VIRGINIA TECH TRANSPORTATION INSTITUTE
VIRGINIA TECH

Advancing Transportation through Innovation

AN EMPIRICAL ASSESSMENT ON THE EFFECTS OF GEOMETRY AND NON-GEOMETRY FACTORS IN WORK-ZONE CRASHES WITH UNOBSERVED HETEROGENEITY

SESSION 15: ROADWAY INFRASTRUCTURE

THURSDAY, JUNE 9, 2022
ZAPPEION MEGARON, ROOM VI

MOUYID ISLAM, PhD

AGENDA

- INTRODUCTION
- RESEARCH MOTIVATION
- METHODOLOGY AND DATA
- ANALYSIS AND MODEL RESULTS
- SUMMARY CONCLUSION AND FUTURE WORK
- DISCUSSION: QUESTION - ANSWER

BACKGROUND
PRIMER

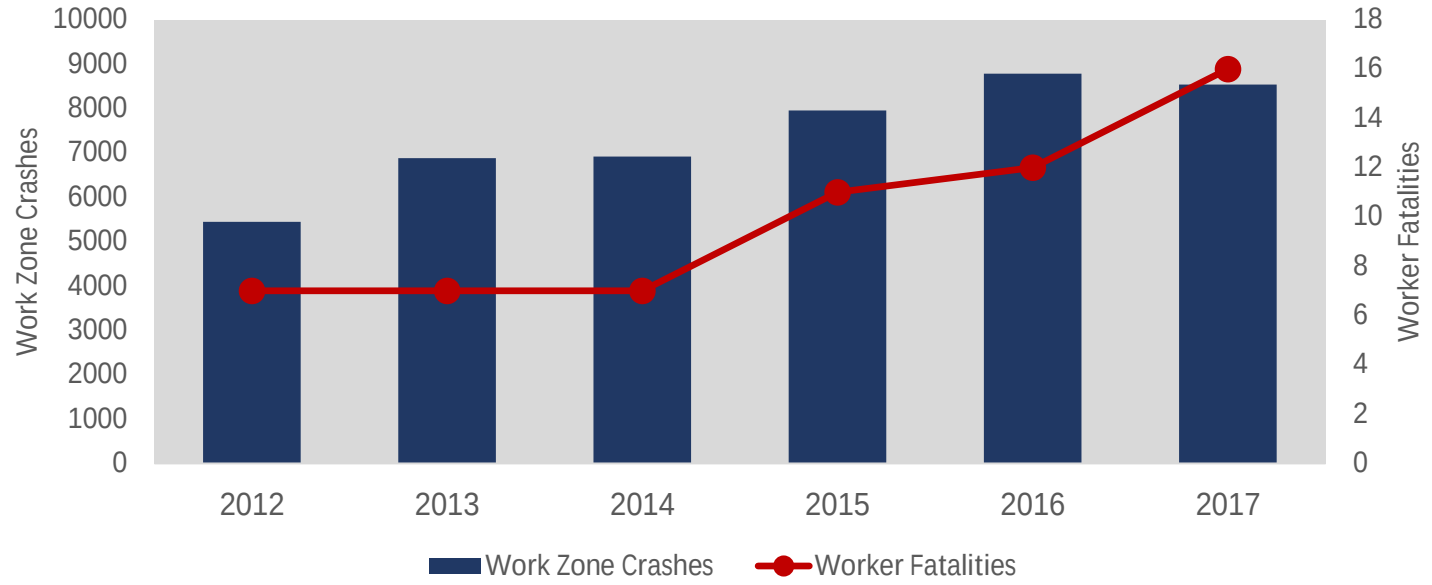
On average, in 2016-2017:

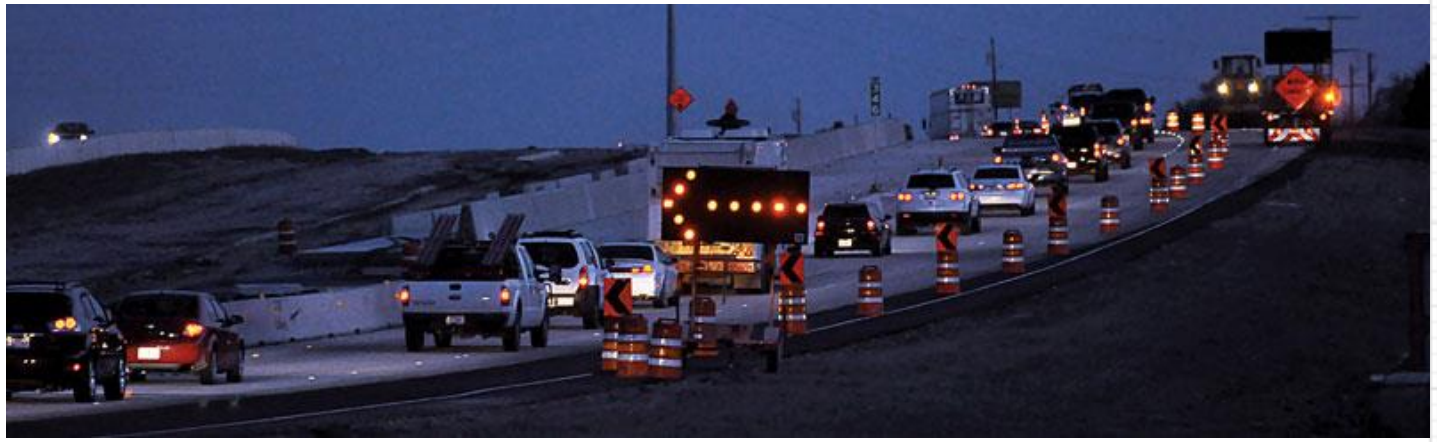
- A work zone crash occurred once **every hour** in Florida.
- Every day, **9** work zone crashes occurred that resulted in at least one injury.
- Every week, **1** work zone crash occurred that resulted in at least one fatality.

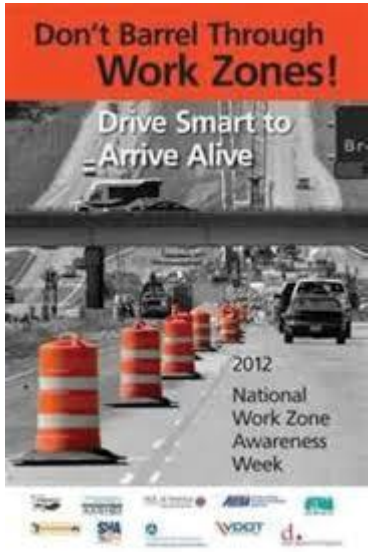
Worker Fatalities ⇦

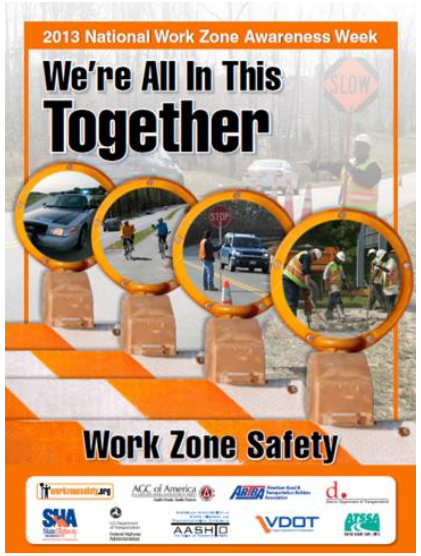
3rd	2nd	3rd	3rd	2nd	2nd
2nd	2nd	2nd	2nd	2nd	2nd

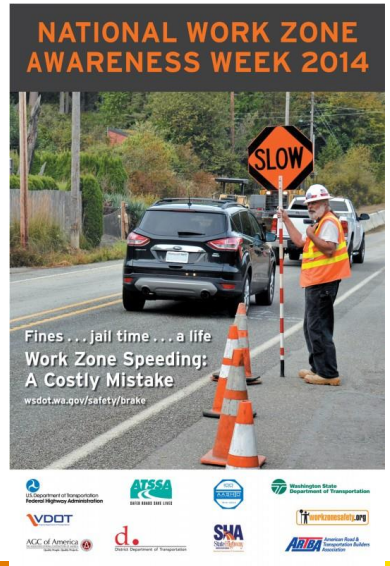
⇨ Work Zone Fatalities



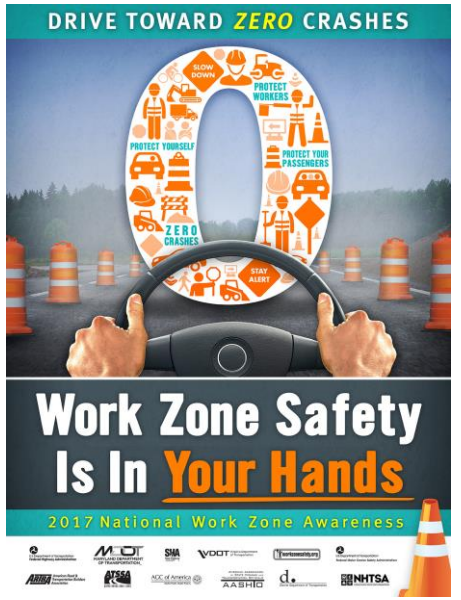



Don't Barrel Through
Work Zones!
Drive Smart to
Arrive Alive
2012
National
Work Zone
Awareness
Week


2013 National Work Zone Awareness Week
We're All In This
Together
Work Zone Safety


NATIONAL WORK ZONE
AWARENESS WEEK 2014
SLOW
Fines . . . jail time . . . a life
Work Zone Speeding:
A Costly Mistake
wsdot.wa.gov/safety/brake


2016 National Work Zone Awareness
Don't Be THAT Driver!
Work on Safety. Get Home Safely. Every Day.


DRIVE TOWARD ZERO CRASHES
SLOW DOWN
PROTECT WORKERS
PROTECT YOURSELF
PROTECT YOUR PASSENGERS
ZERO CRASHES
STAY ALERT
Work Zone Safety
Is In Your Hands
2017 National Work Zone Awareness

INTRODUCTION

PRIME FOCUS

- With increasing emphasis on the maintenance and reconstruction of existing highways and infrastructure, as well as the growing need to build new roadway facilities, work-zone safety is a growing priority for both workers and motorists.

- However, the geometric configuration of work zones has not been addressed as a contributing factor in work-zone crash severity models despite a general agreemenent that it plays **a role**.

- For example, in Florida, geometry was identified as a contributing factor in about 25% of total work-zone crashes from 2012 to 2017.

- Single-vehicle crashes in work zones comprise about 20% of all crashes in Florida according to crash statistics.

- They are of particular interest because they reflect how the fundamentals of work-zone design impact potential driver errors.

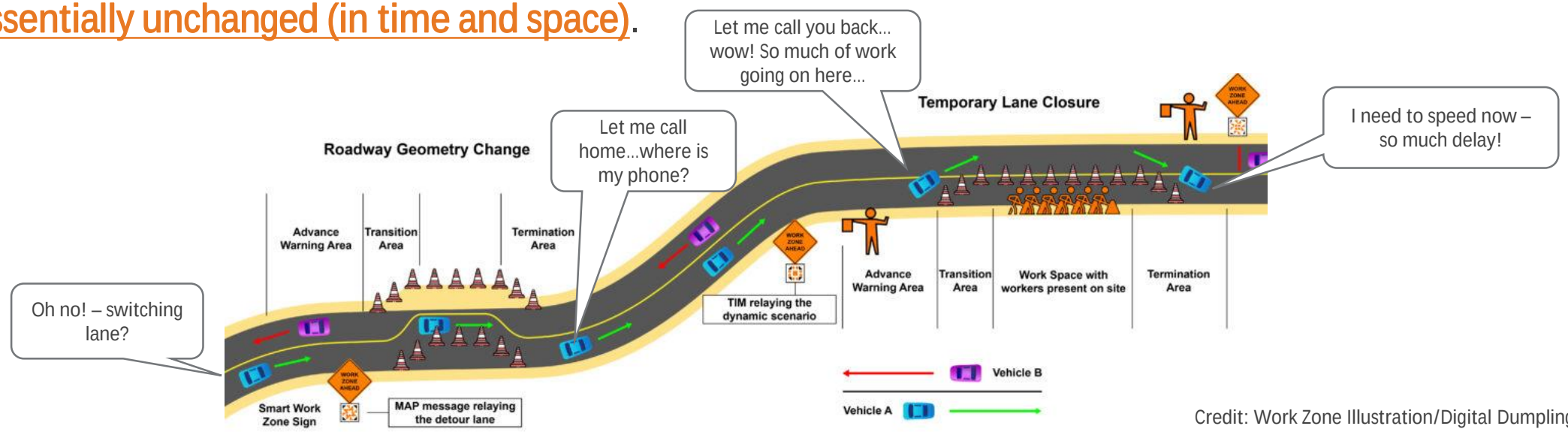
INTRODUCTION

OTHER STUDIES

- Work zone safety with injury severities in work zone crashes, has been the emphasis of a number of research studies over the years (Li and Bai, 2008, 2009; Harb et al., 2010; Meng et al., 2010; Tarko et al., 2011; Osman et al., 2018; Islam et al., 2020; Islam, 2022).

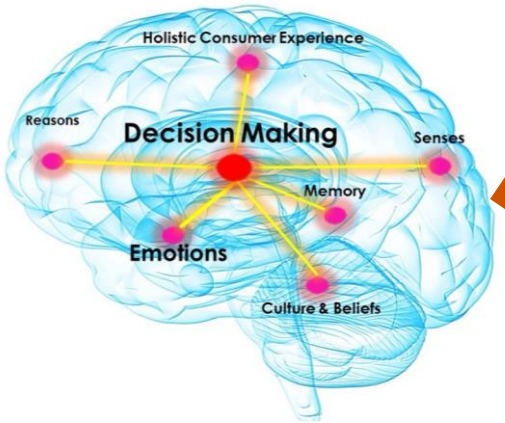
- While all of these studies have provided insights into the factors that determine work zone-injury severity, the issue of geometry and non-geometry aspect (separately) in statistical models of work zone-injury severity has not really been addressed to date.

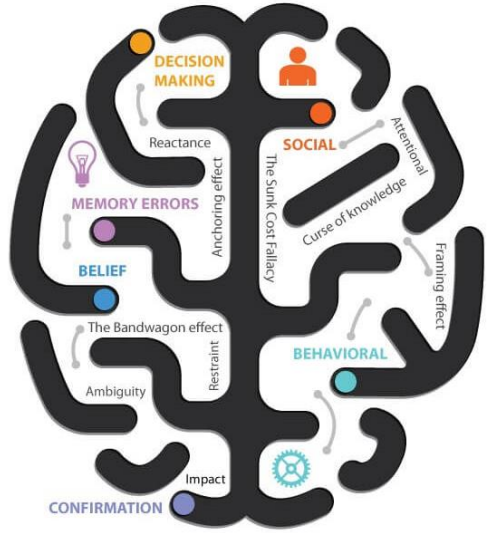
- This is because most past studies assess possible factors over a highway network (city or state) that is essentially unchanged (in time and space).

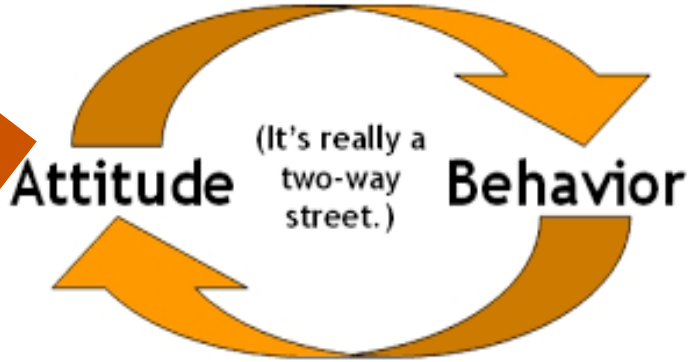


Credit: Work Zone Illustration/Digital Dumpling

RESEARCH MOTIVATION



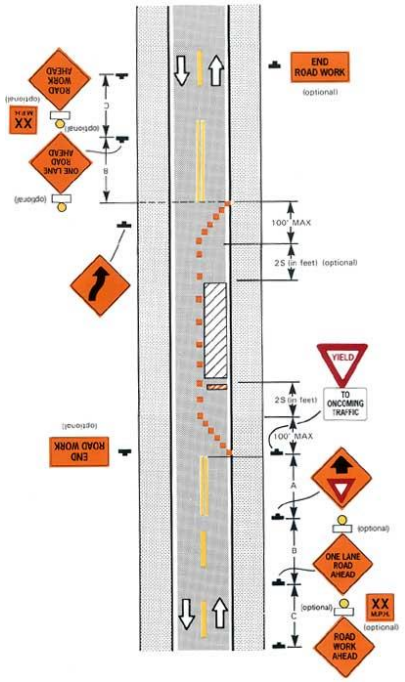




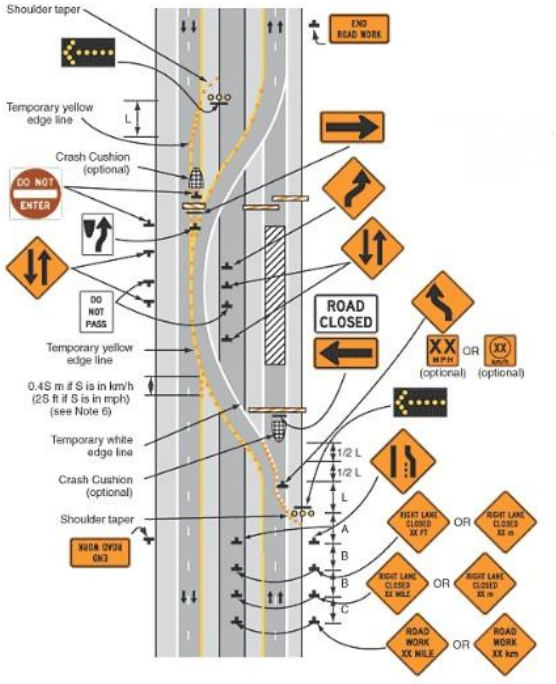
RESEARCH MOTIVATION

RESEARCH QUESTIONS

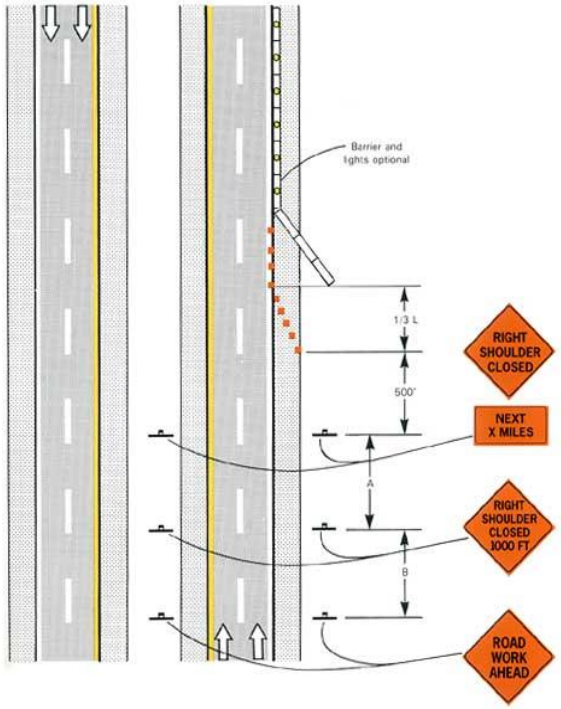
Each work zone is unique with a unique set of unobservables and the mix of highway work zones changes as projects are started and completed.



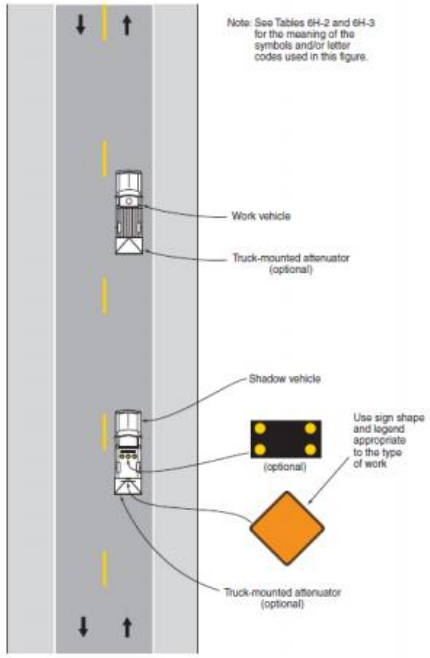
A. Lane Closure



B. Lane Shift/ Cross Over



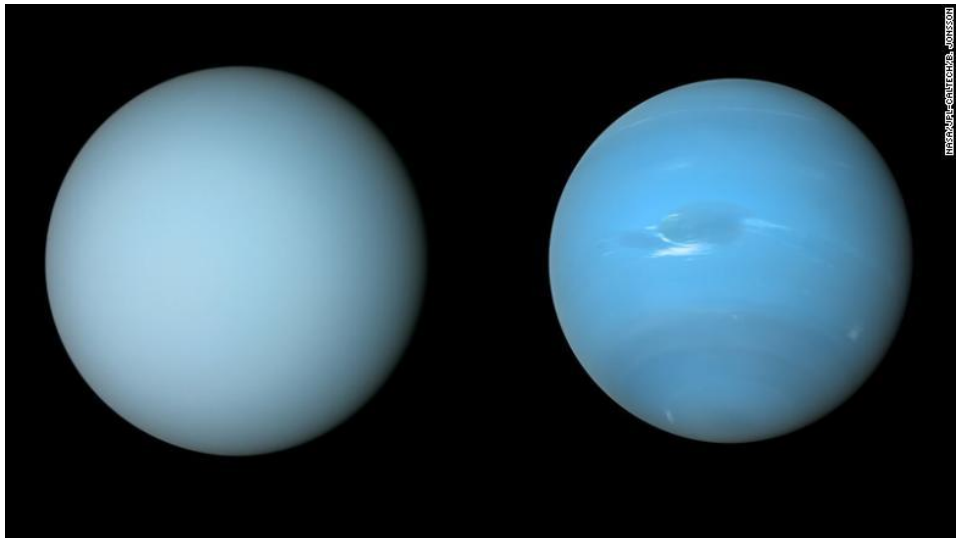
C. Work on Shoulder/ Median



D. Intermittent/Mobile

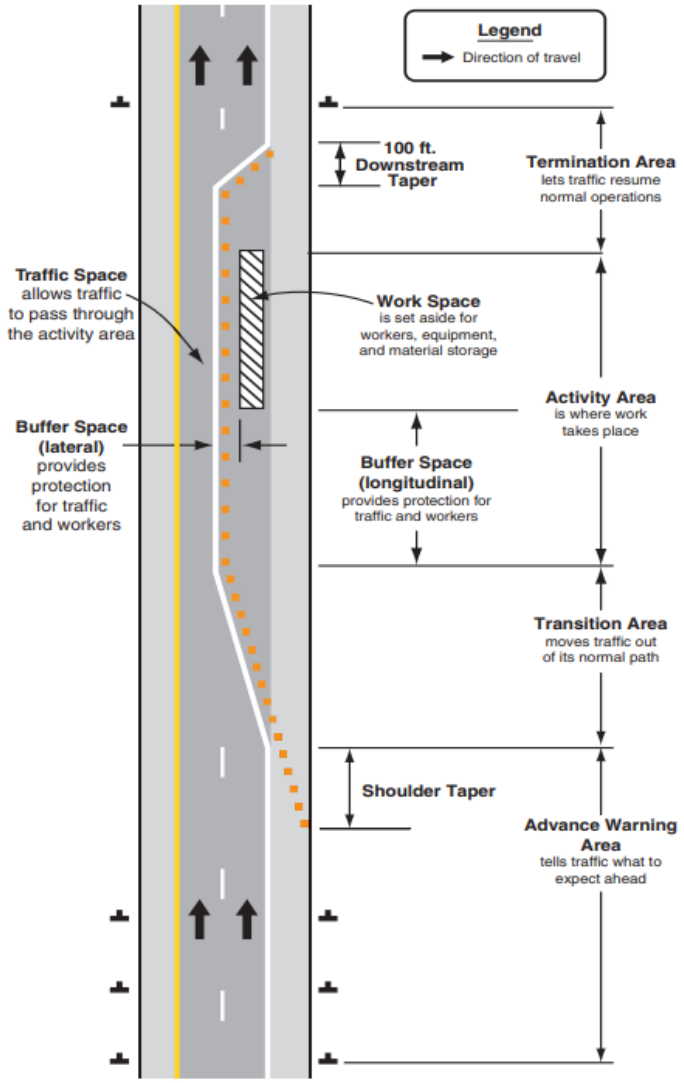
RESEARCH MOTIVATION

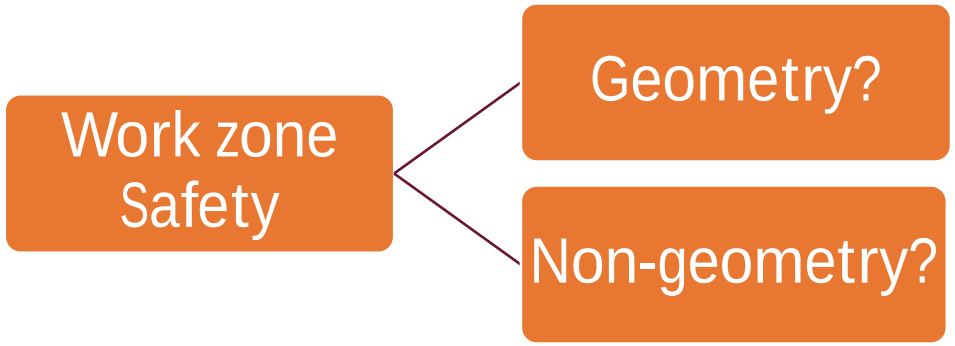
RESEARCH QUESTIONS

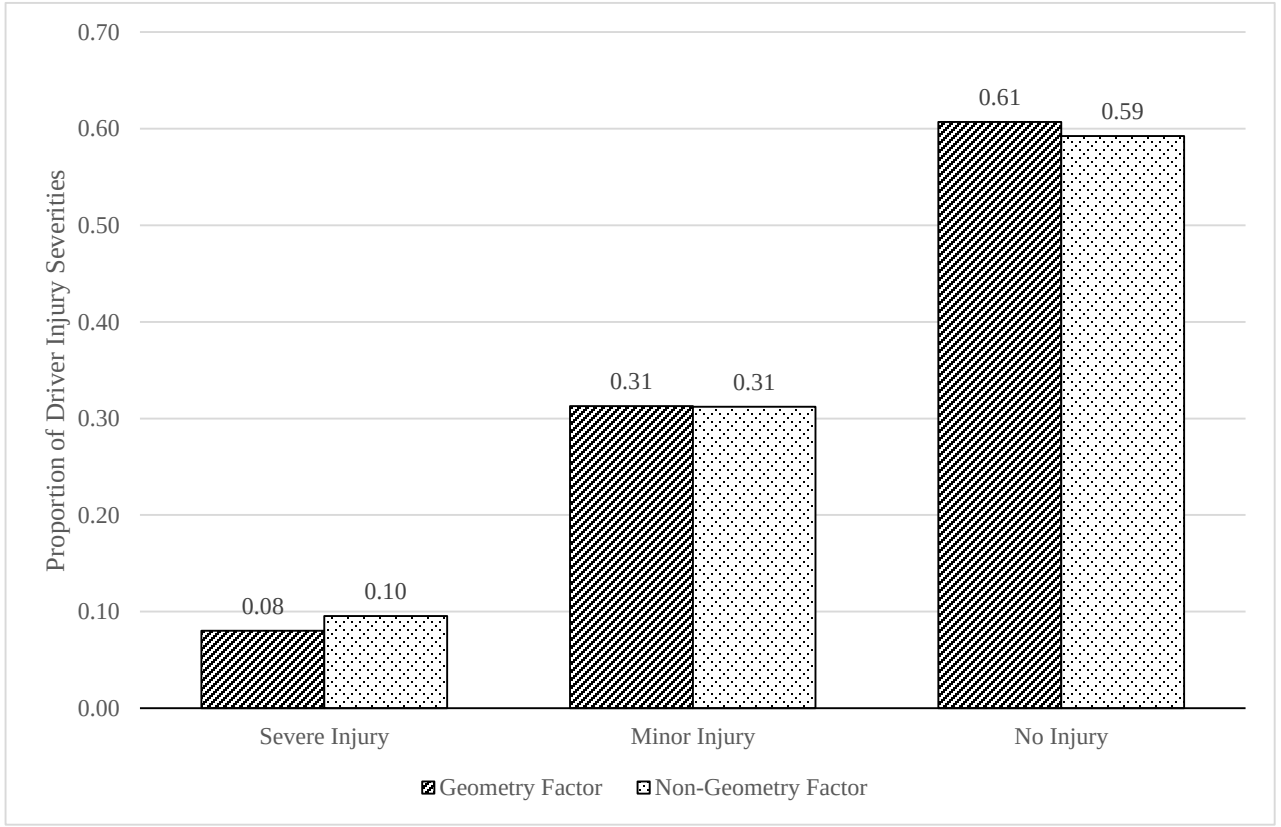


RESEARCH MOTIVATION

RESEARCH QUESTIONS







METHODOLOGY

RPL WITH HETEROGENEITY IN MEAN AND VARIANCE

$$P_n(k) = \int \frac{EXP(\boldsymbol{\beta}_k \mathbf{X}_{kn})}{\sum_{\forall K} EXP(\boldsymbol{\beta}_k \mathbf{X}_{kn})} f(\boldsymbol{\beta}_k \mid \boldsymbol{\varphi}_k) d\boldsymbol{\beta}_k$$

where,

X_{kn} is a vector of explanatory variables that affect work zone single-vehicle injury-severity level k,

β_k is a vector of estimable parameters,

$f(\beta_k|\phi_k)$ is the density function of β_k and ϕ_k is a vector of parameters describing the density function (mean and variance)

$P_n(k)$ is the probability that work-zone single-vehicle crash n that will result in driver-injury severity outcome k and K is the set of the three possible injury-severity outcomes

$$\boldsymbol{\beta}_{kn} = \beta + \Theta_{kn}\mathbf{Z}_{kn} + \sigma_{kn} EXP(\Psi_{kn}\mathbf{W}_{kn})\ \nu_{kn}$$

where,

β is the mean parameter estimate across all crashes,

Z_{kn} is a vector of crash-specific explanatory variables that captures heterogeneity in the mean that affects work zone single-vehicle injury-severity level k,

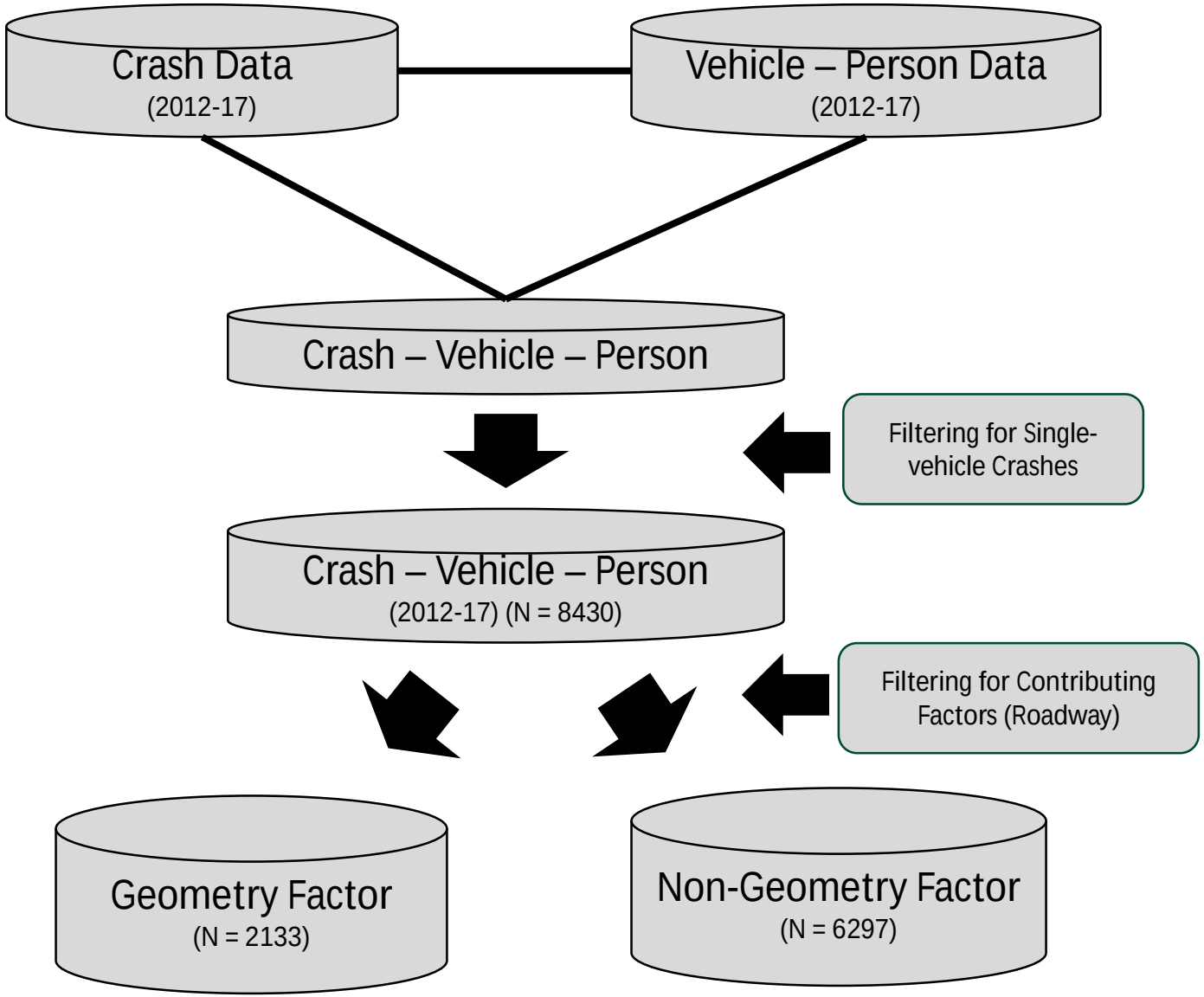
Θ_{kn} is a corresponding vector of estimable parameters,

W_{kn} is a vector of crash-specific explanatory variables that captures heterogeneity in the standard deviation σ_{kn} with corresponding parameter vector Ψ_{kn}, and v_{kn} is a disturbance term

DATA DESCRIPTION

DATASET PROCESSING

Characteristics	Variables
Spatial	FDOT District (1-7)
Temporal	Time of Day, Month of Year
Geometric	Shoulder width, should/median, functional class of roadways
Traffic	Traffic volume, Truck volume
Vehicle	Passenger car, Pickup truck, Van
Harmful event location	Shoulder, Median, Roadside fixed object
Work zone type	Lane closure, Lane Cross-over, Shoulder-median, Intermittent
Work zone crash location	Advanced warning, Transition area, Activity area
Ambient condition	Lighting condition, Weather condition
Driver charcteristics	Age, driving action (negligent, too closely followed, too fast for the conditions)



ANALYSIS AND RESULTS

LIKELIHOOD RATIO TEST

$$\chi^2 = -2\left[LL(\beta_{Workzone\ related\ Crashes}) - LL(\beta_{Geometry-related\ Factor}) - LL(\beta_{Non-geometry-related\ Factor})\right]$$

$LL(\beta_{WZ\ Crashes})$	$LL(\beta_{Geometry})$	$LL(\beta_{Non-Geometry})$	χ^2 value	D.O.F	Confidence interval for rejecting the Null Hypothesis of equal parameters
-8445.278	-1501.761	-6917.962	51.11	14	99.9%

$$\chi^2 = -2\left[LL(\beta_{W_1W_2}) - LL(\beta_{W_1})\right]$$

W_1 \ W_2	Geometry	Non-Geometry
Geometry	–	30.638 (18) [96.9%]
Non-Geometry	137.994 (17) [99.9%]	–

ANALYSIS AND RESULTS

Table: Mixed logit model with heterogeneity in mean and variance for single-vehicle work-zone crashes with geometry-related factor in Florida, 2012-17.

Variable	Parameter Estimates	t-stat	Marginal Effects		
			No Injury	Minor Injury	Severe Injury
Constant [SI]	-2.564	-12.79			
Random parameter (normally distributed)					
Constant [MI] (standard deviation of parameter distribution)	-3.149	-2.23			
	(3.206)	(1.99)			
Heterogeneity in the mean of random parameter					
Constant: Low traffic volume indicator (1 if AADT below 40,000 vehicles/day at the time of crash, 0 otherwise) [MI]	-1.132	-1.87			
Heterogeneity in the variance of random parameter					
Constant: Truck volume between 10% and 20% indicator (1 if truck volume between 10% and 20% of all traffic at the time of crash, 0 otherwise) [MI]	0.486	2.80			
Spatial characteristics					
District 6 indicator (1 if crash occured in District 6, 0 otherwise) [NI]	0.879	2.57	0.0110	-0.0085	-0.0025
District 7 indicator (1 if crash occured in District 7, 0 otherwise) [SI]	0.590	2.45	-0.0058	-0.0008	0.0066
Vehicle characteristics					
Passenger car indicator (1 if passenger car involved in crash, 0 otherwise) [NI]	0.564	3.02	0.0324	-0.0216	-0.0108
Pickup truck indicator (1 if pickup truck involved in crash, 0 otherwise) [MI]	-1.278	-2.04	0.0067	-0.0075	0.0008
Environmental characteristics					
Daylight indicator (1 if crash occurred in the daylight, 0 otherwise) [NI]	0.446	2.49	0.0255	-0.0159	-0.0097
Geometric characteristics					
Large shoulder width indicator (1 if crash occurred at right shoulder width between 6 to 10 ft,0 otherwise) [NI]	-0.416	-2.06	-0.0122	0.0069	0.0053
Work on shoulder or median indicator (1 if crash occurred while work on shoulder or median, 0 otherwise) [SI]	0.626	2.95	-0.0152	-0.0020	0.0172
Transition area indicator (1 if crash occurred in the work zone's transition area, 0 otherwise) [SI]	-0.767	-2.00	0.0024	0.0003	-0.0027
Crash charcteristics					
First harmful event on shoulder indicator (1 if first harmful event occurred at the shoulder at the time of crash, 0 otherwise) [SI]	0.605	2.68	-0.0076	-0.0011	0.0087
Traffic characteristics					
Low truck volume indicator (1 if truck volume below 10% of all traffic at the time of crash, 0 otherwise) [MI]	0.832	2.00	-0.0243	0.0265	-0.0021
Driver characteristics					
Negligent driver indicator (1 if negligent driving involved in crash, 0 otherwise) [MI]	0.988	2.21	-0.0246	0.0268	-0.0022
Other factors					
No worker presence indicator (1 if no worker was present at the time of crash, 0 otherwise) [MI]	0.879	2.07	-0.0367	0.0398	-0.0031
Number of observations	2,133				
Log-likelihood at zero	-2343.340				
Log-likelihood at convergence	-1501.761				
McFadden ρ^2	0.359				

SI = Severe Injury; MI = Minor Injury; NI = No Injury

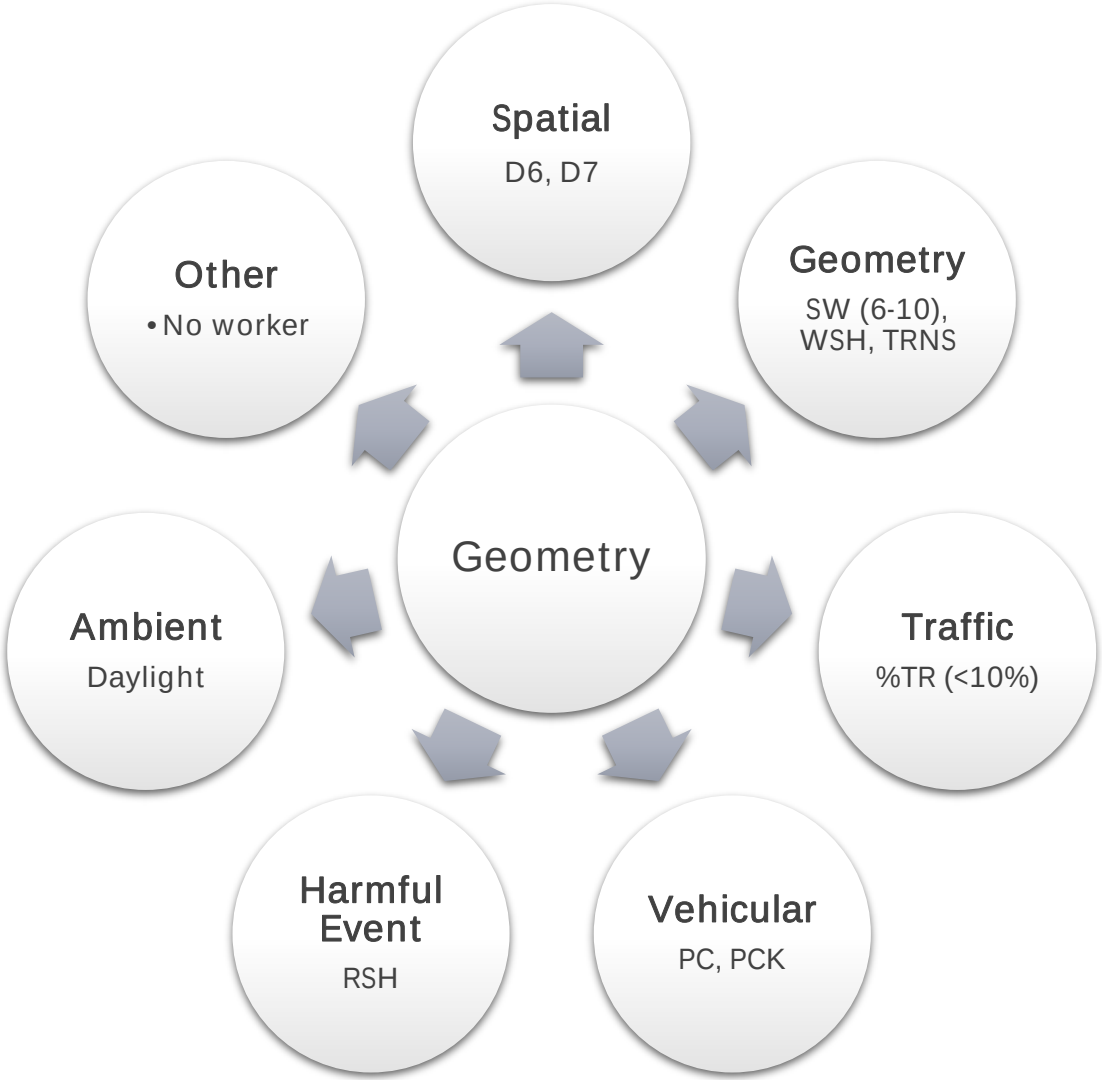
ANALYSIS AND RESULTS

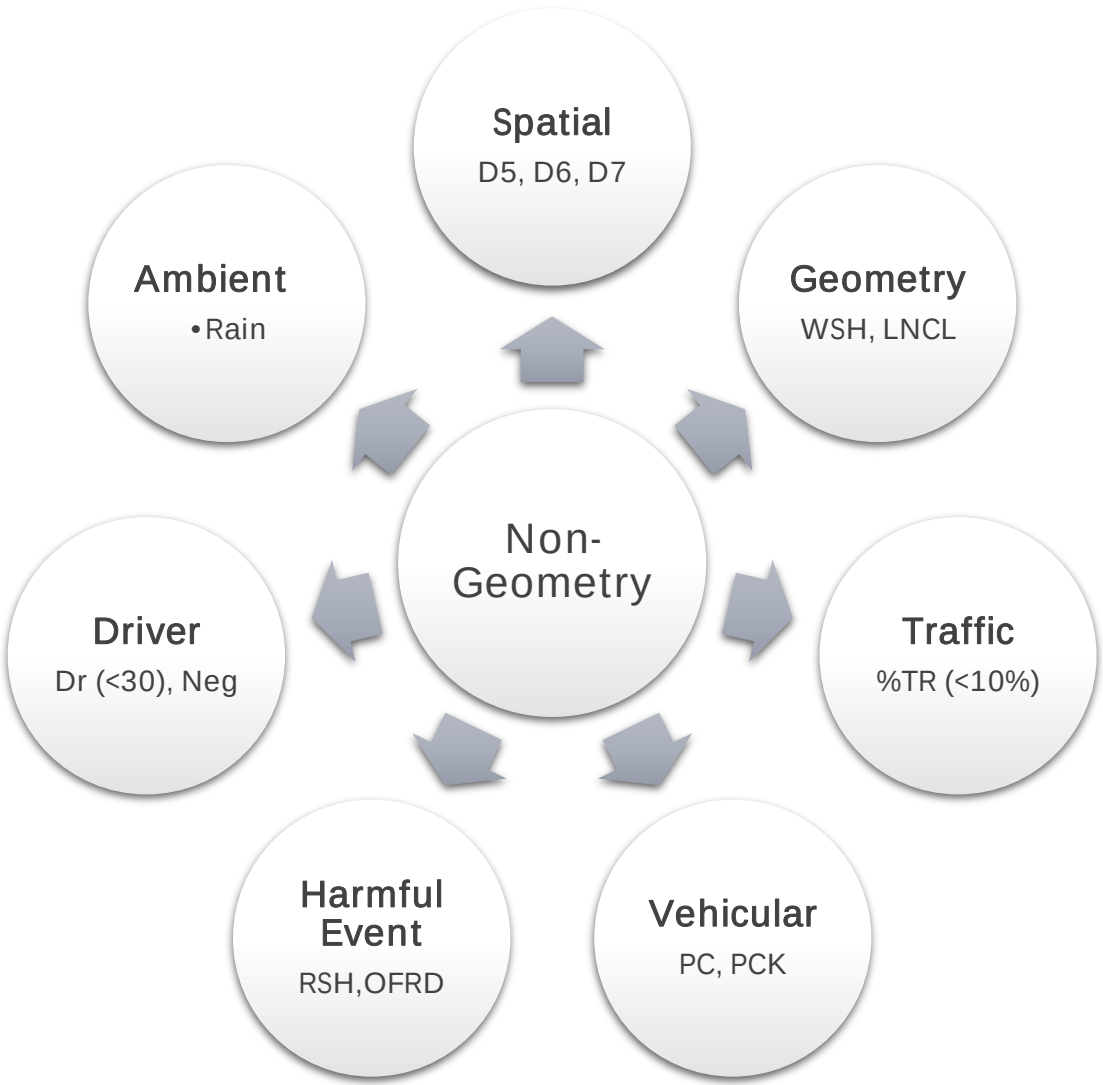
Table: Mixed logit model with heterogeneity in mean and variance for single-vehicle work-zone crashes with Non-geometry-related factor in Florida, 2012-17.

Variable	Parameter Estimates	t-stat	Marginal Effects		
			No Injury	Minor Injury	Severe Injury
Constant [MI]	-3.440	-4.58			
Random parameter (normally distributed)					
Constant [SI] (standard deviation of parameter distribution)	-2.480	-21.15			
	(3.912)	(4.00)			
Heterogeneity in the mean of random parameter					
Constant: First harmful event at shoulder indicator (1 if harmful event was at the shoulder at the time of crash, 0 otherwise) [MI]	0.658	2.77			
Heterogeneity in the variance of random parameter					
Constant: Harmful event fixed object indicator (1 if harmful event occurred with roadside fixed object at the time of crash, 0 otherwise) [MI]	0.178	2.76			
Spatial characteristics					
District 5 indicator (1 if crash occured in District 5, 0 otherwise) [NI]	-0.312	-2.70	-0.0080	0.0041	0.0040
District 6 indicator (1 if crash occured in District 6, 0 otherwise) [NI]	0.507	3.22	0.0062	-0.0041	-0.0020
District 7 indicator (1 if crash occured in District 7, 0 otherwise) [SI]	0.635	4.90	-0.0081	-0.0010	0.0091
Vehicle characteristics					
Passenger car indicator (1 if passenger car involved in crash, 0 otherwise) [NI]	0.655	6.54	0.0372	-0.0226	-0.0146
Pickup truck indicator (1 if pickup truck involved in crash, 0 otherwise) [MI]	-0.867	-3.00	0.0054	-0.0063	0.0008
Environmental characteristics					
Rain indicator (1 if it was rainy at the time of crash, 0 otherwise) [SI]	-0.748	-4.83	0.0051	0.0006	-0.0057
Geometric characteristics					
Work on shoulder or median indicator (1 if crash occurred while work on shoulder or median, 0 otherwise) [SI]	0.327	2.94	-0.0117	-0.0015	0.0132
Lane closure work-zone indicator (1 if crash occurred at lane closure, 0 otherwise) [MI]	-1.002	-3.11	0.0073	-0.0079	0.0006
Crash charcteristics					
Harmful event right shoulder indicator (1 if harmful event occurred at the right shoulder at the time of crash, 0 otherwise) [NI]	-0.574	-5.75	-0.0224	0.0107	0.0118
Harmful event off-road indicator (1 if the harmful event occurred off road at the time of crash, 0 otherwise) [NI]	-0.393	-3.48	-0.0098	0.0046	0.0052
Traffic characteristics					
Low truck volume indicator (1 if truck volume below 10% of all traffic at the time of crash, 0 otherwise) [MI]	0.552	2.84	-0.0143	0.0159	-0.0015
Driver characteristics					
Negligent driver indicator (1 if negligent driving involved in crash, 0 otherwise) [MI]	0.663	3.09	-0.0146	0.0162	-0.0016
Young driver indicator (1 if driver's age below 30 years involved in crash, 0 otherwise) [MI]	0.633	3.21	-0.0168	0.0184	-0.0016
Number of observations	6,297				
Log-likelihood at zero	-4885.814				
Log-likelihood at convergence	-6917.962				
McFadden ρ^2	0.294				

SI = Severe Injury; MI = Minor Injury; NI = No Injury

ANALYSIS AND RESULTS





ANALYSIS AND RESULTS
MARGINAL EFFECTS COMPARISON

Variable	No Injury		Minor Injury		Severe Injury	
	Geometry	Non-Geometry	Geometry	Non-Geometry	Geometry	Non-Geometry
Spatial characteristics						
District 5 indicator (1 if crash occured in District 5, 0 otherwise)	–	-0.0080	–	0.0041	–	0.0040
District 6 indicator (1 if crash occured in District 6, 0 otherwise)	0.0110	0.0062	-0.0085	-0.0041	-0.0025	-0.0020
District 7 indicator (1 if crash occured in District 7, 0 otherwise)	-0.0058	-0.0081	-0.0008	-0.0010	0.0066	0.0091
Vehicular characteristics						
Passenger car indicator (1 if passenger car involved in crash, 0 otherwise)	0.0324	0.0372	-0.0216	-0.0226	-0.0108	-0.0146
Pickup truck indicator (1 if pickup truck involved in crash, 0 otherwise)	0.0067	0.0054	-0.0075	-0.0063	0.0008	0.0008
Environmental characteristics						
Rain indicator (1 if it was rainy at the time of crash, 0 otherwise)	–	0.0051	–	0.0006	–	-0.0057
Daylight indicator (1 if crash occurred in the daylight, 0 otherwise)	0.0255	–	-0.0159	–	-0.0097	–
Geometric characteristics						
Large shoulder width indicator (1 if crash occurred at right shoulder width between 6 to 10 ft, 0 otherwise)	-0.0122	–	0.0069	–	0.0053	–
Lane closure work-zone indicator (1 if crash occurred at lane closure, 0 otherwise)	–	0.0073	–	-0.0079	–	0.0006
Work on shoulder-median work indicator (1 if crash occurred while work on shoulder or median, 0 otherwise)	-0.0152	-0.0117	-0.0020	-0.0015	0.0172	0.0132
Transition area indicator (1 if crash occurred in the work zone's transition area, 0 otherwise)	0.0024	–	0.0003	–	-0.0027	–
Crash charcteristics						
Harmful event off-road indicator (1 if the harmful event occurred off road, 0 otherwise)	–	-0.0098	–	0.0046	–	0.0052
Harmful event on right shoulder indicator (1 if harmful event occured at the right shoulder, 0 otherwise)	-0.0076	-0.0224	-0.0011	0.0107	0.0087	0.0118
Traffic characteristics						
Low truck volume indicator (1 if truck volume below 10% of all traffic at the time of crash, otherwise)	-0.0243	-0.0143	0.0265	0.0159	-0.0021	-0.0015
Driver characteristics						
Young driver indicator (1 if driver's age below 30 years involved in crash, 0 otherwise)	–	-0.0168	–	0.0184	–	-0.0016
Negligent driver indicator (1 if negligent driving involved in crash, 0 otherwise)	-0.0246	-0.0146	0.0268	0.0162	-0.0022	-0.0016
Other factors						
No worker presence indicator (1 if no worker was present at the time of crash, 0 otherwise)	-0.0367	–	0.0398	–	-0.0031	–

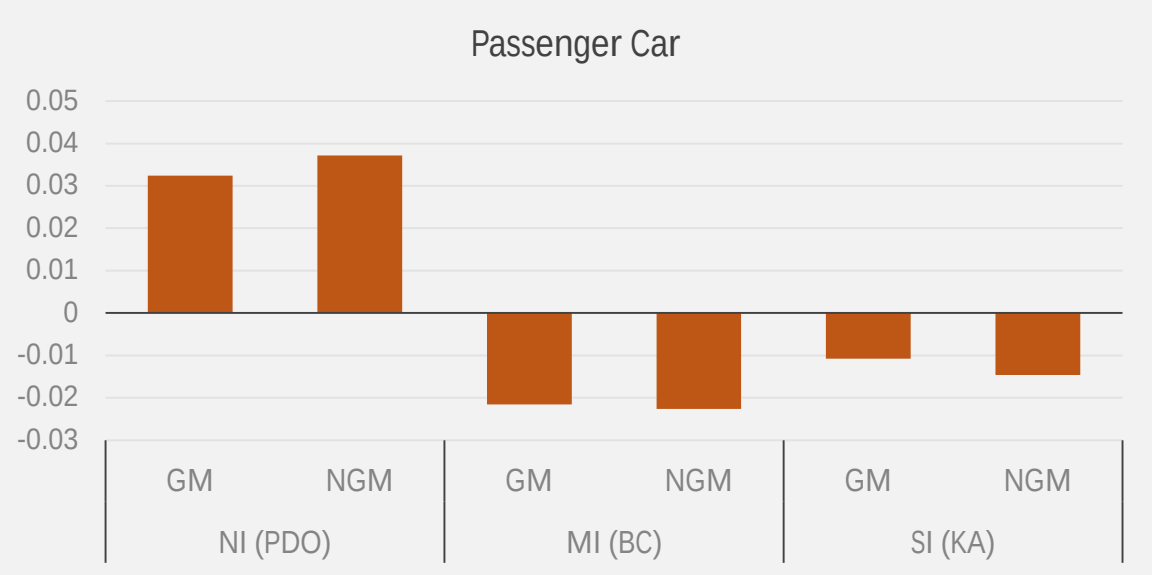
ANALYSIS AND RESULTS

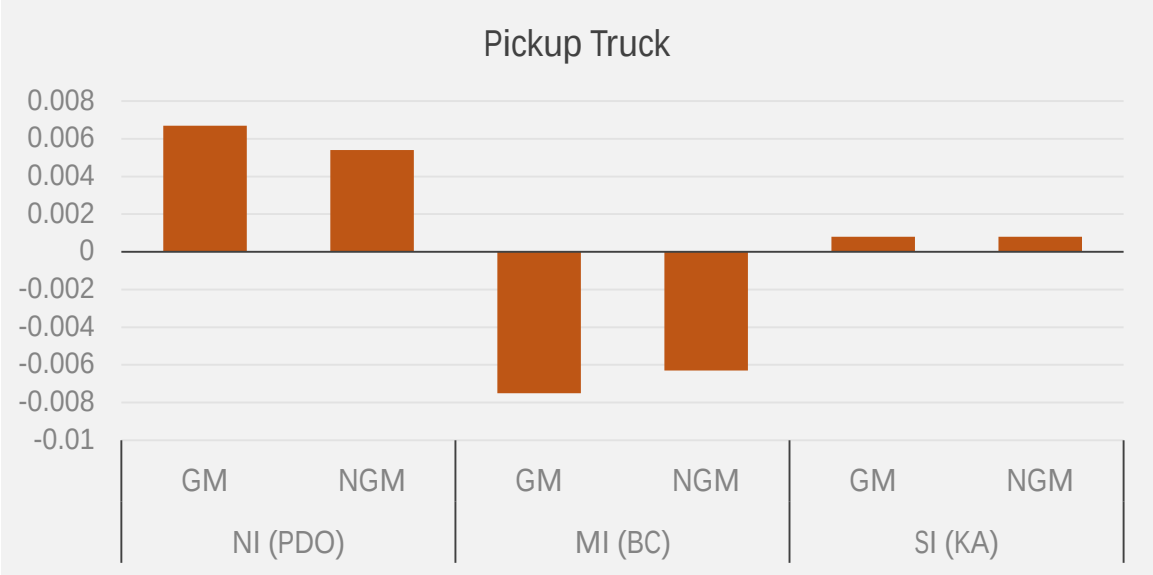
MARGINAL EFFECTS - SPATIAL

GM – Ge

ANALYSIS AND RESULTS

MARGINAL EFFECTS – VEHICLE TYPES

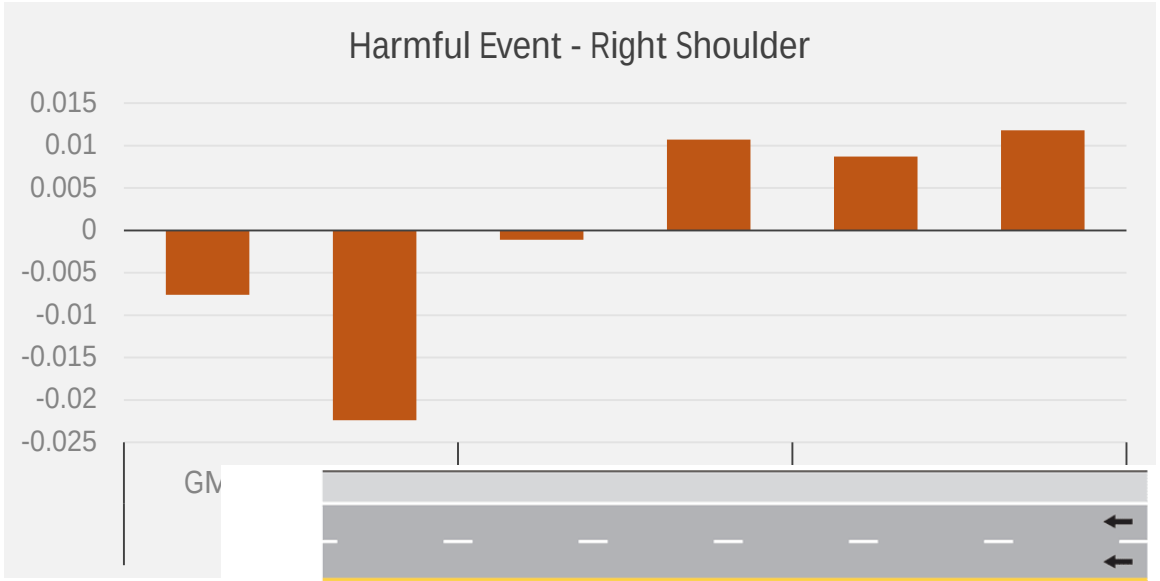




GM – Geometry: NGM – Non-Geometrv

ANALYSIS AND RESULTS

MARGINAL EFFECT – EVENTS AND TRAFFIC VOLUME



GM – Geometry

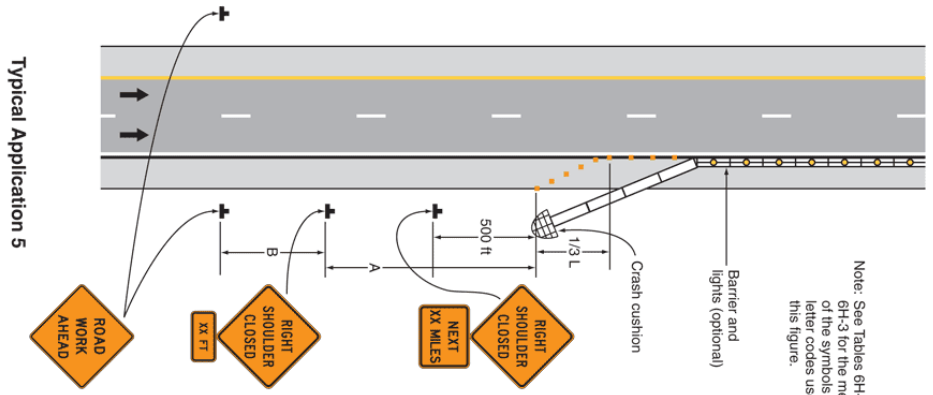
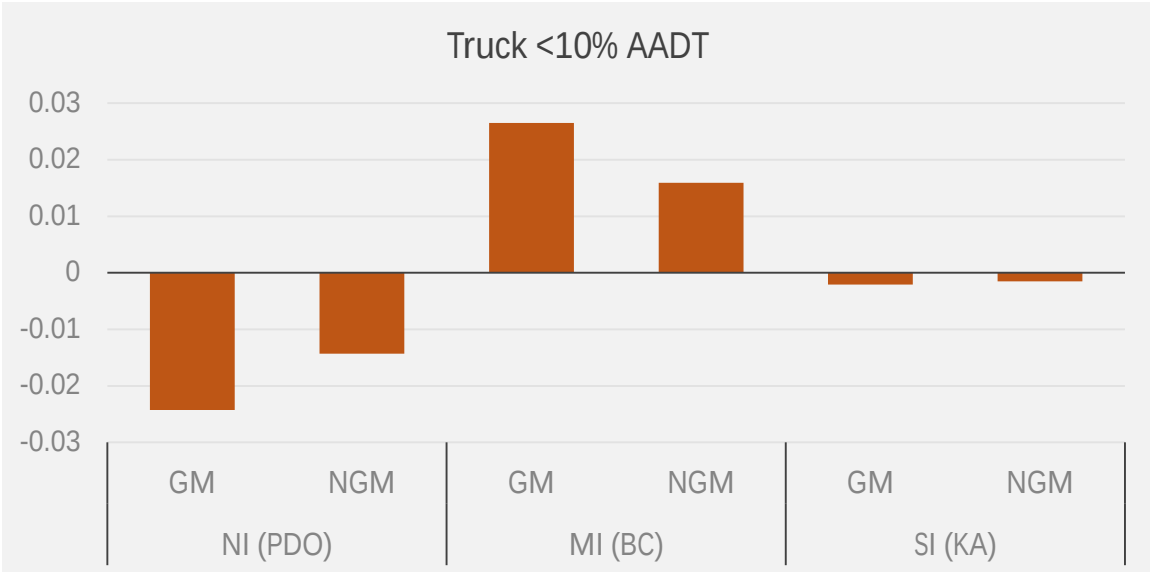
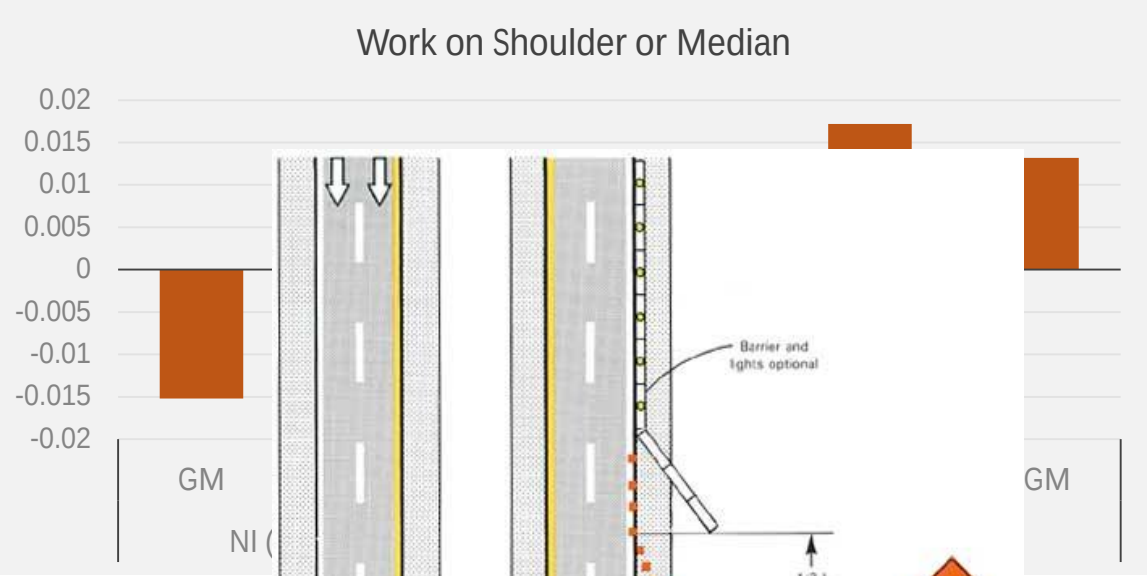


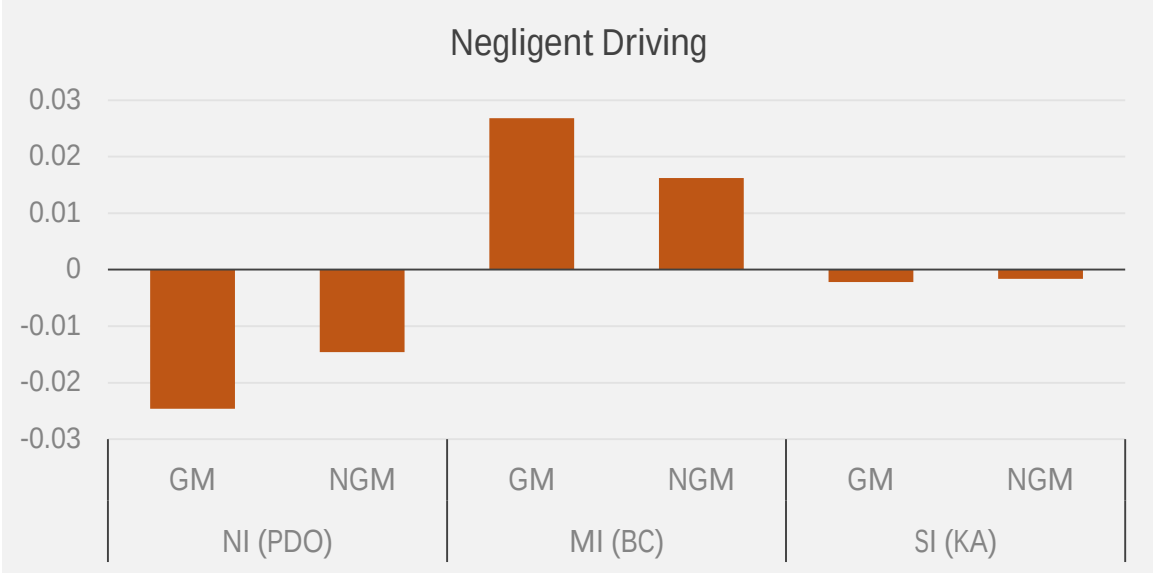
Figure 6H-5. Shoulder Closure on a Freeway (TA-5)



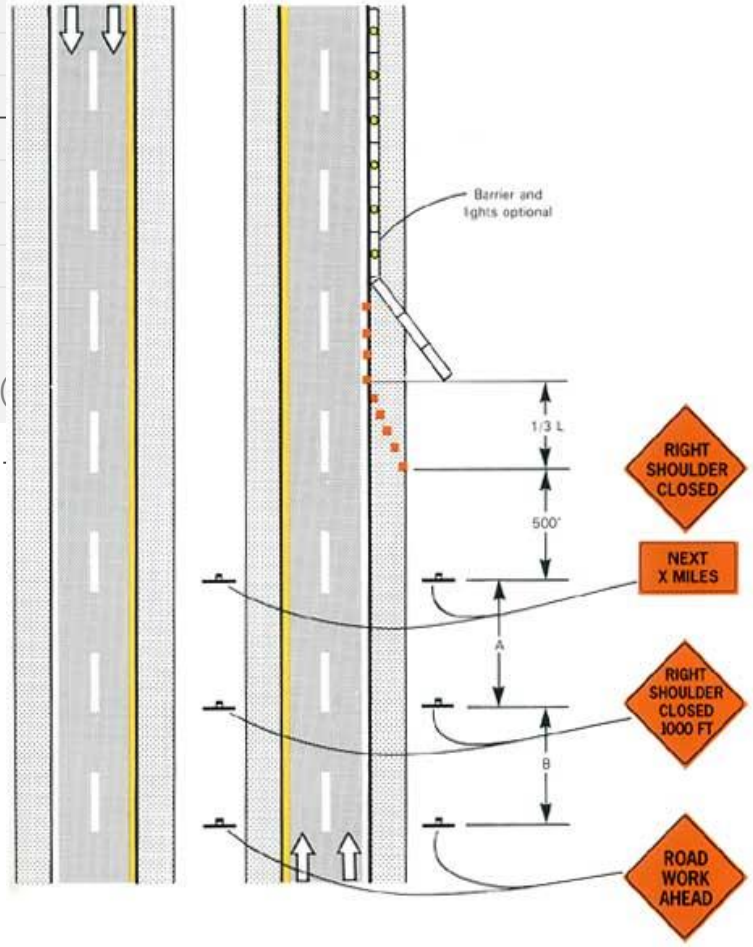
ANALYSIS AND RESULTS

MARGINAL EFFECTS – WORK ZONE TYPE AND DRIVING BEHAVIOR



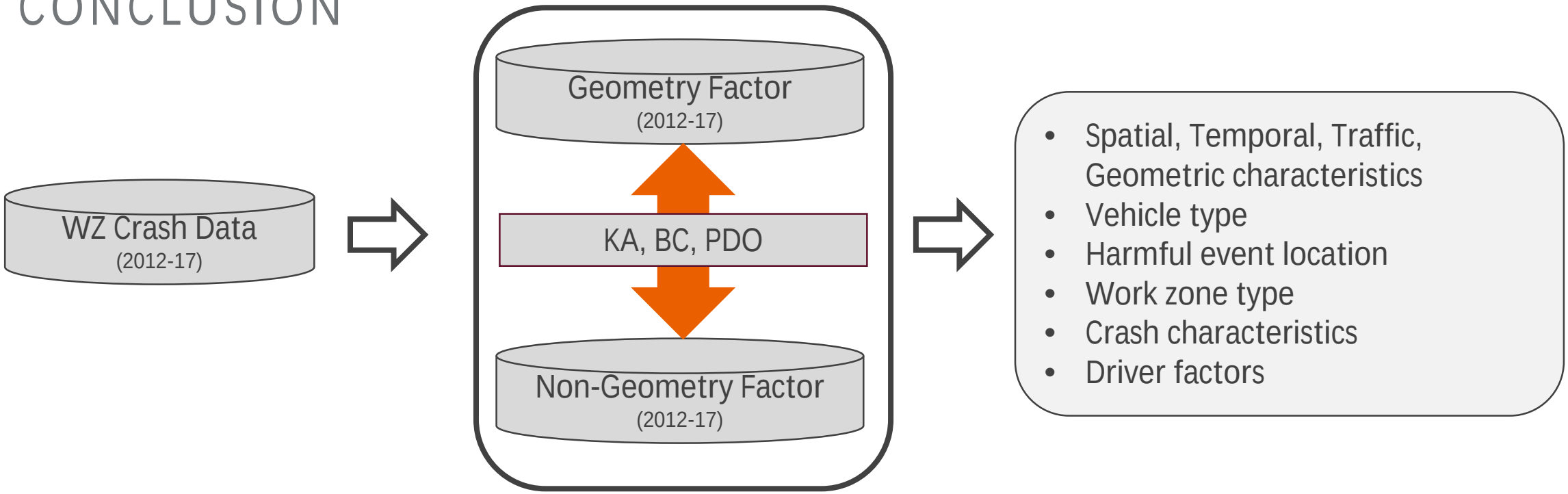


GM – Geometry; NGM



SUMMARY AND FUTURE WORK

CONCLUSION



- There are some consistencies between these two factors: geometry & non-geometry in work-zone crashes. (of the 17 variables, **8 of these were found to be statistically significant in both factors**)

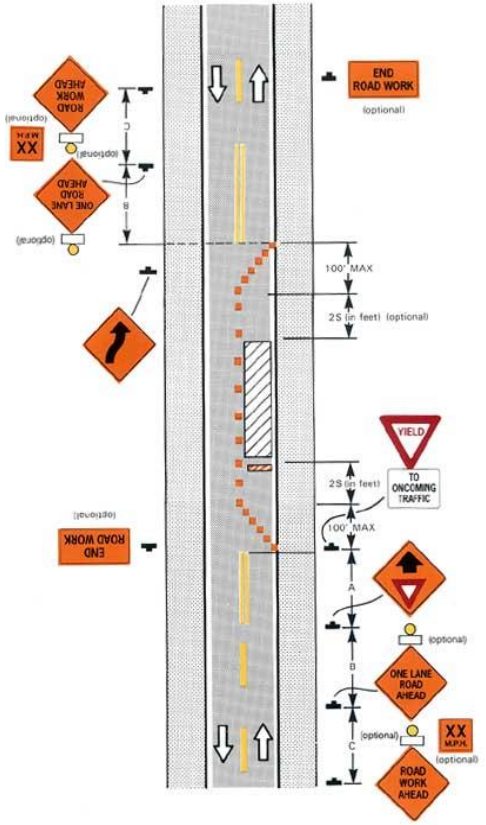
- Likelihood ratio tests show that the estimated parameters were **different for driver injuries** in Florida work-zone-related crashes for geometry and non-geometry factors.

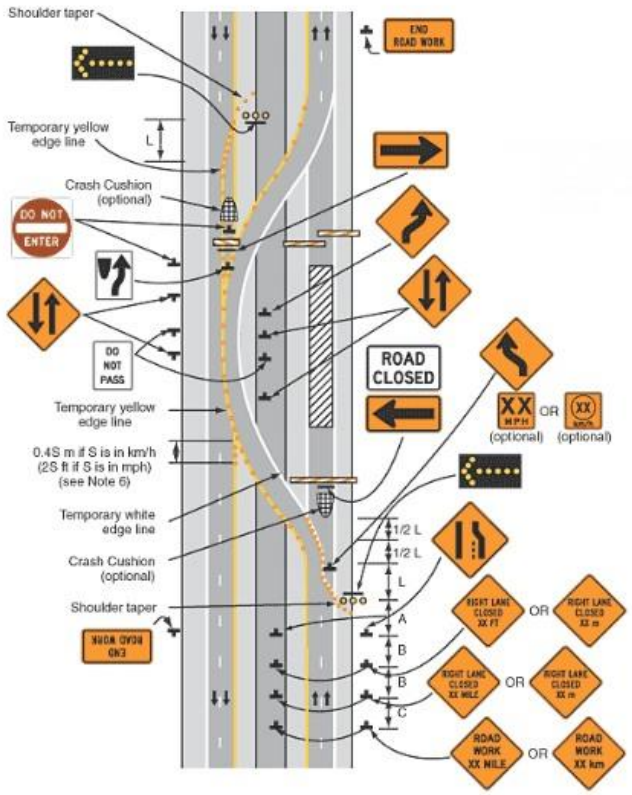
SUMMARY AND FUTURE WORK

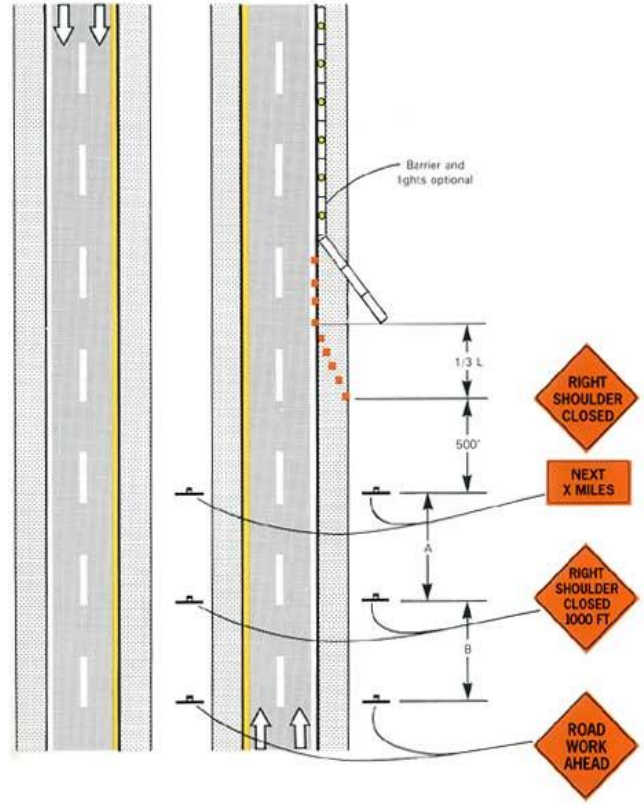
FUTURE WORK

- Temporal instability

Work Zone Type	Potential Factors
Lane Closure	Disregarding traffic sign
Lane shift/Cross-over	Exceeding speed limit
Work on Shoulder/ Median	Over correction







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Thank you!

Discussions: Question – Answer

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