING POSITION
☐ ☐ ☐ 13 LEAVING PARKING POSITION
☐ ☐ ☐ 14 PROPERLY PARKED
☐ ☐ ☐ 15 IMPROPERLY PARKED
☐ ☐ ☐ 16 DRIVERLESS MOVING VEHICLE
☐ ☐ ☐ 17 CROSSING ROAD
☐ ☐ ☐ 18 WALKING WITH TRAFFIC
☐ ☐ ☐ 19 WALKING AGAINST TRAFFIC
☐ ☐ ☐ 20 STANDING
☐ ☐ ☐ 21 LYING
☐ ☐ ☐ 22 GETTING ON/OFF VEHICLE
☐ ☐ ☐ 23 WORKING ON/PUSHING VEHICLE
☐ ☐ ☐ 24 WORKING ON ROAD
☐ ☐ ☐ 97 OTHER ______________
☐ ☐ ☐ 99 UNKNOWN

24 —**LOCATION OF PEDESTRIAN/CYCLIST**

UNIT #

☐ ☐ ☐ 1 MARKED CROSSWALK at INTERSECTION
☐ ☐ ☐ 2 AT INTERSECTION BUT NO CROSSWALK
☐ ☐ ☐ 3 NON-INTERSECTION CROSSWALK
☐ ☐ ☐ 4 DRIVEWAY ACCESS CROSSWALK
☐ ☐ ☐ 5 SCHOOL CROSSWALK
☐ ☐ ☐ 6 IN ROADWAY (not in crosswalk/intersection)
☐ ☐ ☐ 7 MEDIAN (but not on shoulder)
☐ ☐ ☐ 8 ISLAND
☐ ☐ ☐ 9 SHOULDER
☐ ☐ ☐ 10 SIDEWALK
☐ ☐ ☐ 11 ROADSIDE
☐ ☐ ☐ 12 OUTSIDE OF TRAFFICWAY
☐ ☐ ☐ 13 DEDICATED BIKE LANE
☐ ☐ ☐ 14 SHARED-USE PATH
☐ ☐ ☐ 15 INSIDE BUILDING
☐ ☐ ☐ 97 OTHER ______________
☐ ☐ ☐ 99 UNKNOWN

01-2704B R12/2010



ARIZONA CRASH REPORT

CONTINUED

1
POLICE ONLY—FORWARD COPY TO
ADOT TRAFFIC RECORDS SECTION, 064R
206 S. 17TH AVE., PHOENIX, ARIZONA 85007-3233

REPORT ID

YEAR	MONTH	DAY	HOUR	NCIC NO.	OFFICER ID NO.

Agency Report Number

25 VEHICLE DAMAGED AREA(S) - (CIRCLE UP TO THREE AREAS PER UNIT)

Unit # ___ 2 3 4 / 1 9 5 / 8 7 6 0—NONE 10—UNDERCARRIAGE 97—OTHER 99—UNKNOWN	Unit # ___ 2 3 4 / 1 9 5 / 8 7 6 0—NONE 10—UNDERCARRIAGE 97—OTHER 99—UNKNOWN	Unit # ___ 2 3 4 / 1 9 5 / 8 7 6 0—NONE 10—UNDERCARRIAGE 97—OTHER 99—UNKNOWN

26 GLOBAL POSITION Latitude: Longitude:

27 —**ROADWAY ALIGNMENT**
UNIT #
_ _ _
☐ ☐ ☐ 1 - STRAIGHT
☐ ☐ ☐ 2 - CURVE LEFT
☐ ☐ ☐ 3 - CURVE RIGHT
☐ ☐ ☐ 99 - UNKNOWN

28 —**LANE**

Please enter unit's number and lane of travel before first crash event

UNIT ___	UNIT ___	UNIT ___

0 TWO-WAY CONTINUOUS LEFT TURN
1-9 1= FIRST LANE NEXT TO A MEDIAN THRU 9
10 CROSSWALK
L1 THRU LX - LEFT TURN ONLY LANES (L1= 1ST LEFT TURN AFTER MEDIAN/ CENTERLINE)
R1 THRU RX - RIGHT TURN LANES (R1=1ST RIGHT TURN AFTER THROUGH LANES)
BL DEDICATED BIKE LANE
HOV HIGH OCCUPANCY VEHICLE
97 NON-ROADWAY
99 UNKNOWN

29 —**EJECTION**
0 NOT APPLICABLE
1 NOT EJECTED
2 EJECTED, PARTIALLY
3 EJECTED, TOTALLY
4 UNKNOWN DEGREE
99 UNKNOWN

30 —**EXTRICATION**
0 NOT APPLICABLE
1 EXTRICATED
99 UNKNOWN

Unit # and Seat Position from front page.
Driver seat position = 11

Unit #	Seat Pos	Ejection	Extrication

31 —**SEQUENCE OF EVENTS**

SEE EXAMPLE BELOW

UP TO FOUR CRASH EVENTS FOR EACH UNIT IN THE ORDER OF OCCURRENCE

NON-COLLISION

1 OVERTURN/ROLLOVER
2 FIRE/EXPLOSION
3 IMMERSION
4 JACKKNIFE
5 CARGO/EQUIPMENT LOSS/SHIFT
6 FELL/JUMPED FROM VEHICLE
7 THROWN OR FALLING OBJECT
8 OTHER NON-COLLISION ______________
9 EQUIPMENT FAILURE (tires, brakes)
10 SEPARATION OF UNITS
11 RAN OFF ROAD RIGHT
12 RAN OFF ROAD LEFT
13 CROSS MEDIAN
14 CROSS CENTERLINE
15 DOWNHILL RUNAWAY

COLLISION WITH PERSON, MOTOR VEHICLE, OR NON-FIXED OBJECT

16 MOTOR VEHICLE IN TRANSPORT
17 PEDESTRIAN
18 PEDALCYCLE
19 RAILWAY VEHICLE (TRAIN, ENGINE)
20 LIGHT RAILWAY/RAILCAR VEHICLE
21 ANIMAL, WILD—NON GAME ______________
22 ANIMAL, WILD—GAME ______________
23 ANIMAL—PET____________
24 ANIMAL—LIVESTOCK ______________
25 PARKED MOTOR VEHICLE
26 WORK ZONE/MAINT. EQUIP.
27 STRUCK BY FALLING, SHIFTING CARGO OR ANYTHING SET IN MOTION BY ANOTHER VEHICLE
28 OTHER NON-FIXED OBJ. ______________

COLLISION WITH FIXED OBJECT

29 IMPACT ATTENUATOR/CRASH CUSHION
30 BRIDGE/OVERHEAD STRUCTURE
31 BRIDGE RAIL
32 CULVERT
33 CURB
34 DITCH
35 EMBANKMENT
36 GUARDRAIL FACE
37 GUARDRAIL END
38 CONCRETE TRAFFIC BARRIER
39 CABLE TRAFFIC BARRIER
40 OTHER TRAFFIC BARRIER
41 TREE, BUSH, STUMP (standing)
42 TRAFFIC SIGN SUPPORT
43 TRAFFIC SIGNAL SUPPORT
44 UTILITY POLE/LIGHT SUPPORT
45 OTHER POST, POLE, OR SUPPORT
46 FENCE
47 MAILBOX
48 BUILDING
49 OTHER FIXED OBJ. ______________

99 UNKNOWN

SEQUENCE OF EVENTS

UNIT ___	UNIT ___	UNIT ___	
			FIRST EVENT
			SECOND EVENT
			THIRD EVENT
			FIRST HARMFUL (based on the crash)

EXAMPLE- SEQUENCE OF EVENTS

VEHICLE 1—SEQUENCE OF EVENTS

11— RAN OFF ROAD RIGHT
14— CROSS CENTERLINE
16— MOTOR VEHICLE IN TRANSPORT

VEHICLE 2—SEQUENCE OF EVENTS

16— MOTOR VEHICLE IN TRANSPORT

SEQUENCE OF EVENTS

UNIT 1	UNIT 2	UNIT _	
11	16		FIRST EVENT
14			SECOND EVENT
16			THIRD EVENT
Note: Fill FIRST HARMFUL based on the crash			**FIRST HARMFUL**

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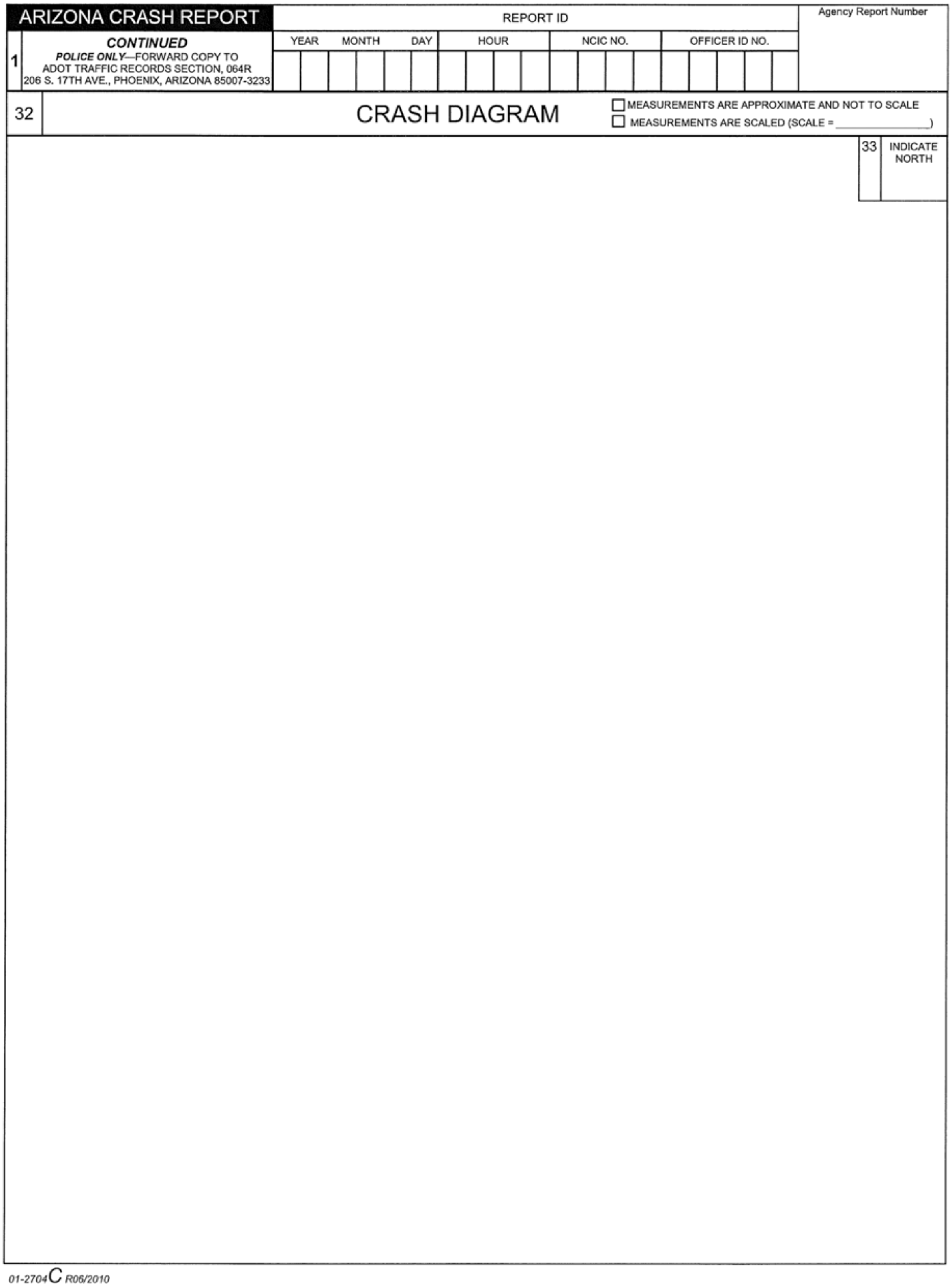

ARIZONA CRASH REPORT

CONTINUED

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REPORT ID					
YEAR	MONTH	DAY	HOUR	NCIC NO.	OFFICER ID NO.

Agency Report Number

32 CRASH DIAGRAM

☐ MEASUREMENTS ARE APPROXIMATE AND NOT TO SCALE
☐ MEASUREMENTS ARE SCALED (SCALE = _______________)

33 INDICATE NORTH

01-2704C R06/2010

ARIZONA CRASH REPORT

1 **_CONTINUED_**

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REPORT ID						Agency Report Number
YEAR	MONTH	DAY	HOUR	NCIC NO.	OFFICER ID NO.	

34 NARRATIVE Describe what happened

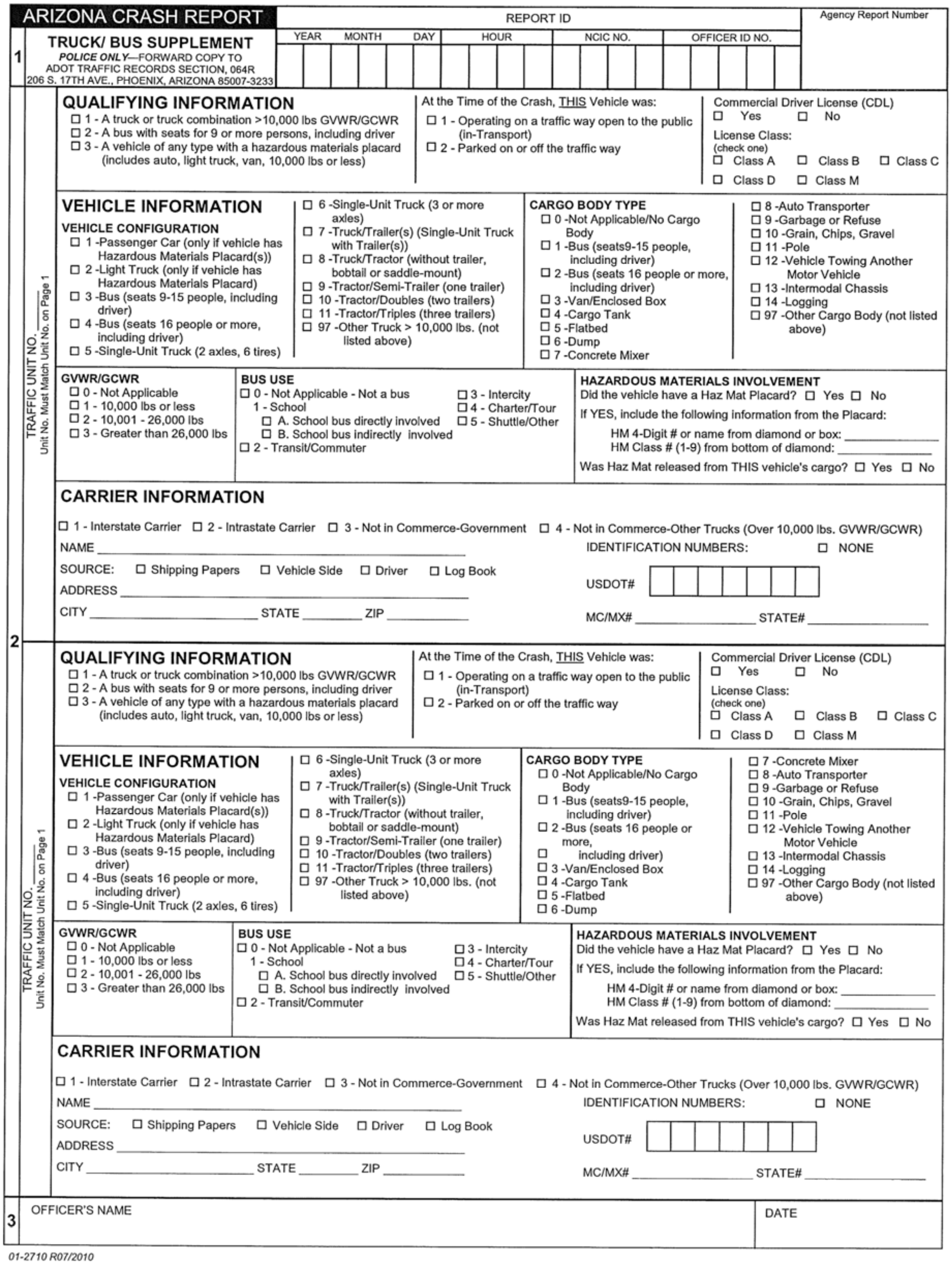
ADDITIONAL PASSENGERS

Unit #	Seat Pos	SD	IS	Name	Address	City	State	Zip Code	Telephone No.	D.O.B./Age	Sex

ADDITIONAL WITNESSES

Name	Address	City	State	Zip Code	Telephone Number	D.O.B/Age

01-2704C R06/2010



ARIZONA CRASH REPORT

TRUCK/ BUS SUPPLEMENT

POLICE ONLY—FORWARD COPY TO
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206 S. 17TH AVE., PHOENIX, ARIZONA 85007-3233

1

REPORT ID						Agency Report Number
YEAR	MONTH	DAY	HOUR	NCIC NO.	OFFICER ID NO.	

2

TRAFFIC UNIT NO. ____
Unit No. Must Match Unit No. on Page 1

QUALIFYING INFORMATION

☐ 1 - A truck or truck combination >10,000 lbs GVWR/GCWR
☐ 2 - A bus with seats for 9 or more persons, including driver
☐ 3 - A vehicle of any type with a hazardous materials placard (includes auto, light truck, van, 10,000 lbs or less)

At the Time of the Crash, THIS Vehicle was:
☐ 1 - Operating on a traffic way open to the public (in-Transport)
☐ 2 - Parked on or off the traffic way

Commercial Driver License (CDL)
☐ Yes ☐ No
License Class:
(check one)
☐ Class A ☐ Class B ☐ Class C
☐ Class D ☐ Class M

VEHICLE INFORMATION

VEHICLE CONFIGURATION
☐ 1 -Passenger Car (only if vehicle has Hazardous Materials Placard(s))
☐ 2 -Light Truck (only if vehicle has Hazardous Materials Placard)
☐ 3 -Bus (seats 9-15 people, including driver)
☐ 4 -Bus (seats 16 people or more, including driver)
☐ 5 -Single-Unit Truck (2 axles, 6 tires)
☐ 6 -Single-Unit Truck (3 or more axles)
☐ 7 -Truck/Trailer(s) (Single-Unit Truck with Trailer(s))
☐ 8 -Truck/Tractor (without trailer, bobtail or saddle-mount)
☐ 9 -Tractor/Semi-Trailer (one trailer)
☐ 10 -Tractor/Doubles (two trailers)
☐ 11 -Tractor/Triples (three trailers)
☐ 97 -Other Truck > 10,000 lbs. (not listed above)

CARGO BODY TYPE
☐ 0 -Not Applicable/No Cargo Body
☐ 1 -Bus (seats9-15 people, including driver)
☐ 2 -Bus (seats 16 people or more, including driver)
☐ 3 -Van/Enclosed Box
☐ 4 -Cargo Tank
☐ 5 -Flatbed
☐ 6 -Dump
☐ 7 -Concrete Mixer
☐ 8 -Auto Transporter
☐ 9 -Garbage or Refuse
☐ 10 -Grain, Chips, Gravel
☐ 11 -Pole
☐ 12 -Vehicle Towing Another Motor Vehicle
☐ 13 -Intermodal Chassis
☐ 14 -Logging
☐ 97 -Other Cargo Body (not listed above)

GVWR/GCWR
☐ 0 - Not Applicable
☐ 1 - 10,000 lbs or less
☐ 2 - 10,001 - 26,000 lbs
☐ 3 - Greater than 26,000 lbs

BUS USE
☐ 0 - Not Applicable - Not a bus
1 - School
☐ A. School bus directly involved
☐ B. School bus indirectly involved
☐ 2 - Transit/Commuter
☐ 3 - Intercity
☐ 4 - Charter/Tour
☐ 5 - Shuttle/Other

HAZARDOUS MATERIALS INVOLVEMENT
Did the vehicle have a Haz Mat Placard? ☐ Yes ☐ No
If YES, include the following information from the Placard:
HM 4-Digit # or name from diamond or box: ____________
HM Class # (1-9) from bottom of diamond: ____________
Was Haz Mat released from THIS vehicle's cargo? ☐ Yes ☐ No

CARRIER INFORMATION

☐ 1 - Interstate Carrier ☐ 2 - Intrastate Carrier ☐ 3 - Not in Commerce-Government ☐ 4 - Not in Commerce-Other Trucks (Over 10,000 lbs. GVWR/GCWR)

NAME ______________________________
SOURCE: ☐ Shipping Papers ☐ Vehicle Side ☐ Driver ☐ Log Book
ADDRESS ______________________________
CITY ____________ STATE ________ ZIP ________

IDENTIFICATION NUMBERS: ☐ NONE
USDOT# ☐☐☐☐☐☐☐
MC/MX# ____________ STATE# ____________

TRAFFIC UNIT NO. ____
Unit No. Must Match Unit No. on Page 1

QUALIFYING INFORMATION

☐ 1 - A truck or truck combination >10,000 lbs GVWR/GCWR
☐ 2 - A bus with seats for 9 or more persons, including driver
☐ 3 - A vehicle of any type with a hazardous materials placard (includes auto, light truck, van, 10,000 lbs or less)

At the Time of the Crash, THIS Vehicle was:
☐ 1 - Operating on a traffic way open to the public (in-Transport)
☐ 2 - Parked on or off the traffic way

Commercial Driver License (CDL)
☐ Yes ☐ No
License Class:
(check one)
☐ Class A ☐ Class B ☐ Class C
☐ Class D ☐ Class M

VEHICLE INFORMATION

VEHICLE CONFIGURATION
☐ 1 -Passenger Car (only if vehicle has Hazardous Materials Placard(s))
☐ 2 -Light Truck (only if vehicle has Hazardous Materials Placard)
☐ 3 -Bus (seats 9-15 people, including driver)
☐ 4 -Bus (seats 16 people or more, including driver)
☐ 5 -Single-Unit Truck (2 axles, 6 tires)
☐ 6 -Single-Unit Truck (3 or more axles)
☐ 7 -Truck/Trailer(s) (Single-Unit Truck with Trailer(s))
☐ 8 -Truck/Tractor (without trailer, bobtail or saddle-mount)
☐ 9 -Tractor/Semi-Trailer (one trailer)
☐ 10 -Tractor/Doubles (two trailers)
☐ 11 -Tractor/Triples (three trailers)
☐ 97 -Other Truck > 10,000 lbs. (not listed above)

CARGO BODY TYPE
☐ 0 -Not Applicable/No Cargo Body
☐ 1 -Bus (seats9-15 people, including driver)
☐ 2 -Bus (seats 16 people or more,
☐ including driver)
☐ 3 -Van/Enclosed Box
☐ 4 -Cargo Tank
☐ 5 -Flatbed
☐ 6 -Dump
☐ 7 -Concrete Mixer
☐ 8 -Auto Transporter
☐ 9 -Garbage or Refuse
☐ 10 -Grain, Chips, Gravel
☐ 11 -Pole
☐ 12 -Vehicle Towing Another Motor Vehicle
☐ 13 -Intermodal Chassis
☐ 14 -Logging
☐ 97 -Other Cargo Body (not listed above)

GVWR/GCWR
☐ 0 - Not Applicable
☐ 1 - 10,000 lbs or less
☐ 2 - 10,001 - 26,000 lbs
☐ 3 - Greater than 26,000 lbs

BUS USE
☐ 0 - Not Applicable - Not a bus
1 - School
☐ A. School bus directly involved
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☐ 4 - Charter/Tour
☐ 5 - Shuttle/Other

HAZARDOUS MATERIALS INVOLVEMENT
Did the vehicle have a Haz Mat Placard? ☐ Yes ☐ No
If YES, include the following information from the Placard:
HM 4-Digit # or name from diamond or box: ____________
HM Class # (1-9) from bottom of diamond: ____________
Was Haz Mat released from THIS vehicle's cargo? ☐ Yes ☐ No

CARRIER INFORMATION

☐ 1 - Interstate Carrier ☐ 2 - Intrastate Carrier ☐ 3 - Not in Commerce-Government ☐ 4 - Not in Commerce-Other Trucks (Over 10,000 lbs. GVWR/GCWR)

NAME ______________________________
SOURCE: ☐ Shipping Papers ☐ Vehicle Side ☐ Driver ☐ Log Book
ADDRESS ______________________________
CITY ____________ STATE ________ ZIP ________

IDENTIFICATION NUMBERS: ☐ NONE
USDOT# ☐☐☐☐☐☐☐
MC/MX# ____________ STATE# ____________

3

OFFICER'S NAME

DATE

01-2710 R07/2010