Evaluating Driver Braking and Stopping Behavior at Rural Intersections using SHRP 2 Naturalistic Driving Study Data

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Outline

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  - Data reduction, Analysis and Results
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Background

- 30% of total crashes and 6% of fatal crashes in rural areas occur at intersections
- Crashes at rural intersections are often due to drivers not seeing the intersection or inappropriate gap selection (Preston et al, 2004)

Background

- Previous research on braking has been done using simulators, closed course studies or controlled instrumented vehicles with test drivers (Montella et al. 2011, Muttart et al 2011, and Bao and Boyle 2008)
- Previous stopping models have used field collected data and surveys to model stopping behavior at intersections and focused on urban intersections (Woldemanuel & Hankes, 2011)
- SHRP 2 Naturalistic Driving Study provides a means to address shortcomings

SHRP 2 Naturalistic Driving Study (NDS)

Largest naturalistic study done to date

Drivers had their car instrumented with equipment to capture data as they drove

- Approximately 3,400 drivers of all genders and ages
- Approximately 4,000 data years including 5 million trip files and 30 million data miles
- 6 states (FL, IN, NY, NC, PA and WA)

image source: SHRP 2

SHRP 2 Naturalistic Driving Study (NDS)

Captured a variety of data

- Vehicle network data (i.e. speed, acceleration, pedal position)
- Accelerometer data (3 axis)
- GPS coordinates
- Forward and rear radar
- Cameras

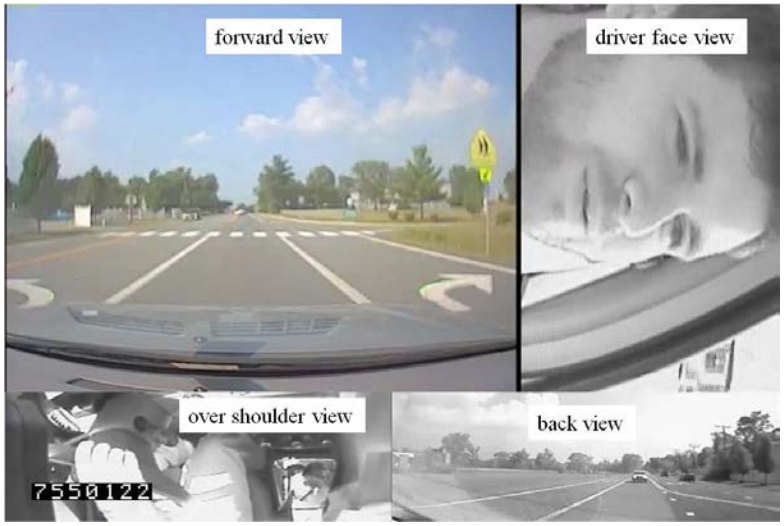


image source: VTTI

SHRP 2 Roadway Information Database (RID)

Data from mobile data collection and other existing roadway data along with supplemental data.

Data collected includes:

- Mobile data collection (~25,000 collection miles)
  - Roadway alignment, shoulder width and type, signing, lighting, intersection locations, rumble strips, etc.
- Existing roadway data
  - Asset management data, ADT, type of pavement, rest areas, etc.
- Supplemental data
  - Crash data, changes to laws, etc.

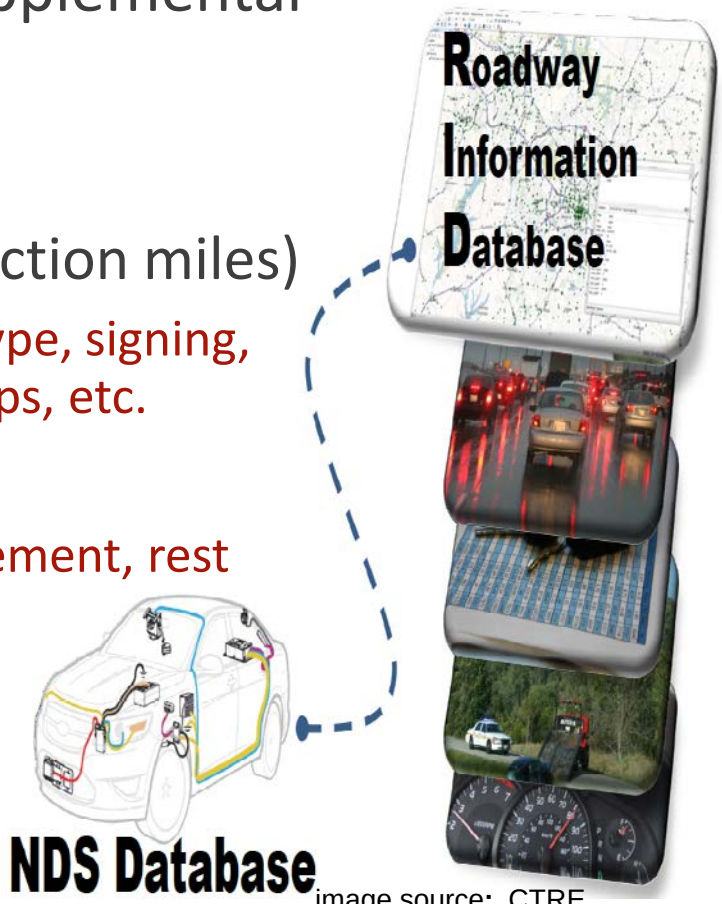


image source: CTRE

Study Objective

Develop models of driver braking and stopping behavior at rural intersections using the SHRP 2 NDS and RID

- Opportunity to study how driver, environmental and roadway characteristic interact to affect braking distance

SHRP 2 NDS Data Received

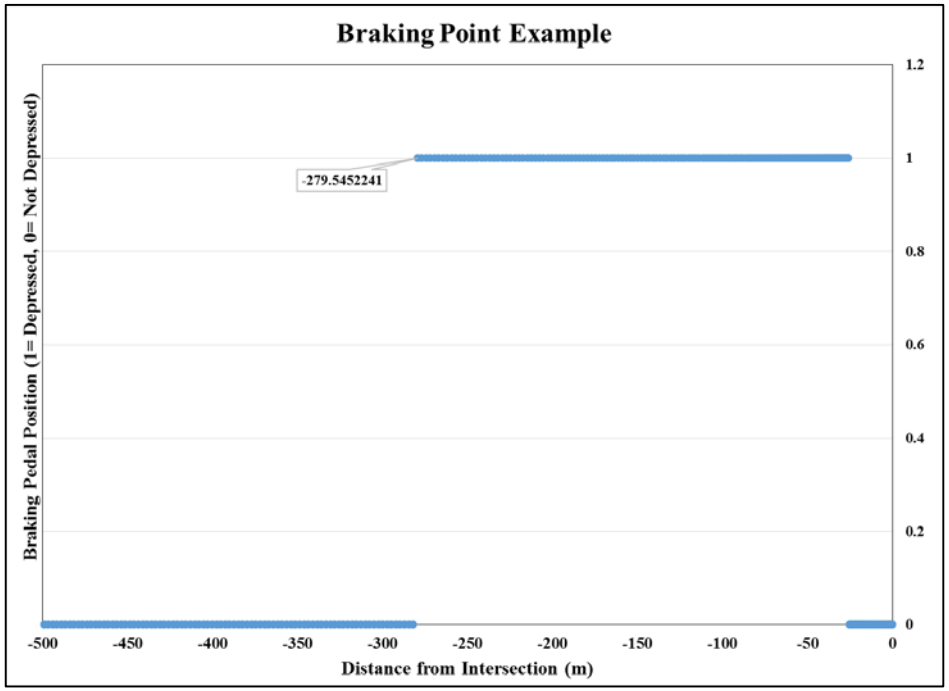
4,000	• Traces through 58 received
339	• Traces through 35 intersections used in braking analysis
358	• Traces at 20 intersections used in stopping analysis

Braking Model

Braking Point Determination

- Intersection was geolocated in time series data and then time and distance were used to determine distance from intersection.

- Braking point determined using the brake pedal indicator and distance was extracted



Analysis

Linear Mixed Effects model

Variables tested

- Dependent: Braking distance in meters
- Independent: roadway, environmental and driver

Best fit model was chosen

- AIC was used to compare models
- 95% significance for variables to be included
- Linear model assumptions were checked

Braking Model Results

Variable		Estimate	Std error	P value
Intercept		259.16	34.55	<.001
Amount over/under the speed limit (mph)		2.93	0.53	<.001
On pavement signing present (1=yes, 0=no)		62.41	32.32	0.05
Advanced stop/intersection warning signs present (1=yes, 0 =no)		-26.53	13.61	0.05
Factors for Speed and Stop sign presence	**Speed limit 25 mph with no stop sign (1 = yes, 0=no)**	-144.44	67.15	0.03
	Speed limit 25 mph with stop sign (1 = yes, 0=no)	-220.81	64.43	<0.001
	Speed limit 35 mph with stop sign (1 = yes, 0=no)	-185.80	23.58	<0.001
	Speed limit 40 mph with stop sign (1 = yes, 0=no)	-133.34	36.25	<0.001
	Speed limit 45 mph with no stop sign (1 = yes, 0=no)	0.84	36.93	0.98
	Speed limit 45 mph with stop sign (1 = yes, 0=no)	-78.45	37.50	0.04
	Speed limit 55 mph with no stop sign (1 = yes, 0=no)	-95.22	33.85	0.005
			Variance	**Std. Dev**
Driver ID Random Effect			2896	53.81
Intersection ID Random Effect			3534	59.45
Residual			1824	42.71

Stopping Model

Stopping Speed Determination

Minimum speed at the intersection was extracted from time series data for 358 traces

- 20 two way stop controlled intersections
- 57 unique drivers

Categorized into one of three types of stopping behavior (Woldemanuel & Hankes, 2011)

- Complete stop: Minimum speed ≤ 0.5 mph
- Rolling stop: Minimum speed >0.5 and < 5mph
- No stop: Minimum speed ≥ 5 mph

Analysis

Ordinal Logistic regression was used to model the probability (odds) of a driver making a *no, rolling or complete stop* at a rural intersection

- 20% confidence interval used due to small sample sizes of factors
- AIC was used to compare models
- no stop < rolling stop < complete stop

$$\log\left(\frac{p_i}{1-p_i}\right) = \beta_0 + B_1 x_1 + \beta_2 x_2 + \beta_3 x_3$$

Stopping Model Results

Parameter description	Estimate	Std. Error	p-value	% of samples
Crash history (1= 1+ crashes, 0=no crashes)	-2.3054	0.7182	0.0013	13.97
Type of movement (1= right, 0 = left or through)	-2.2716	0.3977	<0.001	41.62
Approach grade (1= uphill/downhill, 0 = flat)	1.3073	0.6040	0.0304	15.08
Stop bar present (1=yes, 0=no)	0.9672	0.6756	0.1523	6.70
Threshold coefficients				
No stop to rolling stop	-2.1405	0.3846	<0.001	
Rolling stop to full stop	0.2671	0.3652	0.2324	
Random Effects	***Variance***	***Std. Dev***		
Driver ID	0.7422	0.8615		
Intersection ID	0.3315	0.5757		

Odds Ratios

Parameter description	Odds Ratio Est.
Crash history (1= one or more crashes, 0=no crashes,)	0.0997
Type of movement (1= right, 0 = left or through)	0.1031
Approach grade (1= uphill/downhill, 0 = flat)	3.6962
Stop bar present (1=yes, 0= no)	2.6306

Conclusions

Sample size limitations for both studies

Preliminary braking model found:

- On pavement signing increased braking distance
- Advanced warning signs decreased braking distance
- Drivers speed and speed limit of road affect braking distance

Conclusions

Stopping model found:

- Drivers turning right and drivers with a crash history are more likely to not come to a full stop at the intersection
- Drivers are more likely to stop at intersections with approaches located on grades and those with stop bars

Future Work

Beginning 2nd Phase

- Will incorporate additional roadway information and look at additional countermeasures
- Increase sample sizes
- Incorporate driver distraction and glance data on a subset of data
- Include additional rural intersection types

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Questions?

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