Collaborative Sciences Center for ROAD SAFETY

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Developing a Taxonomy for Human Errors and Violations that Lead to Crashes

Collaboration: University of Tennessee, Knoxville;
Florida Atlantic University

R19 Project Team

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Overview

Research Contributions

This project contributes by:

- Quantifying the contribution of key human, vehicle, and roadway environment factors
- Developing a systematic taxonomy for driving errors and violations and exploring their contribution to the occurrence of safety-critical events (i.e., crashes and near-crashes) in naturalistic settings
- Exploring the pathways of errors and violations that lead to safety-critical events in diverse roadway and built environments

Overview

Research Questions

This project addresses the following research questions:

- What types of driving errors and violations (human factors) result in safety-critical events in naturalistic settings?
- How do driving errors and violations vary across different roadway and built environments?
- How do various built-environment, roadway or other important factors influence crash occurrence both directly and indirectly through driving errors and violations?

R19 Project: Studies Conducted

Study I:

A Taxonomy of Naturalistic Driving Errors and Violations: Evidence from the Naturalistic Driving Study

Study II:

Driver Errors and Violations: Pathways that Lead to Crashes in Diverse Built Environments

Study I (Project R19)

A Taxonomy of Naturalistic Driving Errors and Violations: Evidence from Naturalistic Driving Study

THE UNIVERSITY OF TENNESSEE KNOXVILLE

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

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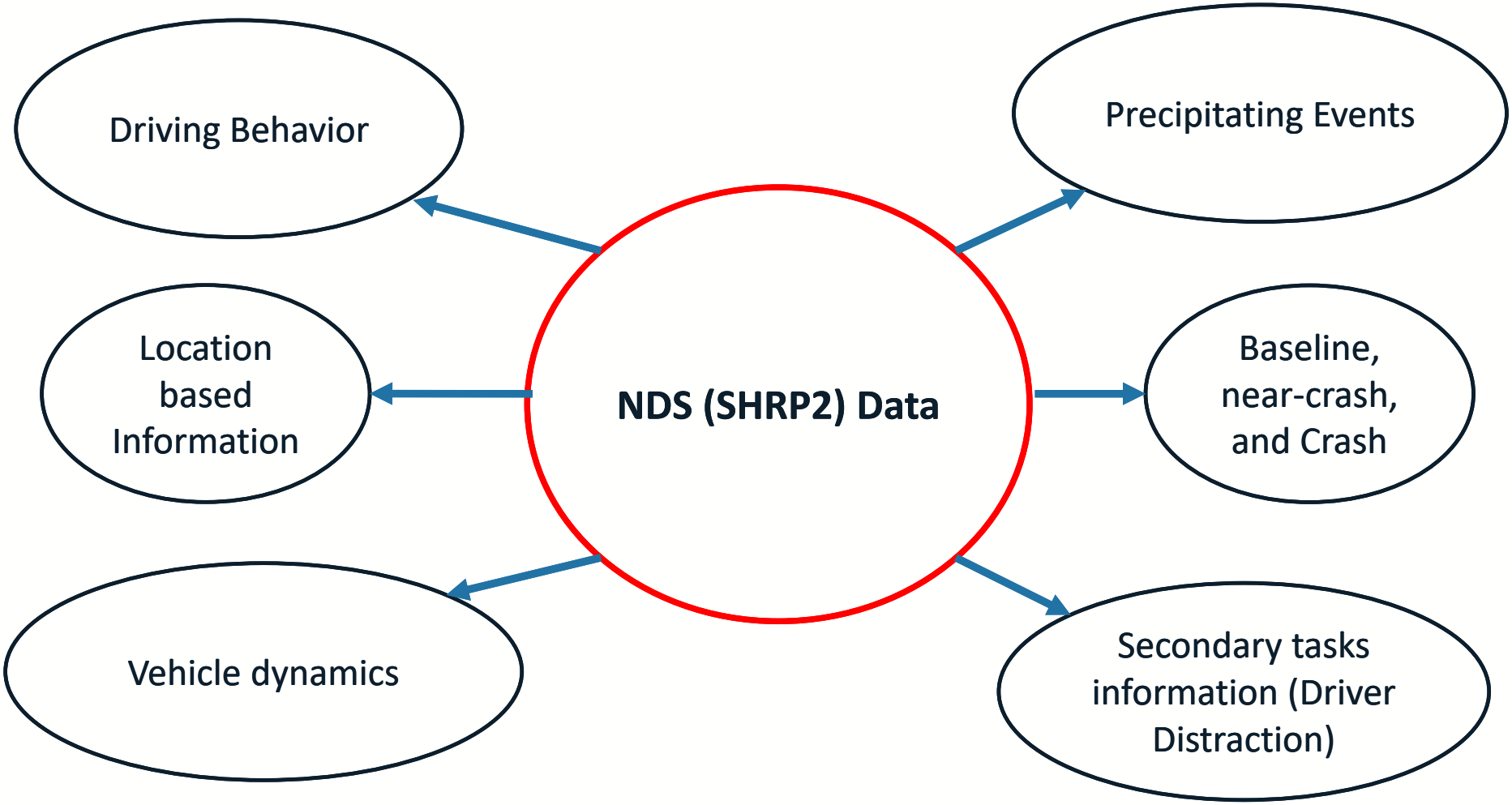
Introduction

- Human Factors contribute in a majority of crashes
- **The Naturalistic Driving Study (SHRP2), compared to Police Crash Reports,** provides extensive information on pre-crash driving behavior, precipitating events, & land-use and roadway environments
- **NDS Data** provides information on "no-event" (baselines), near-crashes & crashes → quantify risk
- **Police-reported crash data** can be subjective, esp. pre-crash

NDS (SHRP2) Data: Overview



NDS data includes 7,589 (79.11%) Baselines, 1,331 (13.87%) Near-crashes, & 673 (7.02%) Crashes

Human, Roadway/Environment, & Vehicle Factors – Deriving them from NDS (SHRP2)

1. Human Factors

- **Driver Behavior** e.g., distraction
- **Secondary Tasks & Secondary Task Outcome**

2. Roadway and Environment Factors

- **Infrastructure** e.g., roadway alignment, road delineation
- **Visual Obstruction** e.g., curve/hill, inadequate roadway lighting system
- **Surface Conditions** e.g., roadway snowy, muddy, and oily

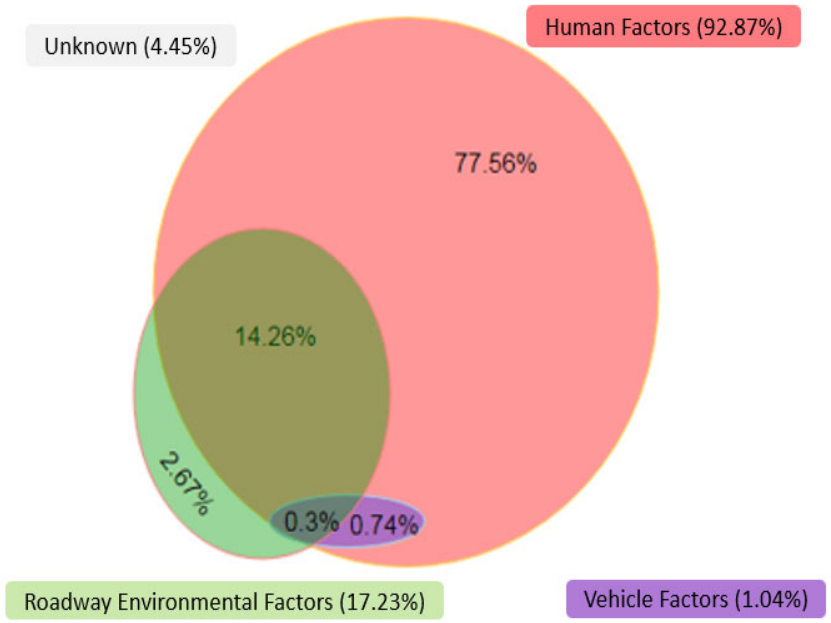
3. Vehicle Factors

- **Visual Obstruction** only those related to vehicle e.g., faulty head-lights
- **Vehicle contributing factors** e.g., faulty tires

Distribution of Key Contributing Factors in Safety Critical Events (Crashes & Near-crashes)

Safety Matrix: NDS Crashes

Human Factors	Vehicle Factors	Roadway Factors	Crash	
			Freq.	%
Y	Y	Y	2	0.30
Y	Y	N	5	0.74
Y	N	N	522	77.56
N	N	N	30	4.45
N	N	Y	18	2.67
N	Y	Y	0	0.00
N	Y	N	0	0.00
Y	N	Y	96	14.26
Total			673	100.0

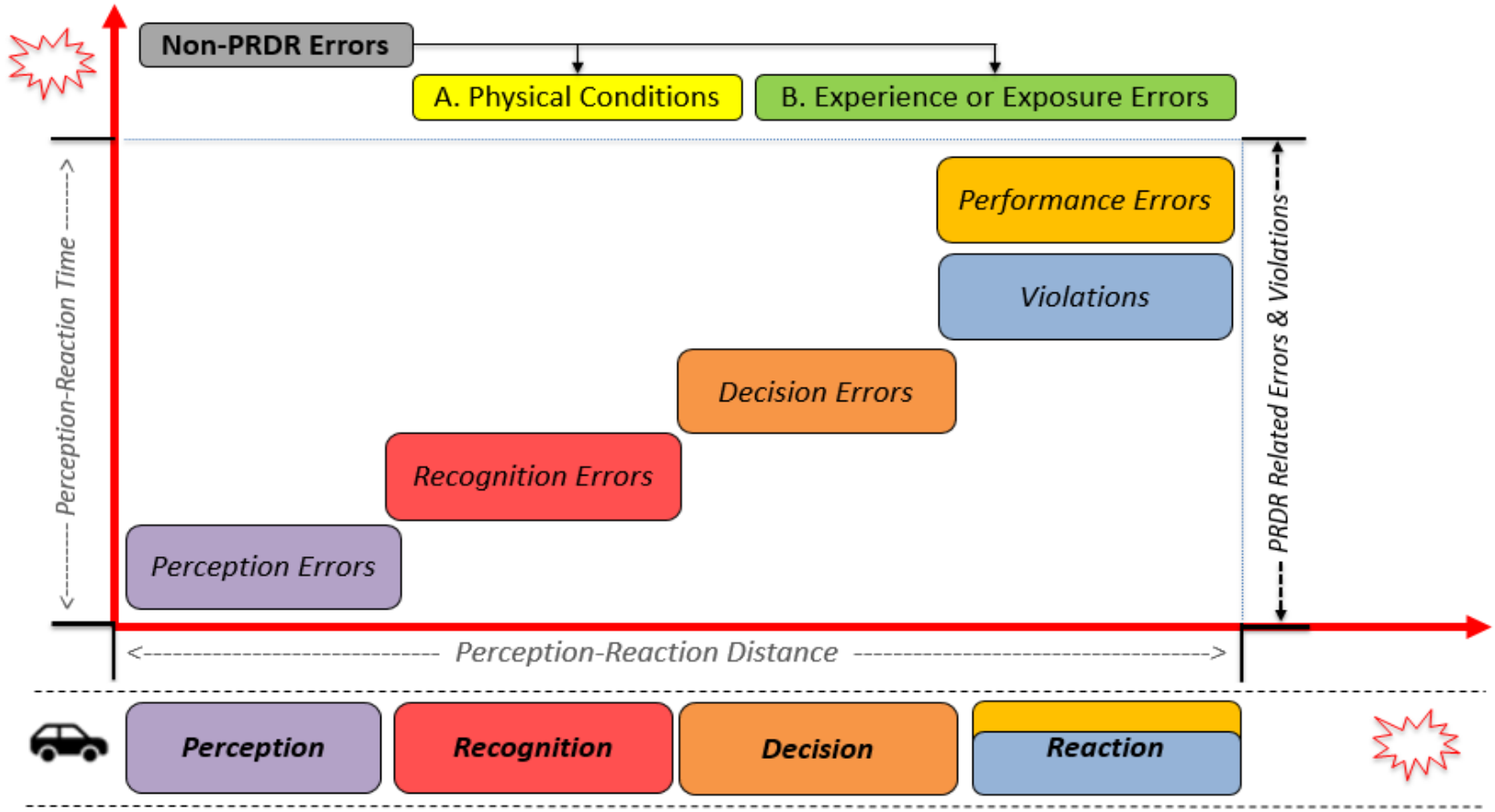


22% of the overall crashes are police reportable

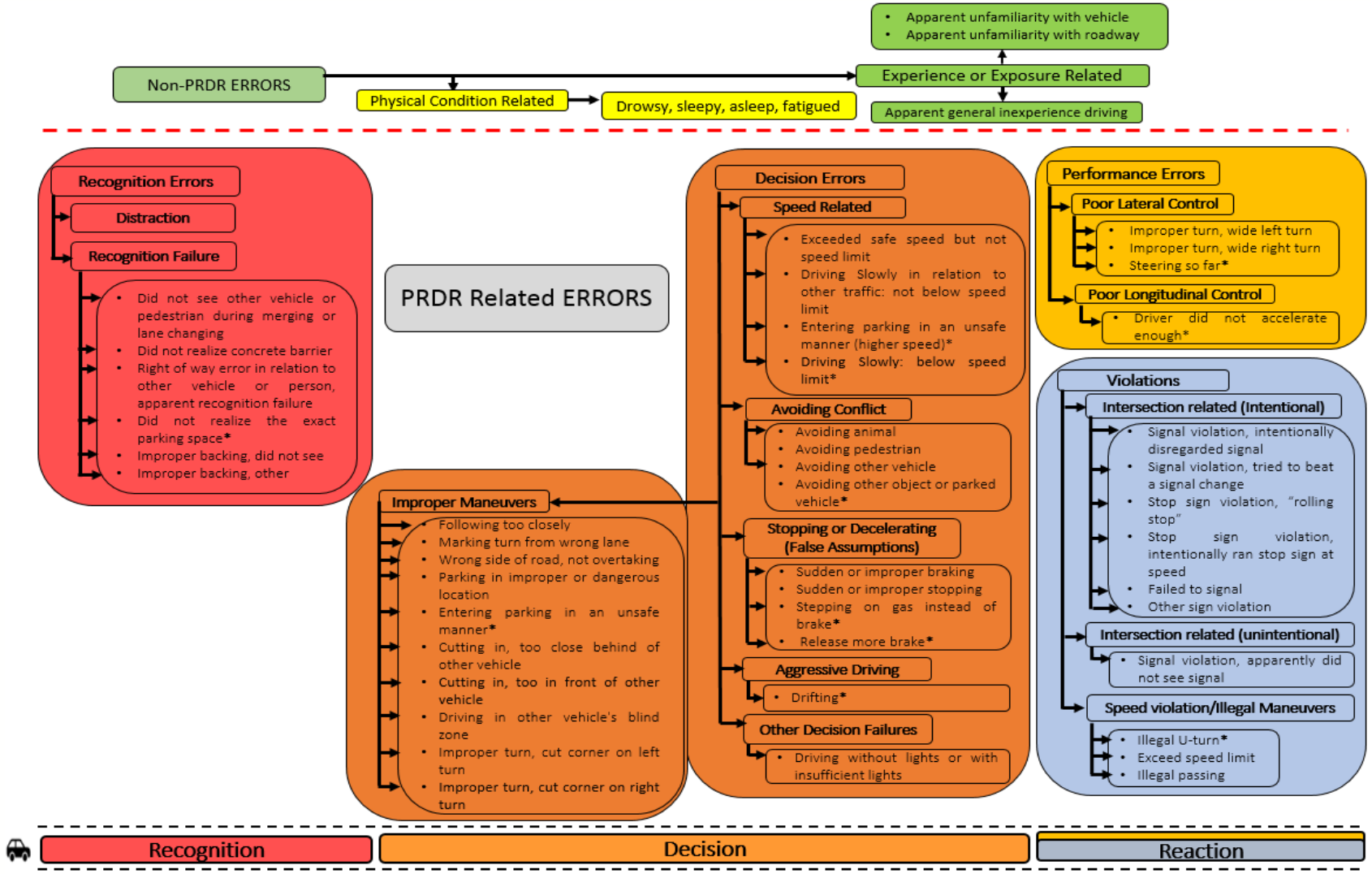
- Human factors solely contribute to 78% of crashes
- Human factors contribute to 93% of crashes (similar to Treat et al. 1979)

Systematic Taxonomy for Driving Errors and Violations in Naturalistic Environment

Evolution of Driving Errors and Violations in the Space-Time Dimension



Systematic Taxonomy for Driving Errors and Violations in Naturalistic Environment



Definition of “Locality” variable (NDS Dictionary)

Value	Definition	Example and Hints
Open country	Other than the roadway, there is nothing but vegetation visible during the time surrounding the Precipitating Event that is described in any of the other categories. Road is not an Interstate or a bypass/divided highway with traffic signals. (Often appears as rural roads, 2 lanes undivided.)	Includes roadways not defined as Interstate or divided highway, when no landmarks mentioned in other categories are visible.
Open Residential	Rural to semi-rural areas where there may be only one or a few houses around (i.e., farmland).	
Moderate Residential	An area where multiple houses or apartment buildings are present, but is not as dense as an Urban Locality.	e.g., residential subdivisions
Business/industrial	Any type of business or industrial structure is present, but is not as dense as an Urban Locality. (If there are also houses visible, this category takes precedence over Open residential and Moderate residential).	
Church	One or more involved vehicle passes a church building at the time of the Precipitating Event.	
Playground	One or more involved vehicle passes any type of playground or children's playing field at the time of the Precipitating Event.	If playground/field is on school grounds, code as School.
School	One or more involved vehicles passes any type of school building or is in a school zone at the time of the Precipitating Event, including adult learning institutions.	Include any training centers, universities, etc. as well as elementary and secondary schools.

Definition… (continued)

Value	Definition	Example and Hints
Urban	Higher density area where blocks are shorter, streets are a mix of one and two way, and traffic can include buses and trams. (This category takes precedence over others when either businesses and/or residences are present.)	
Interstate/bypass/ divided highway with no traffic signals	Vehicle is travelling on an interstate, bypass, or divided highway with no traffic signals (regardless of what buildings can be seen), at the time of the Precipitating Event.	
Bypass/divided highway with traffic signals	Vehicle is travelling on a bypass or divided highway with traffic signals (no other category description is visible) at the time of the Precipitating Event. (Often appears as "Open Country", but with more lanes and/or as a divided road.)	
Other	Locality at the time of the Precipitating Event is one not described in other categories.	Ex. In campground.
Unknown	Cannot determine the Locality due to limitations in video views, lighting, visual obstructions, or limited perspective.	Ex. Part of the video is missing or there is insufficient information in the video to make a determination.

Driving Errors Classified first-prevalence in Safety Critical Events…

Variable	Event Type			Prevalence of Errors in SCEs	
	Baseline (%) (N =7,589)	Near-Crash (%) (N=1,331)	Crash (%) (N=673)	$\frac{\%\text{ in Near Crash}}{\%\text{ in Baseline}}$	$\frac{\%\text{ in Crash}}{\%\text{ in Baseline}}$
Type of Driving Errors And Violations					
• No error / violation	90.12	38.69	7.13	0.43	0.08
• Recognition	0.22	34.03	38.63	154.68	175.59
• Decision	2.69	13.82	34.32	5.14	12.76
• Performance	0.09	0.68	7.58	7.56	84.22
• Physical condition	1.25	1.43	1.34	1.14	1.07
• Experience/exposure	0.07	0.6	1.93	8.57	27.57
• Violation	5.56	10.74	9.06	1.93	1.63
Total	100%	100%	100%	---	---

- Higher hazard → More driving errors and violations, esp. recognition & performance err.
- In baselines (no event), drivers make errors & violations – but they are less frequent

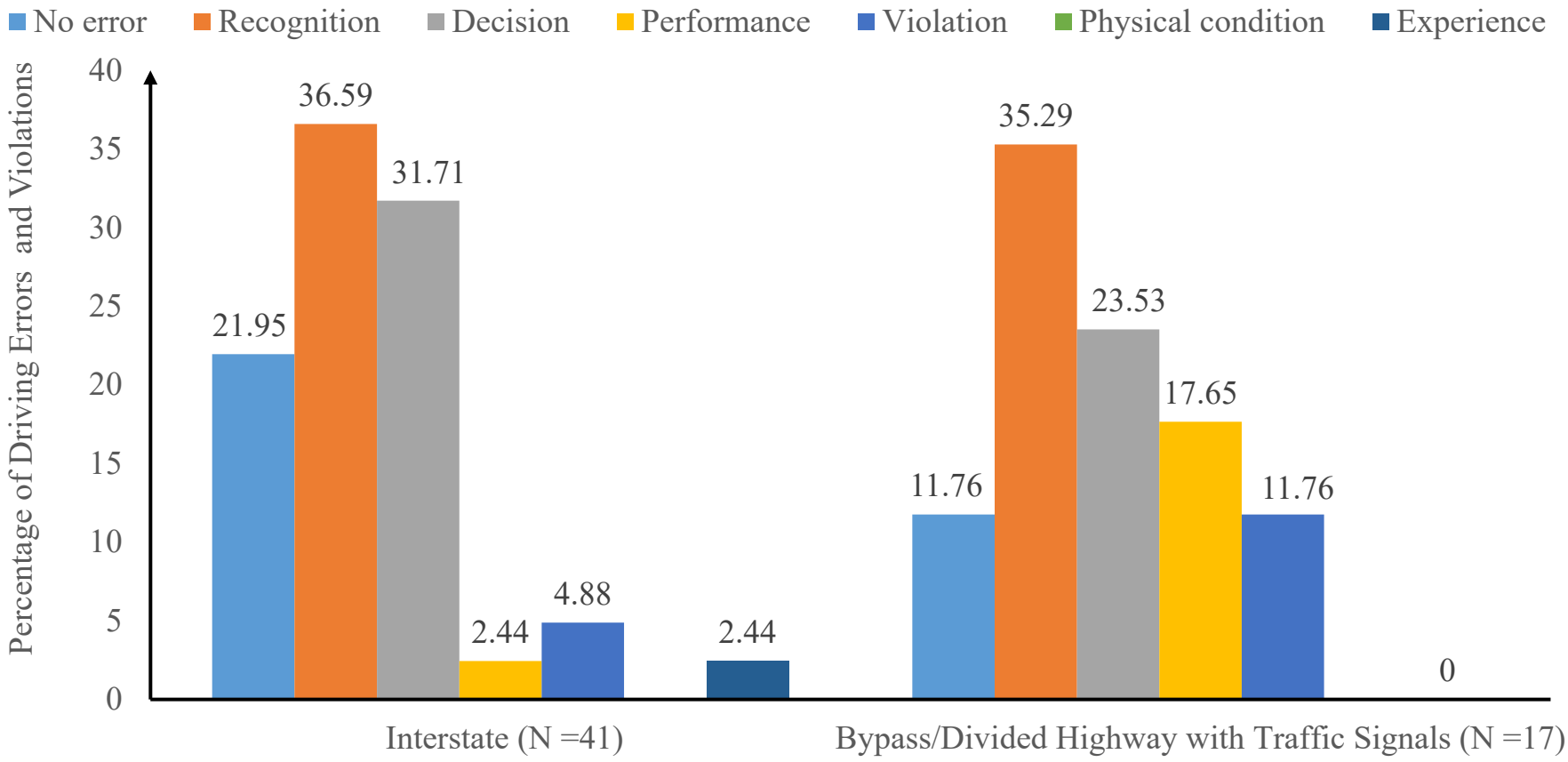
Distribution of Crashes, Near-crashes, & Baselines across Roadways & Environments

VARIABLE	All Cases, N = 9,593) Percent (S.D.)	Baseline (%) (N = 7,589)	Near-Crash (%) (N = 1,331)	Crashes (%) (N = 673)	$\frac{\%\text{ of Crashes}}{\%\text{ of Baselines}}$
ROADWAY LOCALITY					
• Interstate	23.29 (0.4226)	25.6	18.78	6.09	0.2379
• Open Country or Open Residential	8.66 (0.2813)	9.46	5.48	5.94	0.6279
• Moderate Residential	21.21 (0.4088)	22.26	15.55	20.50	0.9209
• School	5.10 (0.2199)	4.51	7.06	7.87	1.7450
• Business/Industrial	34.08 (0.4739)	31.10	40.04	46.21	1.4859
• Urban	2.76 (0.1639)	1.51	7.30	7.88	5.2185
• Bypass or Divided Highways with no Traffic Signals	3.00 (0.1760)	3.04	3.00	2.53	0.8322
• Others (e.g., Church, Playground and Campground)	1.90 (0.1364)	1.66	2.78	2.98	1.7952
Total	100%	100%	100%	100%	

- Higher crash risk areas → urban, school zones, business (commercial) or industrial locations

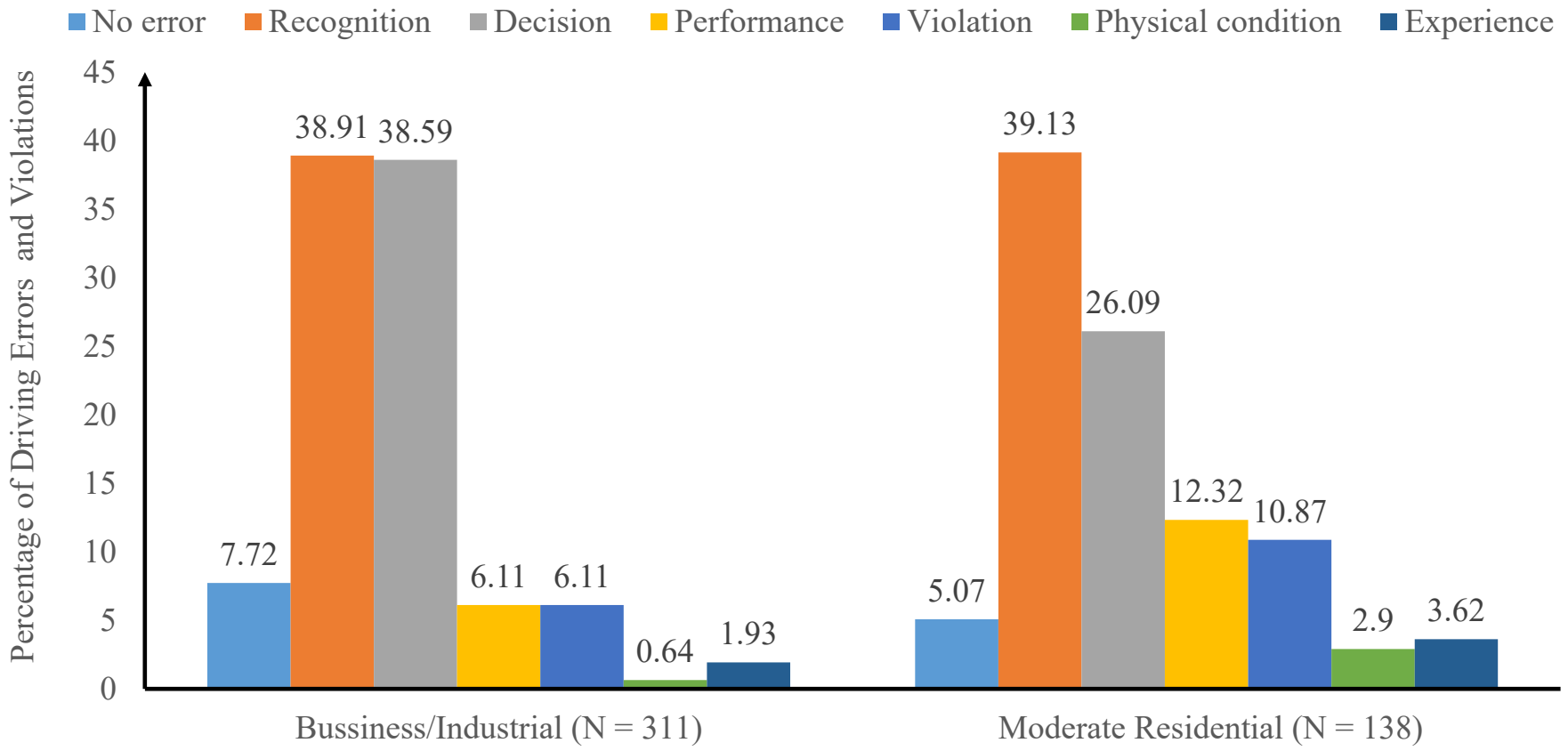
Open country/open residential indicate rural and semi rural settings-NDS dictionary)

Driving Errors and Violations on Interstate and Bypass/Divided Highways with Traffic Signals (in Crashes)



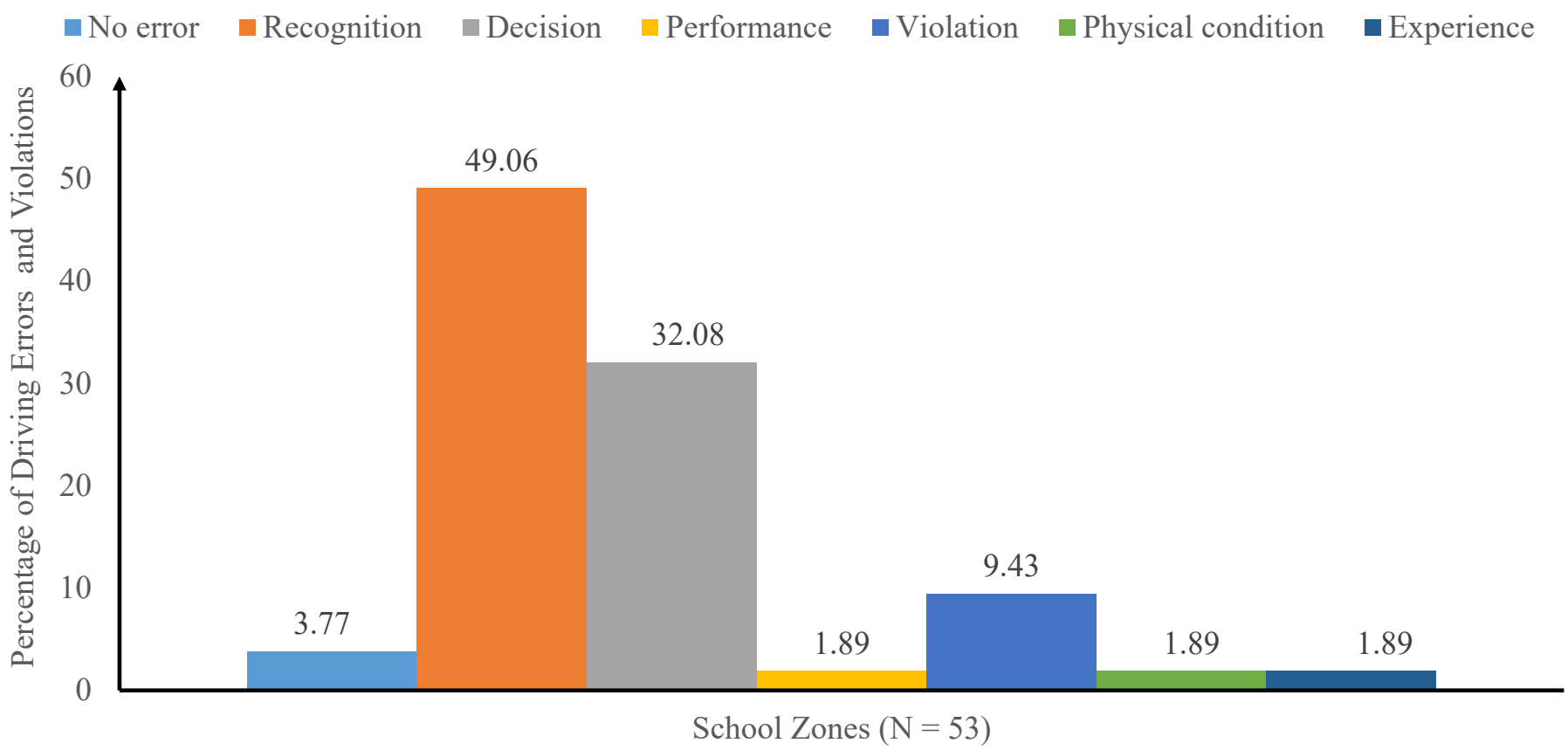
- Recognition and decision errors → prevalent-contribute to interstate & arterial crashes
- Contribution of violations to crashes is lower in NDS data (~5%)

Driving Errors and Violations in Business or Industrial & Residential Locations (in Crashes)



- Business or industrial areas coded to have 46% of 673 crashes: Recognition & decision errors each contribute to 39% of crashes in school zones
- Residential areas: Recognition errors (39%) & decision errors (26%) contribute to crashes

8% Crashes coded on Roadways in School Zones



- School zones: Recognition failures (49%) & decision errors (32%) contribute to crashes
- School zones: Violations contributed to about 9% of crashes

Conclusions

- Human factors still contribute to 93% of crashes in the NDS data
- Recognition and decision errors contributed to 39% and 34% of crashes respectively
- Recognition and decision errors were also the leading driving errors, contributing to 34% and 14% of near-crashes

Implications-countermeasures that can reduce recognition and decision errors

Conclusions

- Near school zones 8% of crashes were coded to occur,
  - Recognition errors contributed to nearly 50% of the crashes
- Near business or industrial structures 46% of crashes were coded to occur
  - Recognition errors and decision errors each were 39% in business or industrial structures
  - Study among the first ones to identify this hazard in a substantive way
- Findings provide a foundation upon which to build a larger transportation safety program
- Valuable insights can be aimed at reducing transportation crashes through data-driven strategies

Implications: Innovations that can reduce errors in complex environments

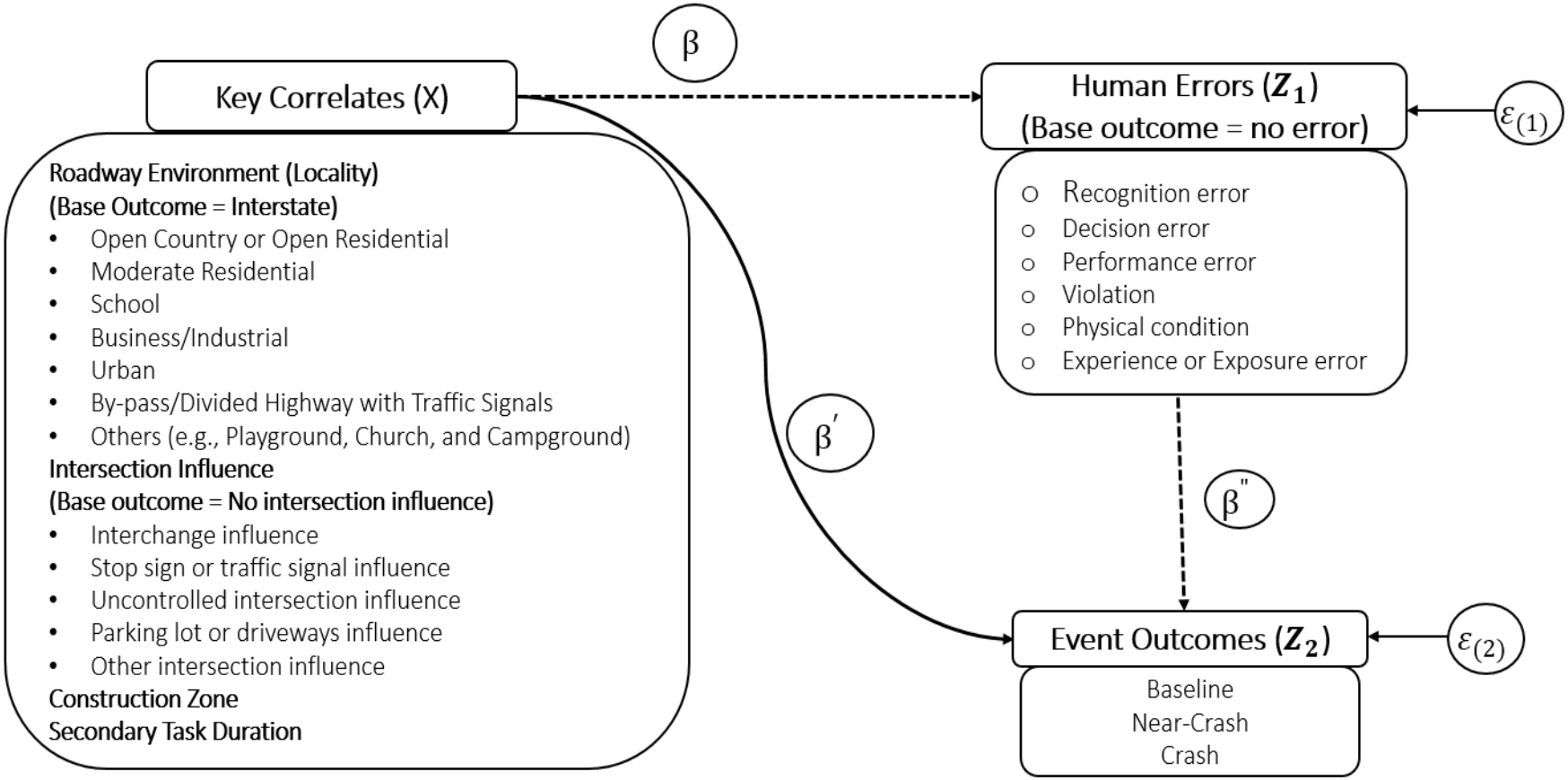
Study 2 (Project R19)

Driver Errors and Violations: Pathways that Lead to Crashes in Diverse Built Environment

Introduction

- Different roadway environments can induce certain driving errors and violations
- Safe systems approach → Path analysis-a nuanced conceptual framework
- **Naturalistic Driving Study (SHRP2)** provides extensive information on driving behavior, land-use and roadway environments
  - **NDS Data** provide information on non-event driving (baselines), near-crashes and crashes
  - Compare risk of crash and near-crash events with non-event baselines

Study Design – Rigorous Path Analyses Framework



Notes: Dotted lines = indirect effects; solid lines = direct effects

Z_1 (Driving errors and violations) multinomial logit framework

Z_2 (severity outcomes) ordered probit regression

Descriptive Statistics-Key Correlates

VARIABLE	All Cases, N = 9,593) Percent (S.D)	Baseline (%) (N = 7,589)	Near-Crash (%) (N = 1,331)	Crashes (%) (N = 673)	% of Crashes / % of Baselines
DRIVING ERRORS					
• No Driving Errors	77.16 (0.4198)	90.12	38.69	7.13	0.0791
• Recognition Errors	7.60 (0.2652)	0.22	34.03	38.63	175.5909
• Decision Errors	6.45 (0.2457)	2.69	13.82	34.32	12.7584
• Performance Errors	0.69 (0.0833)	0.09	0.68	7.58	84.2222
• Violations	6.53 (0.2469)	5.56	10.74	9.06	1.6295
• Physical Conditions	1.28 (0.1125)	1.25	1.43	1.34	1.0720
• Experience or Exposure Errors	0.27 (0.0519)	0.07	0.60	1.93	27.5714
Total	100%	100%	100%	100%	
ROADWAY LOCALITY					
• Interstate	23.29 (0.4226)	25.6	18.78	6.09	0.2379
• Open Country or Open Residential	8.66 (0.2813)	9.46	5.48	5.94	0.6279
• Moderate Residential	21.21 (0.4088)	22.26	15.55	20.50	0.9209
• School	5.10 (0.2199)	4.51	7.06	7.87	1.7450
• Business/Industrial	34.08 (0.4739)	31.10	40.04	46.21	1.4859
• Urban	2.76 (0.1639)	1.51	7.30	7.88	5.2185
• Bypass or Divided Highways with no Traffic Signals	3.00 (0.1760)	3.04	3.00	2.53	0.8322
• Others (e.g., Church, Playground and Campground)	1.90 (0.1364)	1.66	2.78	2.98	1.7952
Total	100%	100%	100%	100%	
INTERSECTION INFLUENCE					
• No Intersection Influence	71.75 (0.4497)	81.42	32.83	41.01	0.5037
• Interchange Influence	3.22 (0.1765)	2.33	8.41	2.97	1.2747
• Stop Sign or Traffic Signal Influence	15.78 (0.3646)	12.06	32.38	24.96	2.0697
• Uncontrolled Intersection Influence	3.38 (0.1807)	1.75	10.14	8.32	4.7543
• Parking Lot or Driving Way Entrance/Exit Influence	4.65 (0.2106)	1.98	11.95	20.36	10.2828
• Other (e.g., crosswalk, railroad crossing, roundabouts)	1.22 (0.1097)	0.46	4.28	2.38	5.1739
Total	100%	100%	100%	100%	
CONSTRUCTION ZONE INDICATOR	3.79 (0.1911)	3.40	6.01	3.86	1.1353
SECONDARY TASK DURATION* (Min (0); Max (24.1))	2.0918 (2.719)	1.75 (2.16)	3.28 (3.83)	3.58 (4.19)	---

Selected Results: Driving Error Model

Independent Variables	Type of Driving Error and Violations							
	Recognition		Decision		Performance		Violation	
	Coeff.	ME	Coeff.	ME	Coeff.	ME	Coeff.	ME
ROADWAY LOCALITY (BASE OUTCOME = INTERSTATE)								
Open Country/Open Residential (Rural/Semi-Rural)	---	---	0.550[a]	0.0328	---	---	---	---
Moderate Residential	0.311[b]	0.0130	0.362[a]	0.0168	2.536[a]	0.0094	---	---
School	0.872[a]	0.0478	0.674[a]	0.0345	---	---	-0.354[b]	-0.0324
Business/Industrial	0.488[a]	0.0251	0.362[a]	0.0177	2.097[a]	0.0058	-0.511[a]	-0.0369
Urban	1.369[a]	0.0800	1.165[a]	0.0665	3.125[a]	0.0133	---	---
Bypass or Divided Highway with traffic signals	---	---	---	---	2.856[a]	0.0132	---	---
Others (e.g., church, playground, & Campground)	0.800[a]	0.0417	0.625[a]	0.0309	2.821[a]	0.0117	---	---

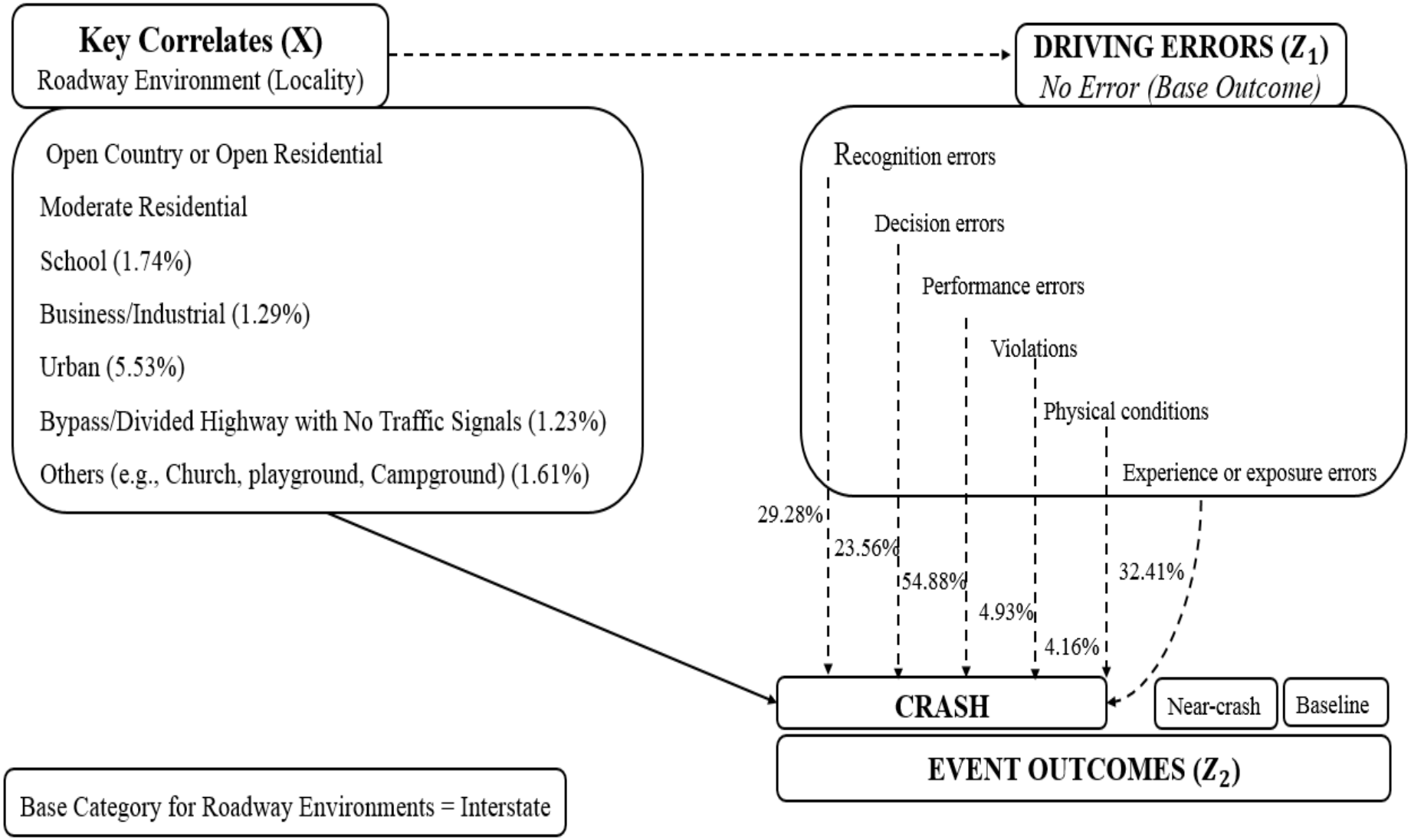
- Recognition & decision errors → More in residential areas, school zones, near business or industrial structures & urban areas (compared to interstates)
- Results for the other factors are not shown here, e.g., intersection influence, distraction duration, and construction zone
- Sample size for estimated model: N=9,593 observations-including 7,589 baselines, 1,331 near-crashes, and 673 crashes

Selected Results: Event Outcome Model

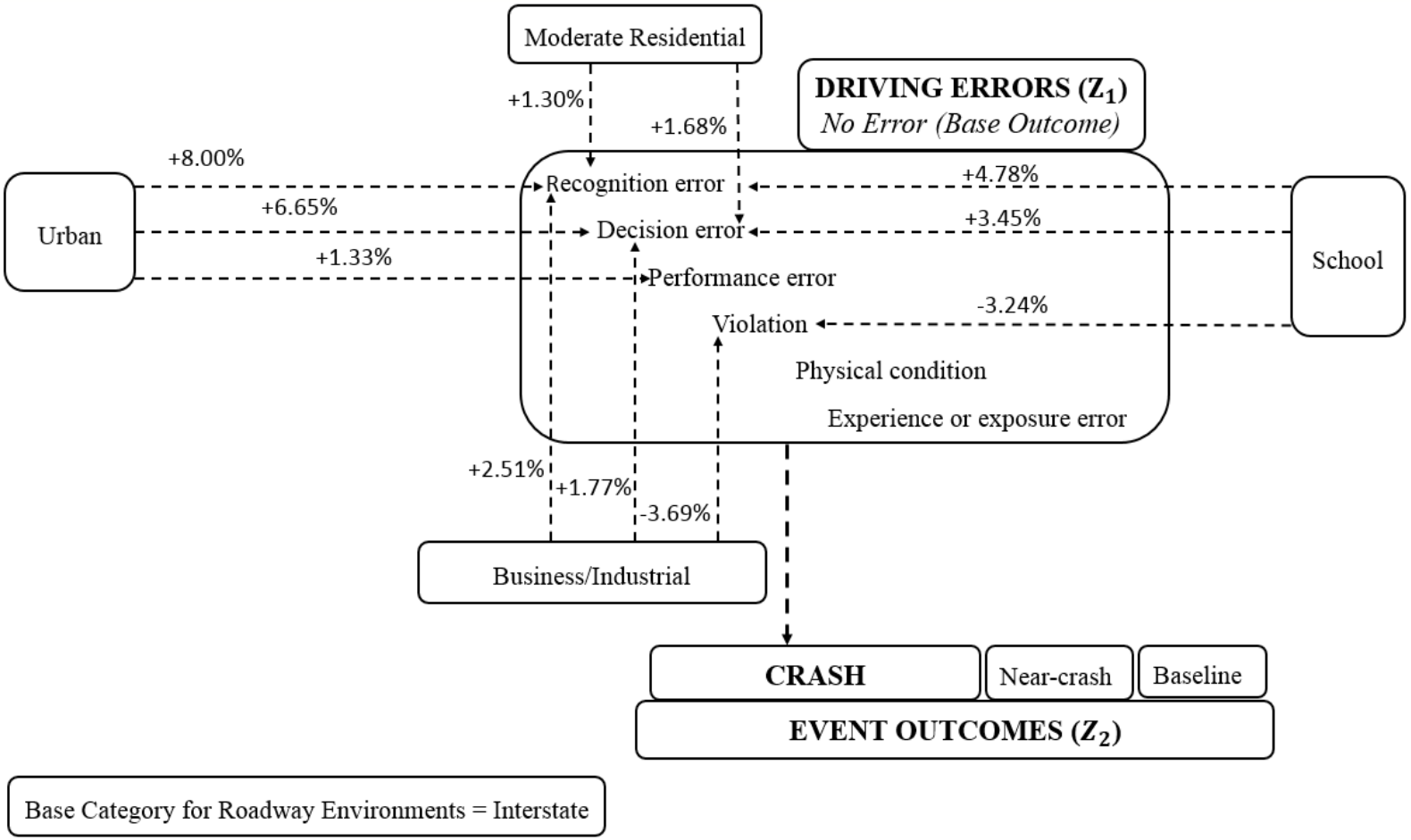
Independent variables	Coeff.	t-stat	p-value	Marginal Effects		
				Baselines	Near-Crash	Crash
DRIVERS ERRORS (BASE OUTCOME = NO DRIVING ERRORS)						
Recognition Errors	2.1886	39.63	<0.001	-0.6482	0.3554	0.2928
Decision Errors	1.9964	36.97	<0.001	-0.5866	0.3510	0.2356
Performance Errors	2.9181	17.83	<0.001	-0.8185	0.2697	0.5488
Violations	0.9973	17.70	<0.001	-0.2337	0.1844	0.0493
Physical Conditions	0.9153	7.30	<0.001	-0.2076	0.1660	0.0416
Experience or Exposure	2.2860	10.10	<0.001	-0.6771	0.3529	0.3241
ROADWAY LOCALITY (BASE OUTCOME = INTERSTATE)						
Open Country or Open Residential (Rural/Semi-Rural)	0.0505*	0.64	0.524	---	---	---
Moderate Residential	-0.0045*	-0.07	0.942	---	---	---
School	0.2534	3.06	0.002	-0.0414	0.0240	0.0174
Business/Industrial	0.1914	3.39	0.001	-0.0305	0.0177	0.0129
Urban	0.6913	7.48	<0.001	-0.1323	0.0769	0.0553
Bypass or Divided Highway with traffic signals	0.1832	1.70	0.089	-0.0291	0.0169	0.0123
Others (e.g., church, playground, and Campground)	0.2357	1.92	0.055	-0.0382	0.0221	0.0161

All types of driving errors & violations → Higher chances of safety critical events

Direct Effects of Roadways and environments and Driving Errors on Crash Occurrence



Indirect Effects of Roadways and environments on Crash Occurrence through Driving Errors



Chance of recognition and decision errors → increases in school zones, urban areas, near business or industrial structures & in residential areas (compared to interstates)

Conclusions

Path analysis results provide following insights:

- Chances of recognition errors & decision errors higher in urban areas, near school zones, near business or industrial structures, and in residential areas (compared to interstates)
- All driving errors & violations associated with high chance of crash occurrence
- School zones & business or industrial land uses correlated with crash propensity directly & indirectly through mediating recognition errors and decision errors

Conclusions

- Complex path structures should be explored in line with the systems approach
  - Certain important insights cannot be obtained without rigorous path analysis
- Understanding of errors and identification of school zones and identification of business (commercial) and industrial structures as posing risks can be used for future formulation of safety countermeasure policies and research
- Future research: Investigate how driver errors and violations may change with some control of the driving task being given to connected and automated vehicles.