

# ANALYSIS OF RURAL CURVE NEGOTIATION USING NATURALISTIC DRIVING DATA

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# OUTLINE

- Background
- Objective
- Data Sources
- Site Selection
- Data Reduction
- Future work
- Benefits

# BACKGROUND

- Horizontal curves have a crash rate 3x that of tangent sections (Glennon et al., 1985)
- 27% of all fatalities in 2007 occurred on horizontal curves (Cheung, 2010)
- 76% of curve related fatal crashes are single vehicles leaving the roadway and striking a fixed object or overturning.
- 11 % of curve related crashes are head-on collisions (AASHTO, 2008)
- Many studies on roadway factors which are relevant
  - Radius and Degree of curve
  - Presence of spirals
  - Shoulder width
- Little research has been done to identify which driver behaviors contribute to curve crashes

# OBJECTIVE

- Assess the relationship between driver behavior and characteristics, roadway factors, environmental factors, and likelihood of lane departures using SHRP 2 Naturalistic Driving Study data and roadway data from the SHRP 2 Roadway Information Database
  - Develop models to quantify the relationship between driver behavior and the roadway environment
  - Focus on curves on rural 2-lane paved roadways



# SHRP 2 NATURALISTIC DRIVING STUDY (NDS)

- Drivers have their car instrumented with equipment to capture data as they drive
  - Approximately 3,100 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)

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

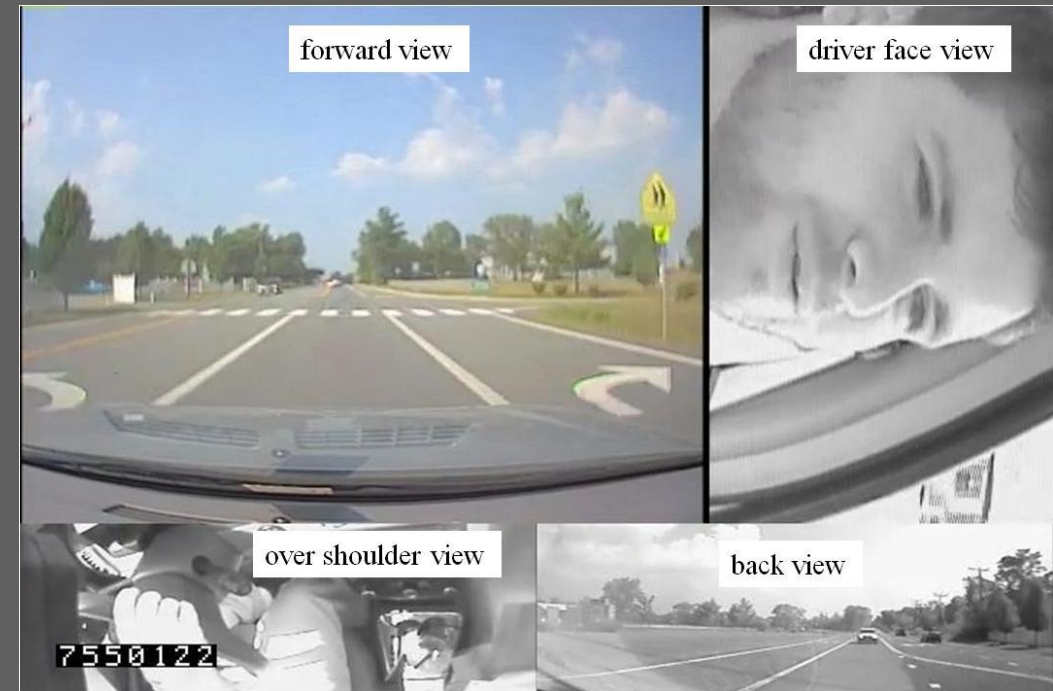


image source: VTTI

# SHRP 2 ROADWAY INFORMATION DATABASE (RID)

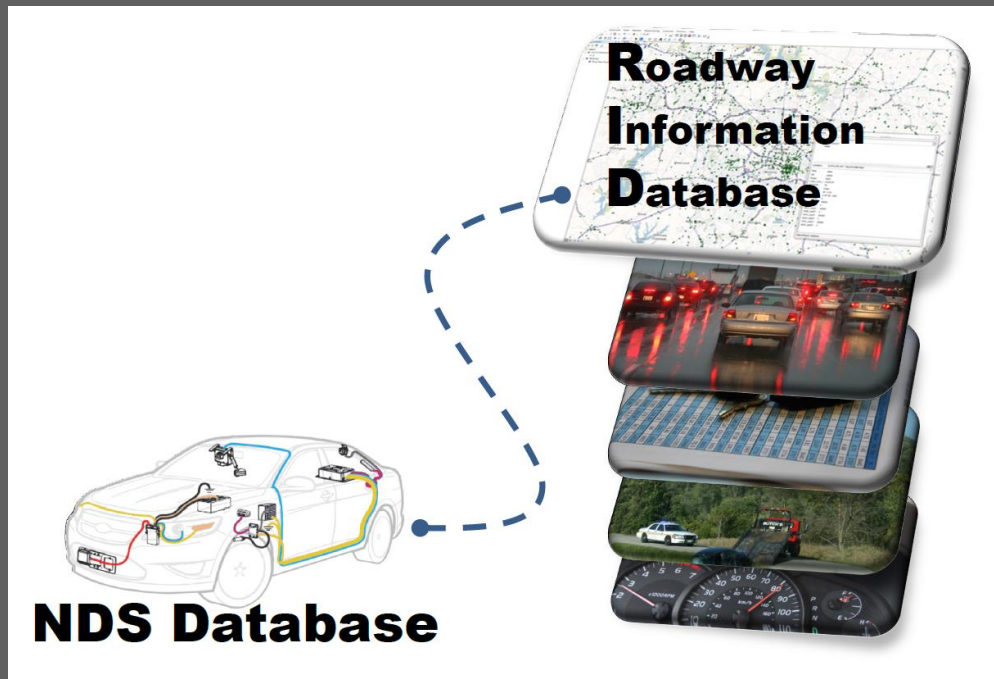


image source: CTRE

- 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.

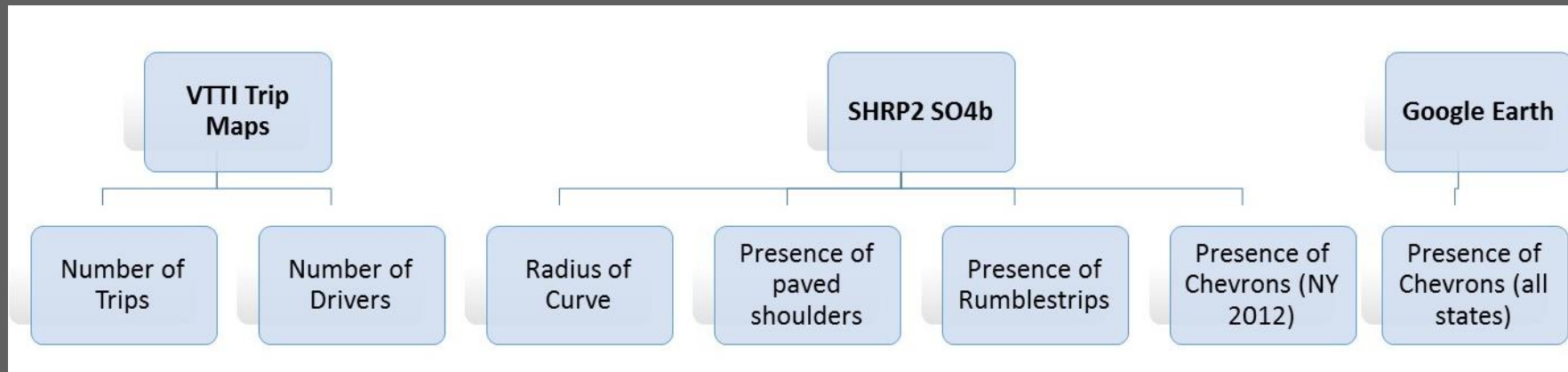
# SAMPLING PLAN

- Balanced:
  - Need for statistically representative sample based on potential number of covariates
  - Cost to procure data
  - Time to reduce and analyze data
  - Time constraints for Phase II
- 200 initial traces
- 800 final traces



# CURVE IDENTIFICATION

- NDS and RID not yet merged
- Queried RID for rural 2-lane curves of interest
  - radius, presence of RS, etc.
- Reviewed other RID data, Google Earth
- Number of trips and drivers



# BUFFERS

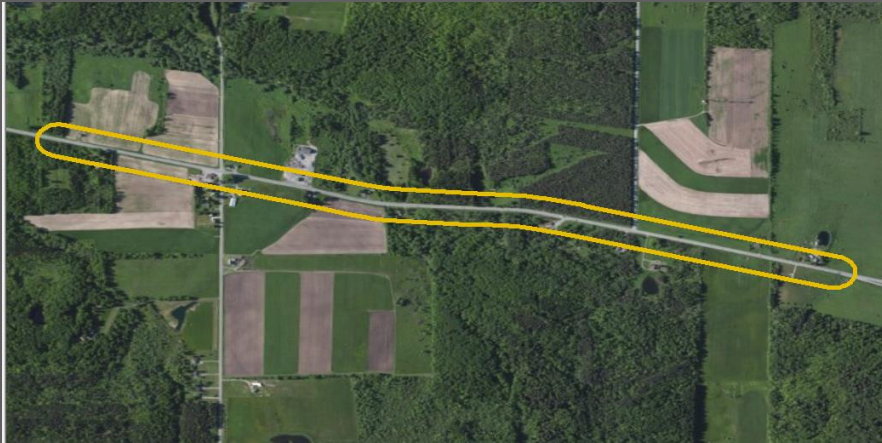


image source: ESRI

- Created buffer shapefiles in ArcGIS
- Created a line over section of interest
  - Single curve if more than 1.0 mile separate subsequent curves of interest
  - Multiple curves if less than 1.0 miles separated

# EVALUATION CRITERIA

- No turning or passing lanes in curve
- At least 0.5 miles of tangent on both sides of curve if it was not within a series of curves within a buffer
- No stop controlled intersection on the major approach in curves and tangents
- No signal controlled intersections in curves or tangents
- No railroad crossings within curve or tangents
- No sites within 0.5 miles of town
- No construction

# DATA REQUEST

- Identified 203 segments with 707 curves (NC, NY, IN, PA)
- 32 existing from FL – had from proof of concept phase, did not request additional data for current work
- Already had from FL – tended towards urban
- WA – large urban component

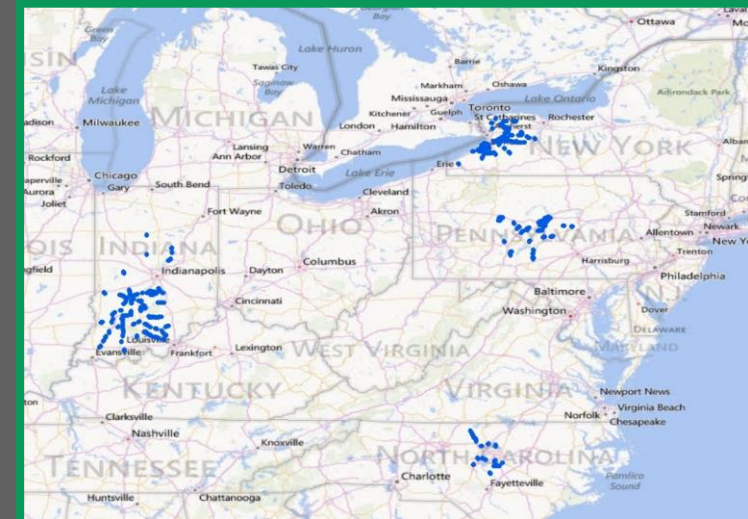


image source: ESRI

# SELECTED CURVE CHARACTERISTICS

## Location of Buffer Segments

State	Buffers	Curves
Indiana (IN)	80	375
New York (NY)	71	173
North Carolina (NC)	20	58
Pennsylvania (PA)	32	101
<b>Total</b>	<b>203</b>	<b>707</b>

## Curve Radius

Radius (feet)	Number of Curves	Radius (feet)	Number of Curves
<=750	110	> 1500 to <=2250	138
> 750 to <=1500	149	≥2250	310

# REDUCTION OF ROADWAY FACTORS

- Gather roadway alignment and countermeasure data (used RID when available)
- Estimate of road furniture
  - rating system of 1 – 3 (ranges from little to no road furniture to significant roadway furniture)

**Table 2: Roadway Variables Extracted**

Feature	ArcGIS	SHRP2 RID	Google Earth
curve radii		✓	
distance between curves	✓		
s curve	✓		
compound curve	✓		
super elevation		✓	
presence of rumble strips		✓	
presence of chevrons		✓	✓
presence of w1-6 signs			✓
presence of paved shoulders		✓	
presence of RPM			✓
presence of guardrail			✓
speed limit		✓	
advisory sign speed limit		✓	✓
curve advisory sign		✓	✓

# REDUCTION OF VEHICLE FACTORS

- Spatially correlated vehicle trace to curve
  - Location of vehicle upstream, within, downstream of curve
- Calculate lane position from lane tracking variables



image source: ESRI



# REDUCTION OF VIDEO

- Forward video
  - When vehicle is not following, following, following closely
  - Whenever another vehicle is passed
  - Sight distance
  - Environmental conditions
    - Day, dawn, dusk, night
    - Clear, raining, snow
    - Visibility
  - Pavement marking condition
  - Pavement condition
  - Locations and presence of curve warning signs

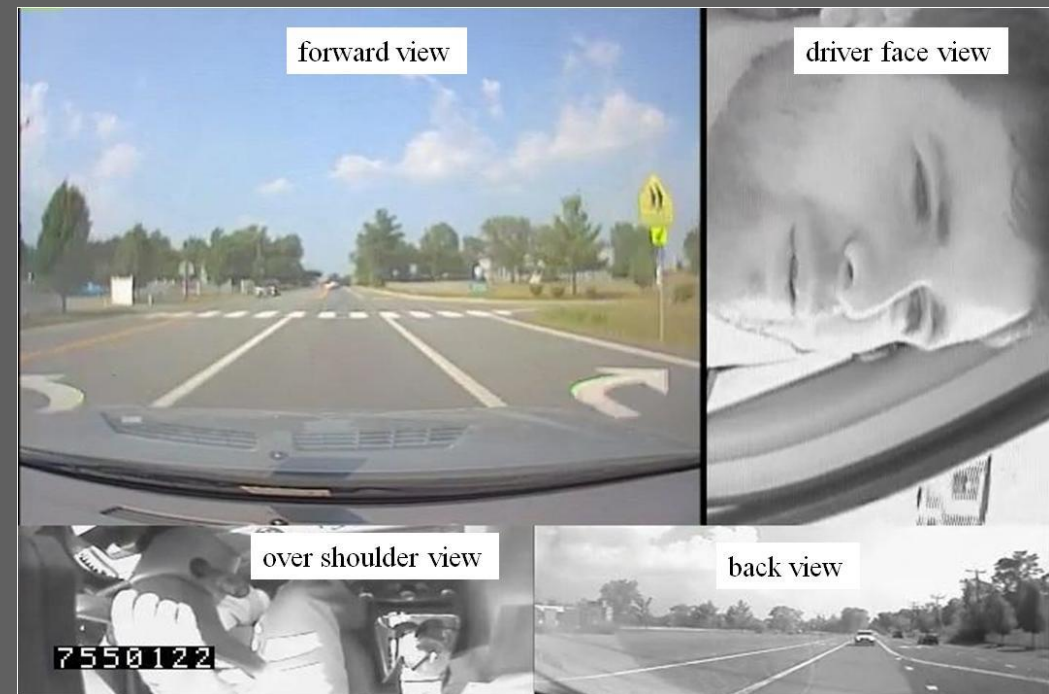


image source: VTTI



# REDUCTION OF KINEMATIC DRIVER FACTORS

- Driver distraction – forward and over shoulder video at secure data enclave
  - type
  - duration -- coded by video time
- Driver forward attention - forward video at secure data enclave
  - Head position
  - Scan (glance) location

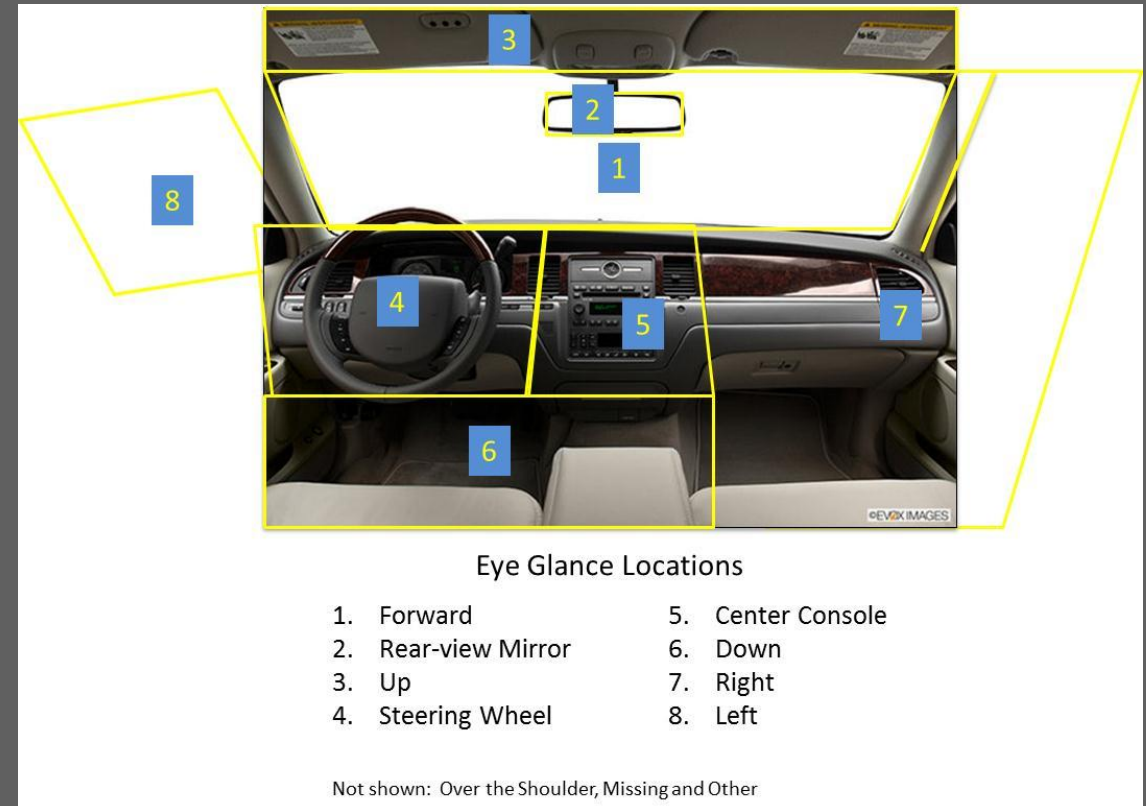


Image sources: VTTI

# RESEARCH QUESTIONS

- Use data to try to answer 3 research questions

1. Define normal curve driving based on curve geometry

- Change in lateral position or speed from tangent to within curve
  - Schurr et al (2002); Krammes and Tyler (1991); Stodart and Donnell (2008)
- Determine where driver begins to react to curve
  - Combination of a filter and potentially time series

$$\Delta V = V_{MPT} - V_{MC}$$

$$\Delta L = L_{MPT} - L_{MC}$$

where

V = speed

L = lateral position

MPT = midpoint of tangent

MC = midpoint of curve

2. What is the relationship between driver distraction, other driver, roadway, and environmental characteristics and risk of lane departure

- Multivariate logistic regression with probability of a left or right side lane departure as response variable
  - Will give odds of a lane departure of a certain magnitude given driver, roadway and environmental variables

3. What roadway cues and countermeasures are the most effective in getting a driver's attention and how do they affect driver response to horizontal curves

- Time series model

# BENEFITS

- Better understanding of relationship between roadway features, driver behavior, and curve negotiation
  - Ability to understand how and why countermeasures work/don't work
  - Implications:
    - Road design
    - Signing
    - Selection and application of countermeasures
    - Policy
    - Advanced vehicle technologies



# Questions?

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