



SHRP2 Implementation Assistance Program (IAP)—Round 4
*Concept to Countermeasures—Research to Deployment Using the SHRP2 Safety Data*

SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

# Use of the SHRP2 Safety Data for Investigation of Driver Behavior in Adverse Weather Conditions: Lessons learned from the Wyoming Department of Transportation Implementation Assistance Program

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U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO
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Transportation Research Board
of the National Academies
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# OUTLINE

## Phase 1 and 2 Results

- Background
- Objectives
- Methodology
- Data Preparation and Description
- Some Key Results
- Conclusions

## Phase 3 Ongoing Work

- Research to Countermeasures
- Integration within Wyoming VSL and CV Pilot
  - Non-VSL Corridors
  - Integrating Driver's Behavior in VSL Algorithms
  - CV Pilot: Better Info
  - Future Connected/Automated Vehicle
  - Speed Compliance and Enforcement
  - Speed Management at Work Zones
- VSL Guidelines

# SHRP2 IAP Projects

| IAP Project | State DOT |
|---|---|
| **Adverse Weather Conditions** | **Wyoming DOT** |
| Horizontal and Vertical Curves | North Carolina DOT |
| Interchange Ramps | Utah DOT |
| Roadway Departure | Iowa DOT |
| Roadway Lighting | Washington DOT |
| Speeding | Michigan DOT<br>Washington DOT |
| Work Zones | Minnesota DOT |
| Pedestrian Safety | Florida DOT<br>Nevada DOT<br>New York DOT |


I-80 Reduced Visibility Condition (Source: WYDOT)

**The Only Study Exclusively Investigating the impacts of Adverse Weather Conditions on Speed Behavior and Driver's Performance**

# WYDOT SHRP 2 IAP

*SHRP2 Safety Data Implementation Assistance Program—Concepts to Countermeasures*

Phase 1 → Phase 2 → Phase 3

1. Proof of Concept
2. In-depth Research & Analysis
3. Countermeasure Implementation

# WEATHER IMPACT

- Fog, snow, rain, strong wind, etc. affect: pavement conditions, vehicle performances, visibility, and **drivers' behavior and performance**.
- Weather contributed to **> 24% of total crashes**,1995-2008 (NHTSA)
- Inclement weather → **31,514 Fatal Crashes**, 2000-2007 (NHTSA)
- **More than 6,000 people are killed and close to 480,000 people are injured** in weather-related crashes every year in the US.
- **~38% of inclement weather crashes in Wyoming**
- Crashes are a leading cause of Interstate Closures.
- 3-40% reductions in speed
- 4-27% reductions in capacity
- $2.3 billion in snow/ice control
- **32.6 billion lost hours for freight industry**

*45 vehicles pileup crash, I-80 April 16, 2015 (Source: WYDOT)*

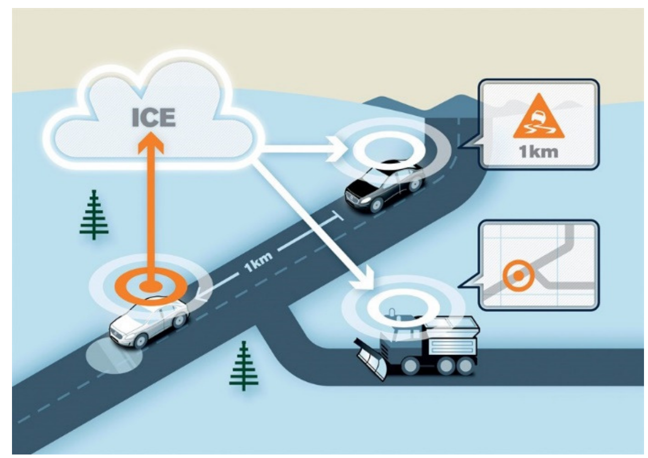
# PROJECT OBJECTIVES


1. Examining the feasibility of using SHRP2 NDS and RID datasets for adverse weather safety research

2. Quantifying driver's microscopic behaviors and performances (i.e., speed selection, lane-keeping, headway, car-following, etc.) in inclement weather

3. Improve VSL and Advanced Traveler Info System

4. Early investigation of CV Weather Applications




(Source: Global Road Safety Review 2016)

# Drivers Response to Adverse Weather Conditions

1. Can inclement weather trips be identified effectively using the NDS and RID data?

2. Can driver responses (i.e., speed and headway adaptation, and lane keeping) during inclement weather be characterized efficiently from the NDS data?

3. What are the best Surrogate Measures for weather-related crashes that can be identified using the NDS data?

4. What type of analysis can be performed and conclusions be drawn from the resulting dataset?

5. Can the NDS data be extrapolated to provide real-time weather information in the context of the Road Weather Connected Vehicle Applications?

# PHASE I - Proof of Concept

## Requested NDS Data

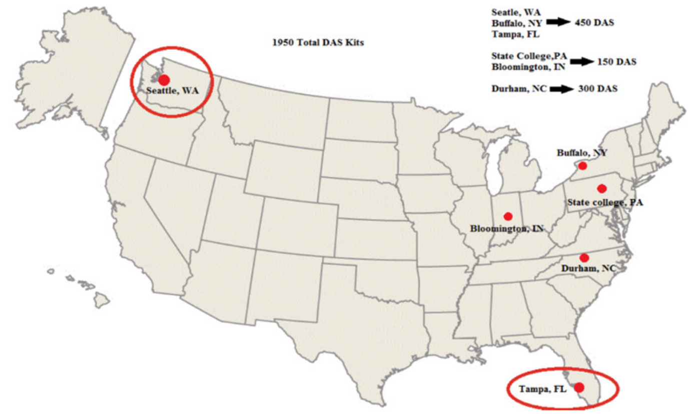
50 NDS Freeway Trips
Heavy Rain > 10 min.

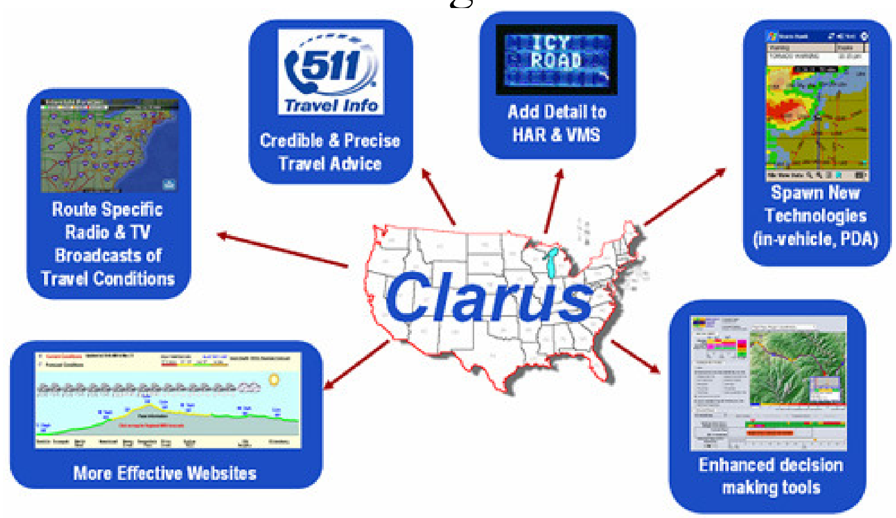
100 NDS Freeway Trips
Clear Weather

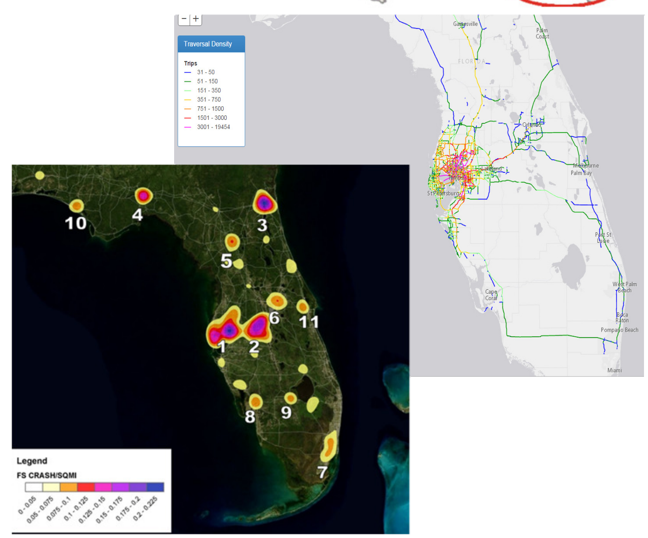
- Florida
- Washington

# PHASE 2 – In-Depth Analysis

- All 6 NDS States.
- All adverse weather conditions.
- More variables.
- Improve the Visualization and Red. Tool.
- External Data to leverage NDS data.



# Data Acquisition

- **Critical Events on Freeways (All Weather and Traffic Conditions)**
  - **16 Crashes and 213 Near-crashes**

- **Normal Driving Trips in Adverse Weather**
  Based on Wiper Status
  Using NCDC data and weather-related crash data


Wiper Status

Using Airport Weather Stations

Using RID Weather-related Crashes

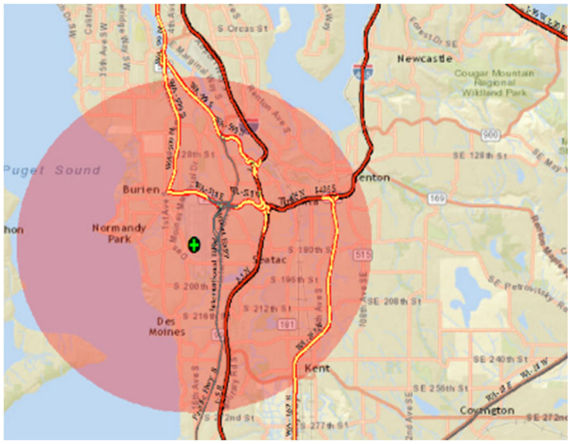
# Data Acquisition

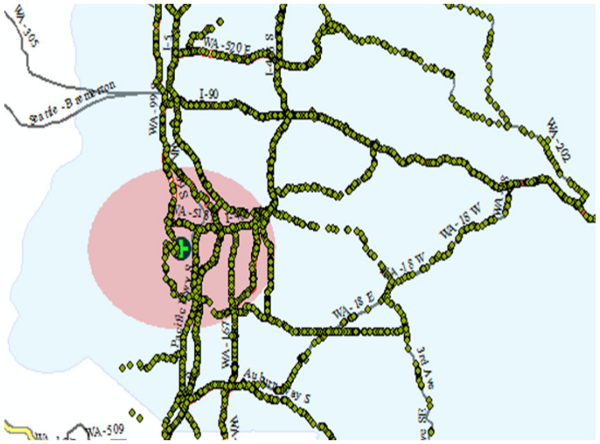
Identify Normal Driving Weather-Related Trips

**<u>Method 1</u>**
Windshield Wiper Status
CAN-Bus

**<u>Method 2</u>**
National Climatic Data Center
(NCDC) Weather Data

**<u>Method 3</u>**
Reported Weather-related
Crashes





# Data Acquisition

Identify Weather-Related Trips

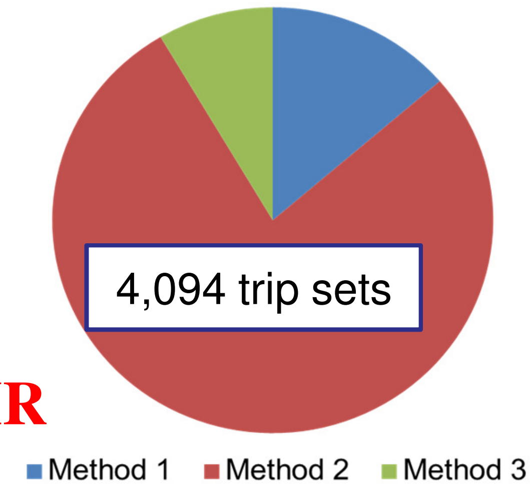
**Method 1**
Windshield Wiper Status

**Method 2**
NCDC Weather Data

**Method 3**
Reported Crashes

11,164 Potential Weather-related Trips &
22,328 Matching Clear Trips

33,492 Total Trips Acquired




**Total Duration Adverse + 2 Matched Clear Trips: 6,700HR**

# Data Acquired

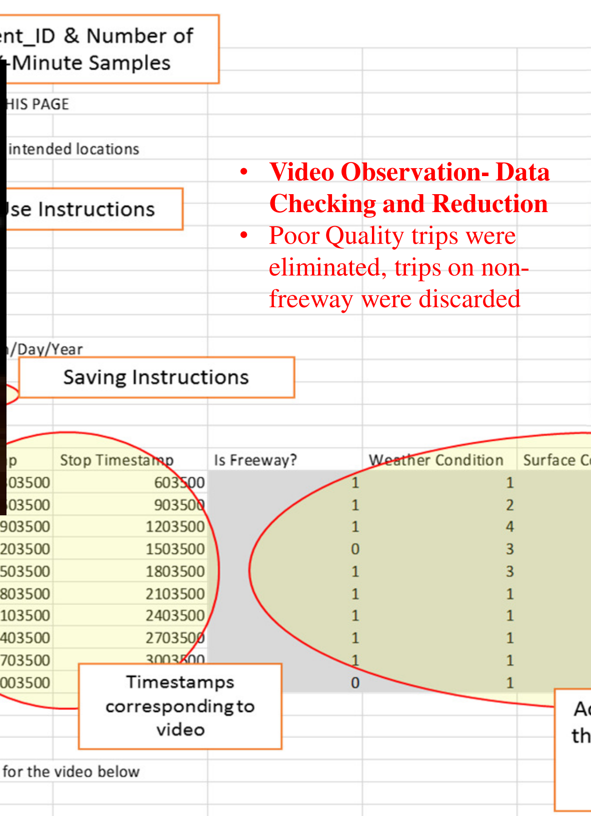
| Weather | Method 1: Wiper | Method 2: NCDC | Method 3: Crashes | Total |
|---|---|---|---|---|
| Rain | 507 | 2,374 | 132 | **3,013** |
| Fog | 14 | 157 | 63 | **234** |
| Snow | 29 | 175 | 116 | **320** |
| Wet surface/ Clear Condition | 10 | 298 | 9 | **317** |
| Snowy surface/ Clear Condition | 0 | 182 | 28 | **210** |
| **Total** | **560** | **3,186** | **348** | **4,094** |

**(More than 1,700 drivers → 3,013 Rain, 234 Fog, 320 Snow, 317 Wet Surface/ Clear, 210 Snowy Surface/ Clear): ~ 85% missing wiper status**

Manual Video verification showed that only **4,094** were weather-related trips

# Data Preparation

## Manual Video Observation




- **Video Observation- Data Checking and Reduction**
- Poor Quality trips were eliminated, trips on non-freeway were discarded

# Data Preparation

## Data Reduction: Weather, Visibility, Surface and Traffic Conditions


Clear


Fog

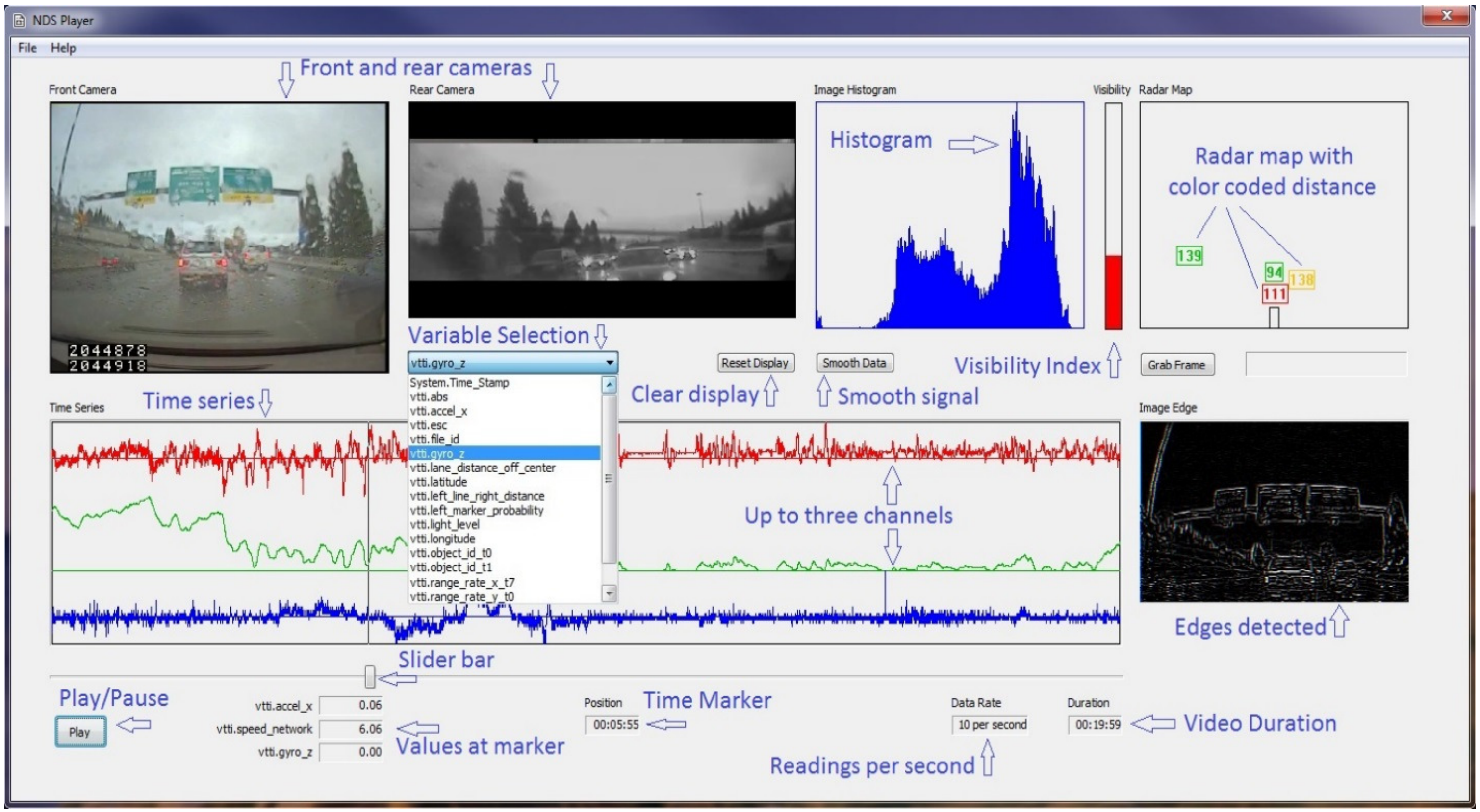

Snowing

| Roadway Type | | Surface Conditions (cont.) | |
|---|---|---|---|
| Non-Freeway | 0 | Snow Covered | 3 |
| Freeway | 1 | Ice Covered | 4 |
| Weather Conditions | | Visibility | |
| Clear | 1 | High | 1 |
| Light Rain | 2 | Medium | 2 |
| Heavy Rain | 3 | Low | 3 |
| Snow | 4 | Traffic Conditions | |
| Fog | 5 | LOS A | 1 |
| Sleet | 6 | LOS B | 2 |
| Mist/ Light Rain | 7 | LOS C | 3 |
| Surface Conditions | | LOS D | 4 |
| Dry | 1 | LOS E | 5 |
| Wet | 2 | LOS F | 6 |


Light Rain

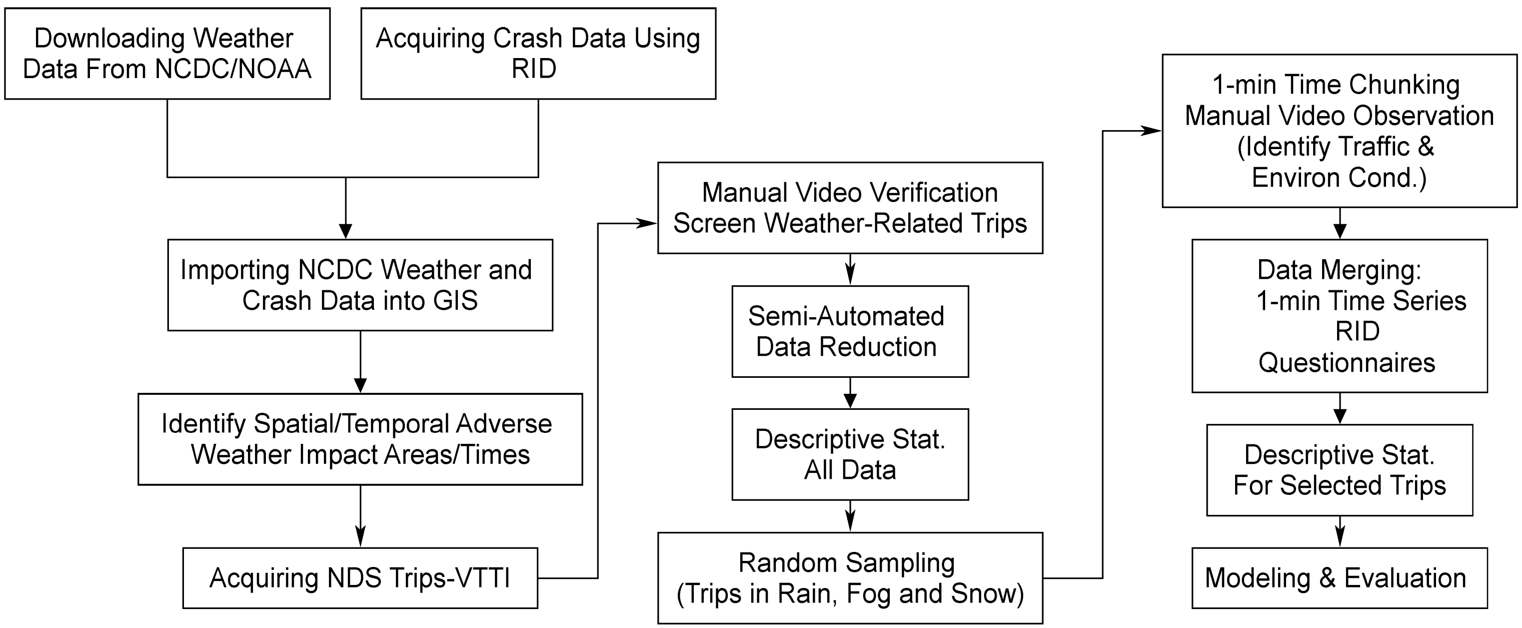

Heavy Rain

# Data Visualization and Reduction Tool




**The accuracy of the Visibility Level estimation algorithm reached 79%**
**Machine Learning of Video and Vehicle Kinematics ~ 90% weather condition**

# Data Preparation




**Conceptual Overview of Phase 2 Data Acquisition and Preparation**

**Complementary Methodologies to Identify Weather Conditions in Naturalistic Driving Study Trips: Lessons Learned from the SHRP 2 Naturalistic Driving Study and Roadway Information Database**

Ali Ghasemzadeh, University of Wyoming
Britton Hammit, University of Wyoming
Mohamed Ahmed, University of Wyoming
Hesham Eldeeb, University of Central Florida

18-00720

Event 281

**Effects of Inclement Weather on Driving Behavior and Traffic Operations**

Halil Ceylan, Iowa State University, presiding

Maintenance and Preservation, Operations and Traffic Management, Safety and Human Factors

AH010

# Descriptive Statistics

Snow: 88 trips (1004 MI),
Rain: 102 (2226MI)
Fog: 22 (593 MI)

**% Sp. Red. = (Sp – Sp Lmt)/ Sp Lmt**

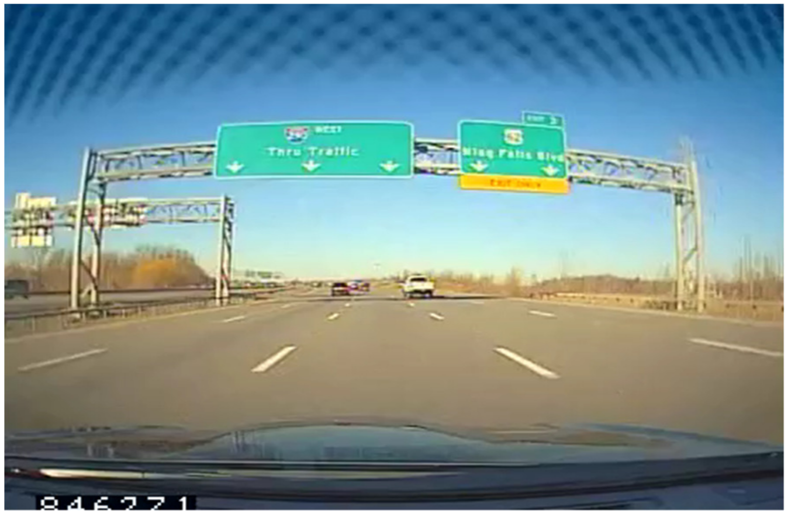
| | | Snow | | Matched Clear | | Rain | | Matched Clear | | Fog | | Matched Clear | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Speed | % Speed Reduction | Speed | % Speed Reduction | Speed | % Speed Reduction | Speed | % Speed Reduction | Speed | % Speed Reduction | Speed | % Speed Reduction |
| Speed ( Kph) | Average | 87.72 | -10.12 | 106.07 | 8.52 | 91.727 | 1.074 | 97.9 | 6.93 | 104.41 | 3.03 | 108.12 | 6.55 |
| | SD | 21.76 | 20.32 | 12.96 | 13.32 | 11.31 | 12.87 | 11.93 | 12.33 | 13.21 | 11.27 | 14.21 | 12.28 |
| | Min. | 22.77 | -74.27 | 28.07 | -88.64 | 51.092 | -49.46 | 32.16 | -63.66 | 44.818 | -44.3 | 26.48 | -72.57 |
| | Max. | 130.43 | 43.25 | 134.76 | 78.02 | 119.284 | 76.74 | 125.7 | 54.02 | 130.89 | 46.33 | 132.67 | 42.59 |
| | Median | 89.05 | -7.75 | 106.65 | 8.98 | 92.046 | 0.742 | 98.75 | 7.18 | 106.14 | 5.12 | 111.42 | 8.25 |
| | t-test | Avg. speed in Snow is sig. lower in snow | | | | Avg. speed sig. lower in Rain | | | | Avg. speed sig. lower in Fog | | | |
| | F-test | Speed variability is higher in Snow | | | | No sig. difference in speed variability | | | | No Sig. Difference in Speed Variability | | | |
| | Z-test | No sig. diff… | | | | …tween the proportion of speeding ≥ 10 km/h | | | | No sig. difference between the proportion of speeding ≥ 10 km/h | | | |
| Acceleration/ Deceleration(g) | | Acc. | | | | | Dec. | Acc. | Dec. | Acc. | Dec. | Acc. | Dec. |
| | Average | 0.017 | | | | | -0.014 | 0.022 | -0.021 | 0.02 | -0.026 | 0.021 | -0.022 |
| | SD | 0.015 | | | | | 0.015 | 0.02 | 0.019 | 0.017 | 0.02 | 0.018 | 0.018 |
| | Min. | 0 | | | | | -0.072 | 0 | -0.105 | 0 | -0.07 | 0 | -0.096 |
| | Max. | 0.076 | | | | | 0 | 0.093 | 0 | 0.074 | 0 | 0.079 | 0 |
| | Median | 0.012 | | | | | -0.009 | 0.016 | -0.015 | 0.014 | -0.02 | 0.016 | -0.019 |
| | t-test | A… | | | | …o sig. difference in Avg. Acc. | | | | No sig. difference in Avg. Acc. | | | |
| | | I… | | | | …vg. dec. is sig. lower in rain, | | | | Avg. dec. is sig. higher in Fog | | | |
| | F-test | Acceleration variability is sig. higher in snow | | | | No sig. difference in Acc. variability | | | | No sig. difference in Acc. variability | | | |
| | | No sig. difference between deceleration variability in snow and Clear | | | | Dec. variability is higher in clear weather | | | | Dec. variability is higher in fog | | | |
| | Z - test | -- | | | | No Acc./Dec. were found higher than ±0.3g | | | | No Acc./Dec. were found higher than ±0.3g | | | |
| Yaw Rate, negative sign = left rotation (deg./s) | | **Pos.** | **Neg.** | **Pos.** | **Neg.** | **Pos.** | **Neg.** | **Pos.** | **Neg.** | **Pos.** | **Neg.** | **Pos.** | **Neg.** |
| | Average | 0.271 | -0.362 | 0.321 | -0.41 | 0.412 | -1.602 | 0.417 | -0.462 | 0.346 | -0.463 | 0.34 | -0.386 |
| | SD | 0.335 | 0.335 | 0.443 | 0.427 | 0.344 | 2.318 | 0.445 | 0.431 | 0.457 | 0.348 | 0.311 | 0.336 |
| | Min. | 0 | -2.761 | 0 | -3.965 | 0.004 | -7.631 | 0.002 | -2.578 | 0.005 | -1.969 | 0.001 | -2.183 |
| | Max. | 3.681 | -0.001 | 4.74 | -0.001 | 1.651 | -0.001 | 3.773 | -0.001 | 3.2 | -0.003 | 1.482 | 0 |
| | Median | 0.183 | -0.261 | 0.203 | -0.287 | 0.299 | -0.485 | 0.267 | -0.322 | 0.226 | -0.403 | 0.246 | -0.297 |
| | t-test | Right rotation in Snow is sig. lower than clear weather | | | | No sig. difference in right rotation, | | | | No sig. difference in right rotation, | | | |
| | | Left rotation in Snow is sig. lower than Clear Weather | | | | Left rotation is sig. higher in Rain. | | | | Left rotation is sig. higher in Fog. | | | |
| | F-test | Right rotation variability is sig. higher in clear weather | | | | Right rotation variability is sig. higher in clear weather | | | | Right rotation variability is sig. higher in Fog | | | |
| | | Left rotation variability is sig. higher in clear weather | | | | Left rotation variability is sig. higher in rain | | | | No sig. difference in left rotation variability | | | |
| Lane Offset (cm) | | **Pos.** | **Neg.** | **Pos.** | **Neg.** | **Pos.** | **Neg.** | **Pos.** | **Neg.** | **Pos.** | **Neg.** | **Pos.** | **Neg.** |
| | Average | 32.996 | -36.096 | 20.74 | -30.568 | 15.46 | -15.913 | 19.644 | -16.119 | 19.162 | -27.956 | 14.695 | -22.447 |
| | SD | 41.074 | 47.163 | 29.717 | 42.838 | 10.416 | 22.169 | 18.234 | 19.412 | 17.053 | 42.499 | 14.108 | 25.582 |
| | Min. | 0.001 | -333.65 | 0.095 | -383.706 | 0.095 | -224.66 | 0.076 | -266.98 | 0.078 | -323.856 | 0.073 | -345.241 |
| | Max. | 377.895 | -0.004 | 155.516 | -0.071 | 51.171 | -0.308 | 121.291 | -0.049 | 76.985 | -0.192 | 68.494 | -0.225 |
| | Median | 19.222 | -18.269 | 12.022 | -18.876 | 14.321 | -10.538 | 15.985 | -9.343 | 15.42 | -17.086 | 10.275 | -17.222 |
| | t-test | Lane offset to the right in Snow is sig higher than clear | | | | Avg. lane offset to the right is lower in rain | | | | Avg. lane offset to the right and left from lane center is sig. higher in Fog | | | |
| | | Lane offset to the left in Snow is sig. higher than clear | | | | No sig. difference in lane offset to the right | | | | | | | |
| | F-test | Lane offset to the right variability is sig. higher in Snow | | | | Lane offset to the right variability is sig. higher in clear weather | | | | Lane offset to the right variability and left variability is sig. higher in Fog | | | |
| | | Lane offset to the left variability in sig. higher in Snow | | | | Lane offset to the left variability is sig. higher in rain | | | | | | | |

**Snow:**
**10% reduction from speed limit**

**~19% from their matched**

# Vehicle Kinematics – Example in Winter Condition

## Weather-Related Trips Similar to Wyoming



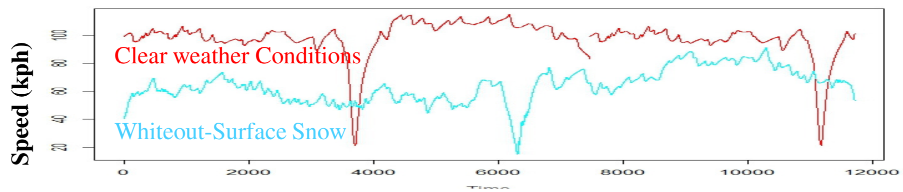

Trip ID: 13910595
Visibility: Fog (NCDC) – whiteout condition visual observation
Trip Location: New York (NDS TS)
Surface: Snow (Video Observation)
Vehicle Average Speed: 39.6 mph (NDS TS)
Standard Deviation of Speed: 11.86
Wind Speed: 33 mph (NCDC)
Speed Limit: (RID Reduced data)

Trip ID: 13904014
Visibility: Clear (NCDC)
Trip Location: New York (NDS TS)
Surface: Dry (Video Observation)
Vehicle Average Speed: 62 mph (NDS TS)
Standard Deviation of Speed: 12.73
Speed Limit: (RID Reduced data)

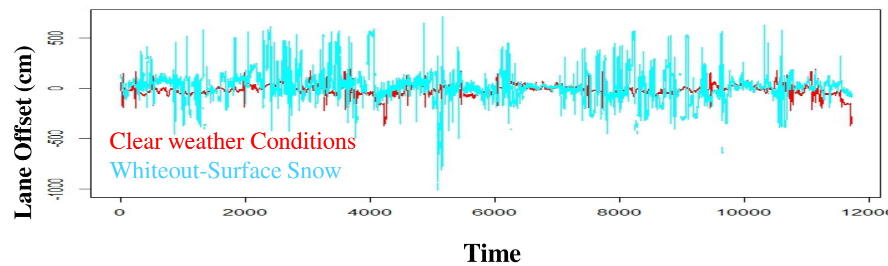
# Speed Selection/ Hot Spot Analysis – Example in Winter Condition

**Route: I-290 & I-190, New York, Length: 19.2 miles (30.8 km), Speed limit source: Roadway Information Database (RID) and Street View in Google Map**

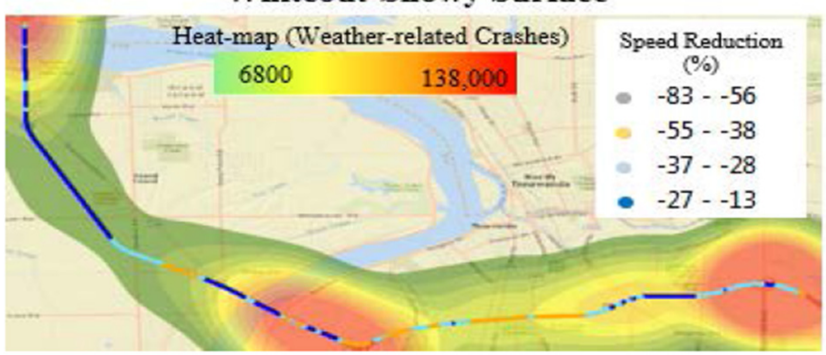
**vtti.speed_network**
Significant Reduction in Speed



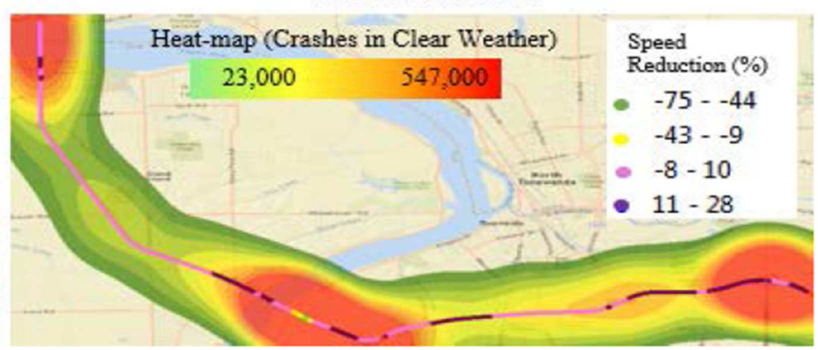

**lane_distance_off_center**
Worse Lane Keeping




**Whiteout-Snowy Surface**




**Clear Weather**



# Speed Selection Model

## Ordered Logit Model

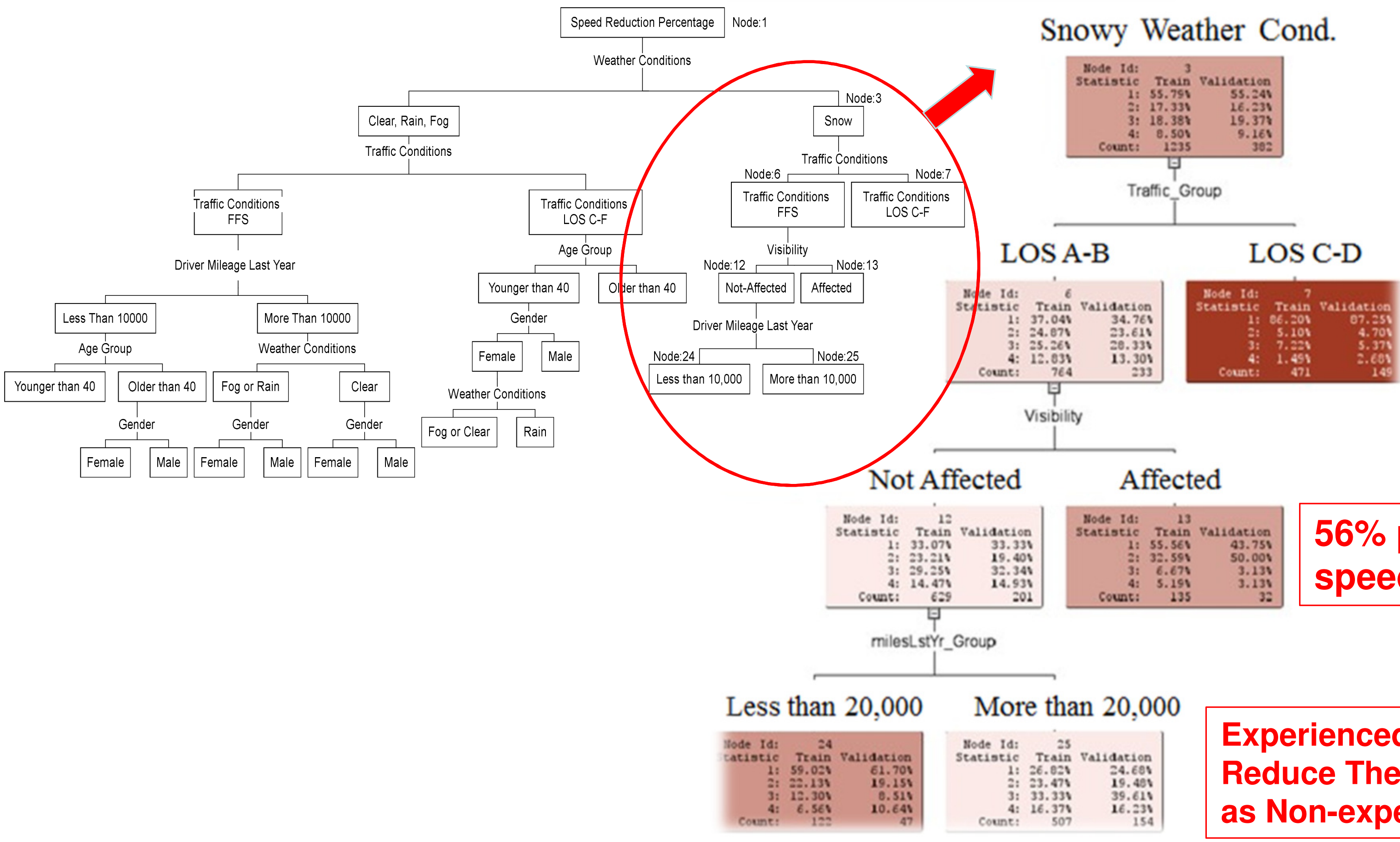
**10,606 1-minute observations=177 hours**

**Response: Percent Speed Reduction (4 Quantiles: > 14% red., 0-14%, 0-10 inc., >10 inc.)**

| Analysis of Maximum Likelihood Estimates | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq | Odds Ratio | Confidence Interval | |
| Intercept | 4 | 1 | -2.57 | 0.09 | 800.41 | <.0001 | - | - | - |
| Intercept | 3 | 1 | -1.3 | 0.09 | 218.23 | <.0001 | - | - | - |
| Intercept | 2 | 1 | 0.32 | 0.09 | 13.93 | 0.0002 | - | - | - |
| **Weather Cond.** | **Fog** | **1** | **0.26** | **0.09** | **7.61** | **0.0058** | **1.29** | **1.08** | **1.55** |
| **Weather Cond.** | **Rain** | **1** | **0.44** | **0.09** | **25.35** | **<.0001** | **1.55** | **1.31** | **1.83** |
| **Weather Cond.** | **Snow** | **1** | **2.23** | **0.06** | **1612.52** | **<.0001** | **9.29** | **8.33** | **10.36** |
| Visibility | Affected | 1 | 0.56 | 0.09 | 35.24 | <.0001 | 1.75 | 1.45 | 2.1 |
| Traffic Cond. | C-F | 1 | 1.28 | 0.04 | 995.02 | <.0001 | 3.6 | 3.32 | 3.89 |
| Gender | Female | 1 | 0.09 | 0.04 | 5 | 0.0254 | 1.09 | 1.01 | 1.18 |
| Age | >40 | 1 | 0.2 | 0.05 | 18.24 | <.0001 | 1.23 | 1.12 | 1.35 |
| Marital Status | Divorced | 1 | 0.81 | 0.09 | 86.57 | <.0001 | 2.25 | 1.9 | 2.67 |
| Marital Status | Widow(er) | 1 | 1.2 | 0.11 | 121.33 | <.0001 | 3.31 | 2.68 | 4.1 |
| Marital Status | Unmrid-partnrs | 1 | -0.94 | 0.1 | 88.74 | <.0001 | 0.39 | 0.32 | 0.48 |
| Marital Status | Married | 1 | 0.34 | 0.05 | 45.09 | <.0001 | 1.4 | 1.27 | 1.55 |
| Mileage Last Year | 10,000 to 20,000 | 1 | -0.5 | 0.05 | 122.3 | <.0001 | 0.61 | 0.56 | 0.66 |
| Mileage Last Year | >20,000 | 1 | -0.58 | 0.06 | 92.33 | <.0001 | 0.56 | 0.5 | 0.63 |

# Speed Selection Model

## Classification and Regression Trees (CART)




**86% prob. of >14% speed reduction**

**56% prob. of >14% speed reduction**

**Experienced Drivers Did Not Reduce Their Speeds as much as Non-exper. drivers**

# Speed Selection and Lane Keeping

**Using Parametric Ordinal Logistic Regression and Nonparametric Decision-Tree Approaches for Assessing the Impact of Weather Conditions on Driver Speed Selection Using Naturalistic Driving Data**

Ali Ghasemzadeh, University of Wyoming
Britton Hammit, University of Wyoming
Mohamed Ahmed, University of Wyoming
Rhonda Young, Gonzaga University

18-01096

Event 281

**Effects of Inclement Weather on Driving Behavior and Traffic Operations**

Halil Ceylan, Iowa State University, presiding
Maintenance and Preservation, Operations and Traffic Management, Safety and Human Factors

AH010

**A Comprehensive Analysis of Driver Lane-Keeping Performance in Fog Weather Conditions Using the SHRP 2 Naturalistic Driving Study Data**

Anik Das, University of Wyoming
Ali Ghasemzadeh, University of Wyoming
Mohamed Ahmed, University of Wyoming

18-06242

**Visibility Committee**

John Bullough, Rensselaer Polytechnic Institute (RPI), presiding
Operations and Traffic Management, Safety and Human Factors

AND40

# Speed Selection and Lane Keeping

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

## The impacts of heavy rain on speed and headway Behaviors: An investigation using the SHRP2 naturalistic driving study data

Mohamed M. Ahmed*, Ali Ghasemzadeh

*Department of Civil and Architectural Engineering, University of Wyoming, Laramie, WY 82071, United States*

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

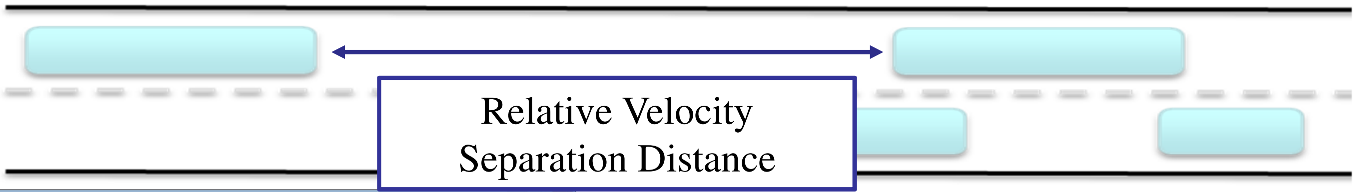
## Utilizing naturalistic driving data for in-depth analysis of driver lane-keeping behavior in rain: Non-parametric MARS and parametric logistic regression modeling approaches

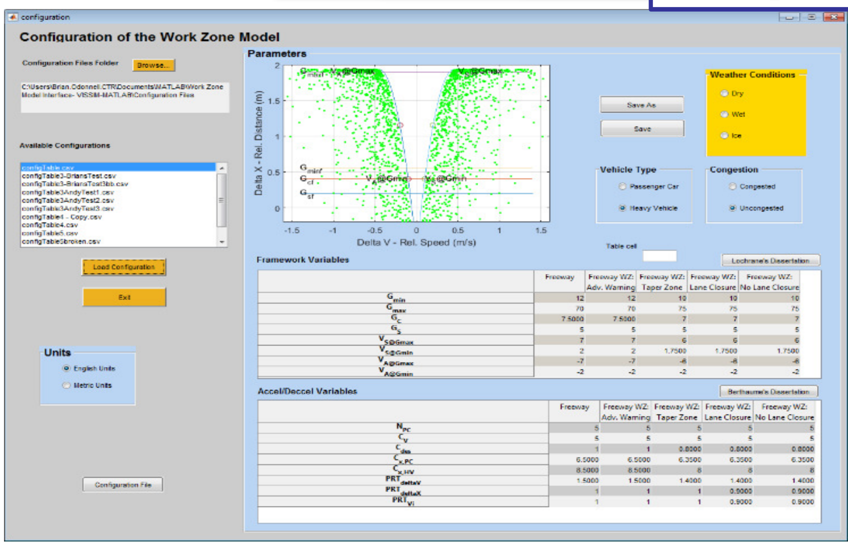
Ali Ghasemzadeh*, Mohamed M. Ahmed

*University of Wyoming, Department of Civil & Architectural Engineering, 1000 E University Ave, Dept. 3295, Laramie, WY 82071, United States*

# Car Following Model

## Modeling Driving Behavior in Non-Free Flow Conditions




**FHWA Work Zone Driver Model Software**

**Evaluation of Weather-Related Freeway Car-Following Behavior Using the SHRP 2 Naturalistic Driving Study**

Britton Hammit, University of Wyoming

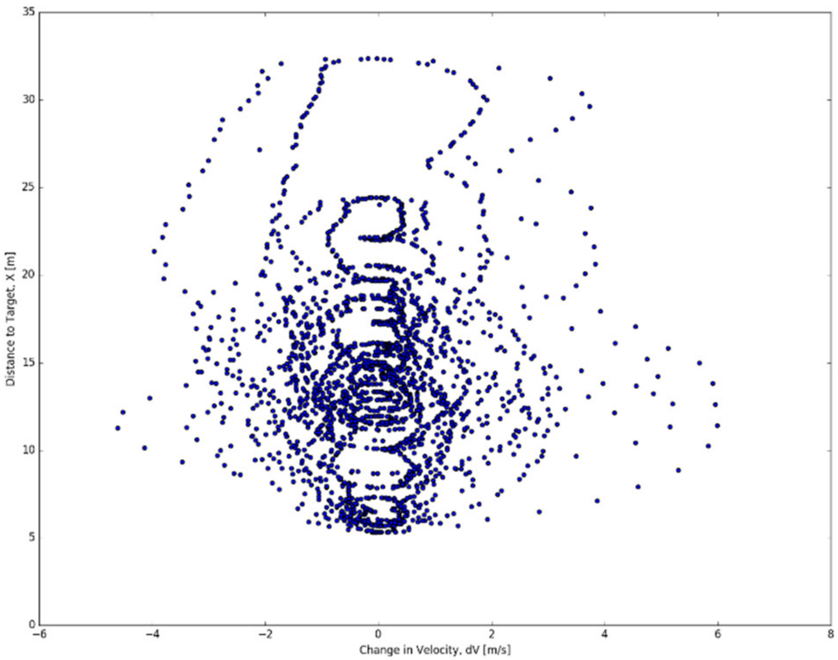
Ali Ghasemzadeh, University of Wyoming 18-03287**

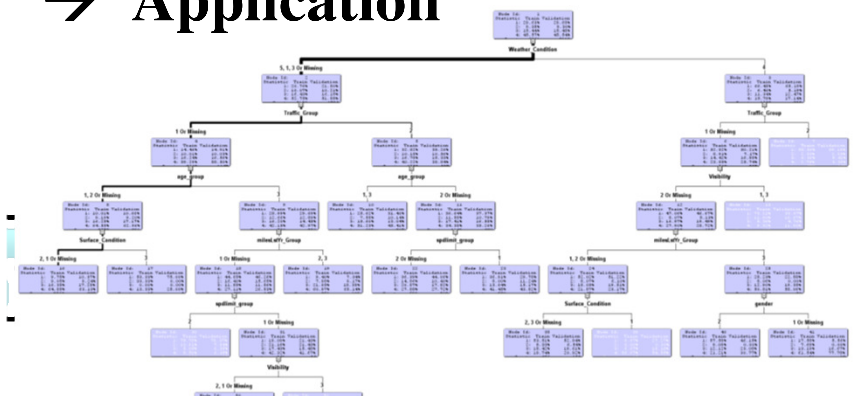
Mohamed Ahmed, University of Wyoming

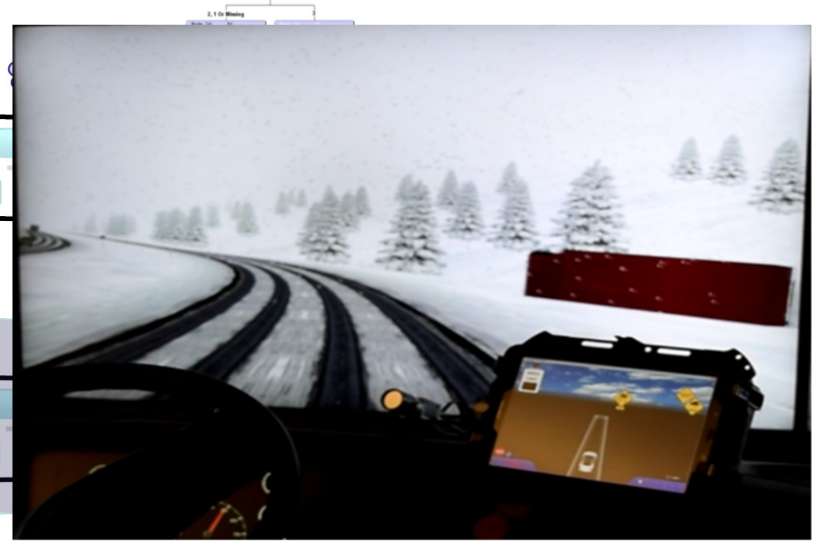
Rhonda Young, Gonzaga University

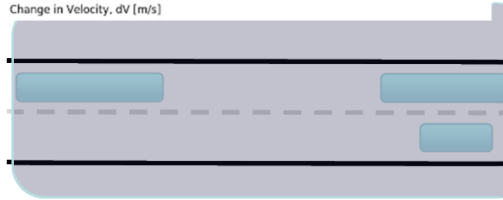
# Microsimulation Modeling

## Raw Data → Application



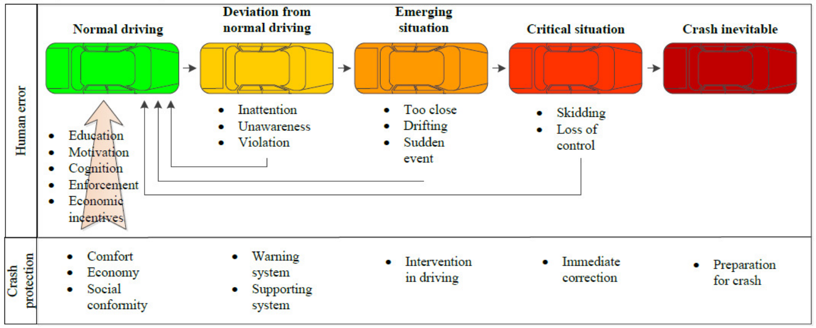





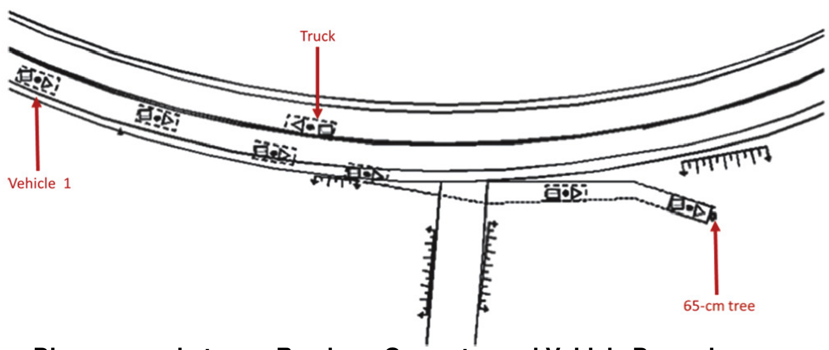


# Identifying Deviation from Normal Driving in CV Environment

- Driver's Acc. Preference
- Observed changes in speed and headway (Radar Data Required)
- Discrepancies between Expected and Actual Vehicle Dynamics based on Roadway Geometry
- TTC, PRT, Headway, Long. And Lat. Acc., Yaw Rate were used in this study.

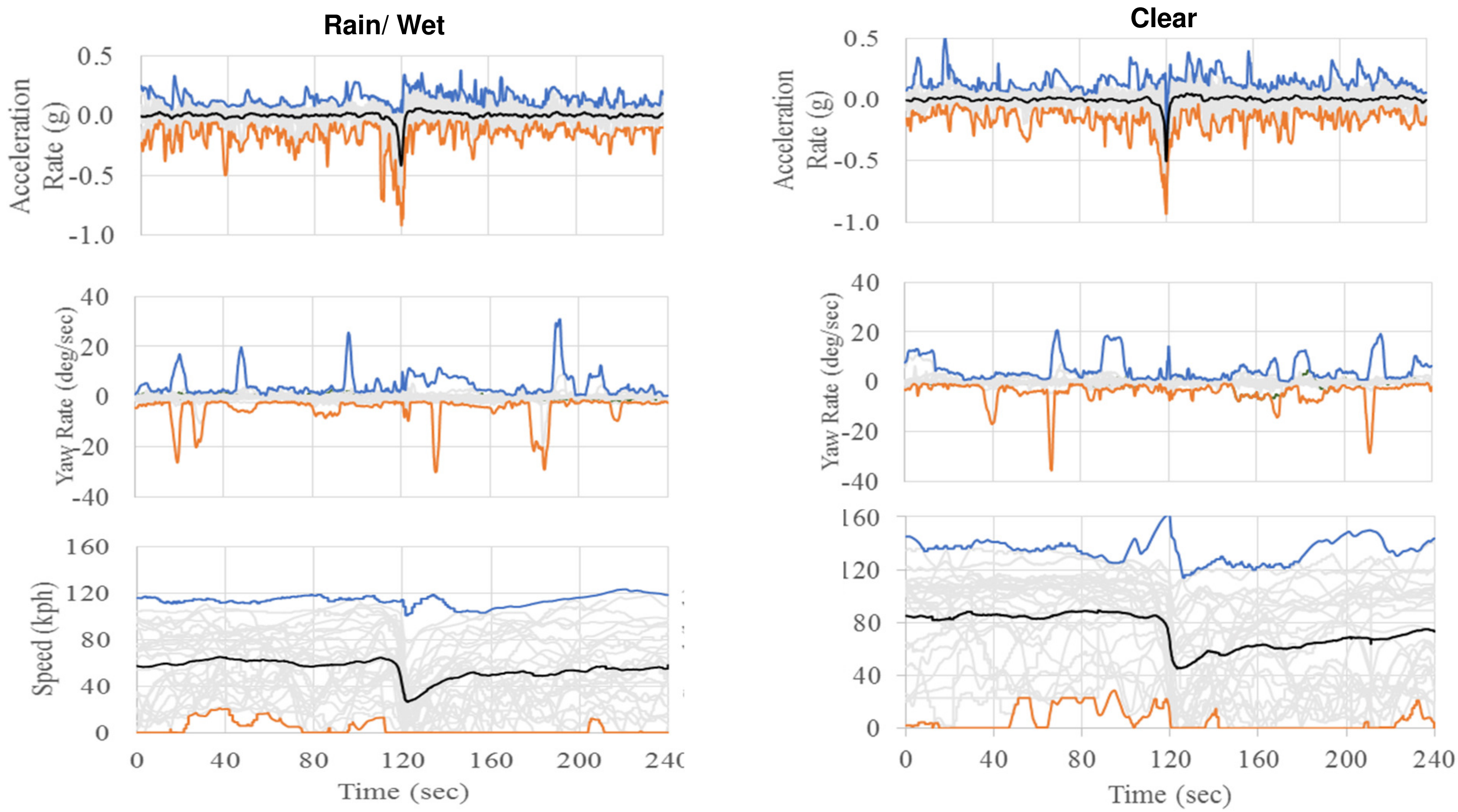



Crash Development (Adapted from Tingval et al., 2009)




Discrepancy between Roadway Geometry and Vehicle Dynamics (Wu and Thor, 2015)

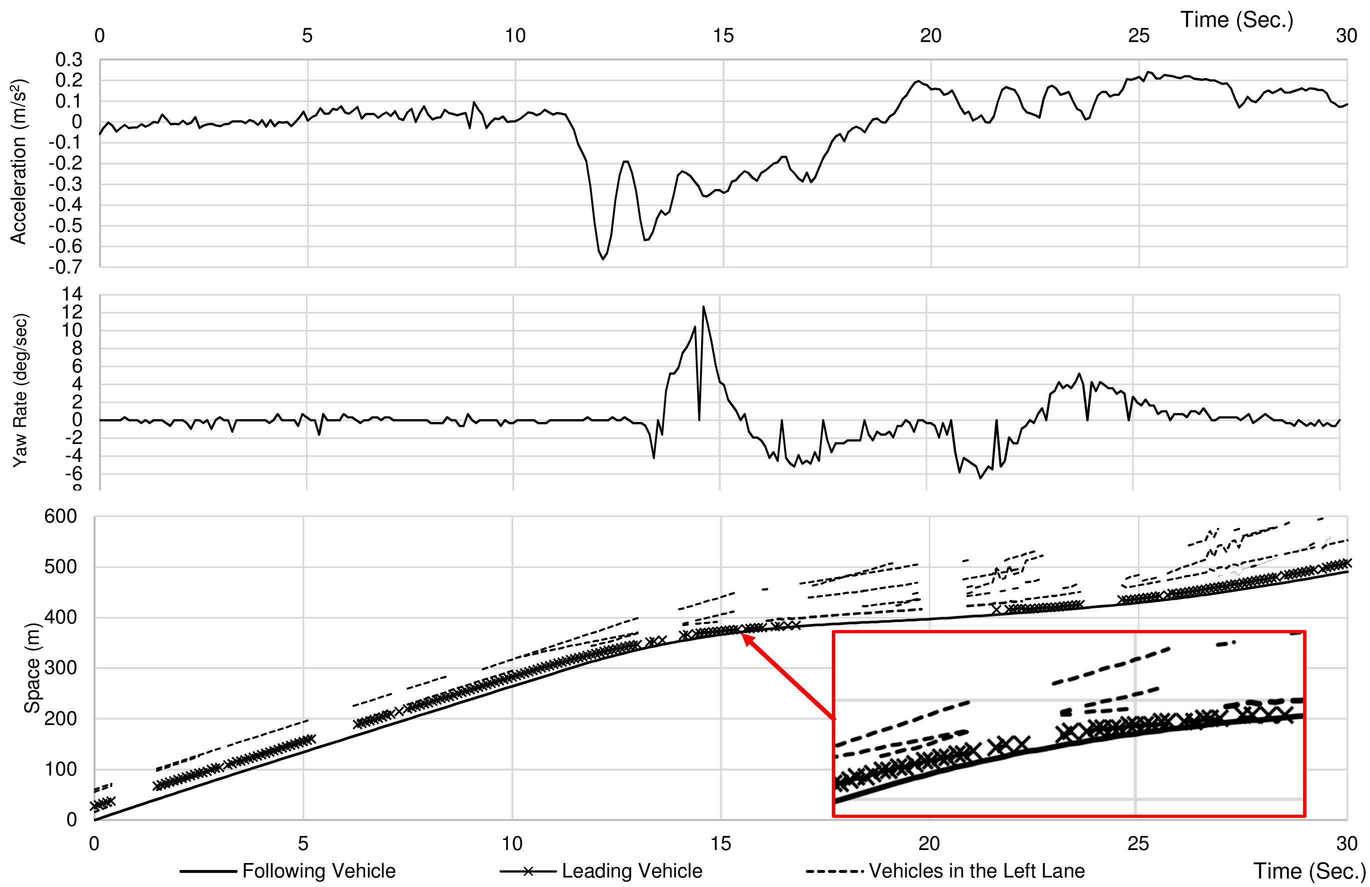
# Identifying Deviation from Normal Driving in CV Environment



# Identifying Deviation from Normal Driving

Timeline Snapshots for a Rear-End Near-Crash

# Identifying Deviation from Normal Driving

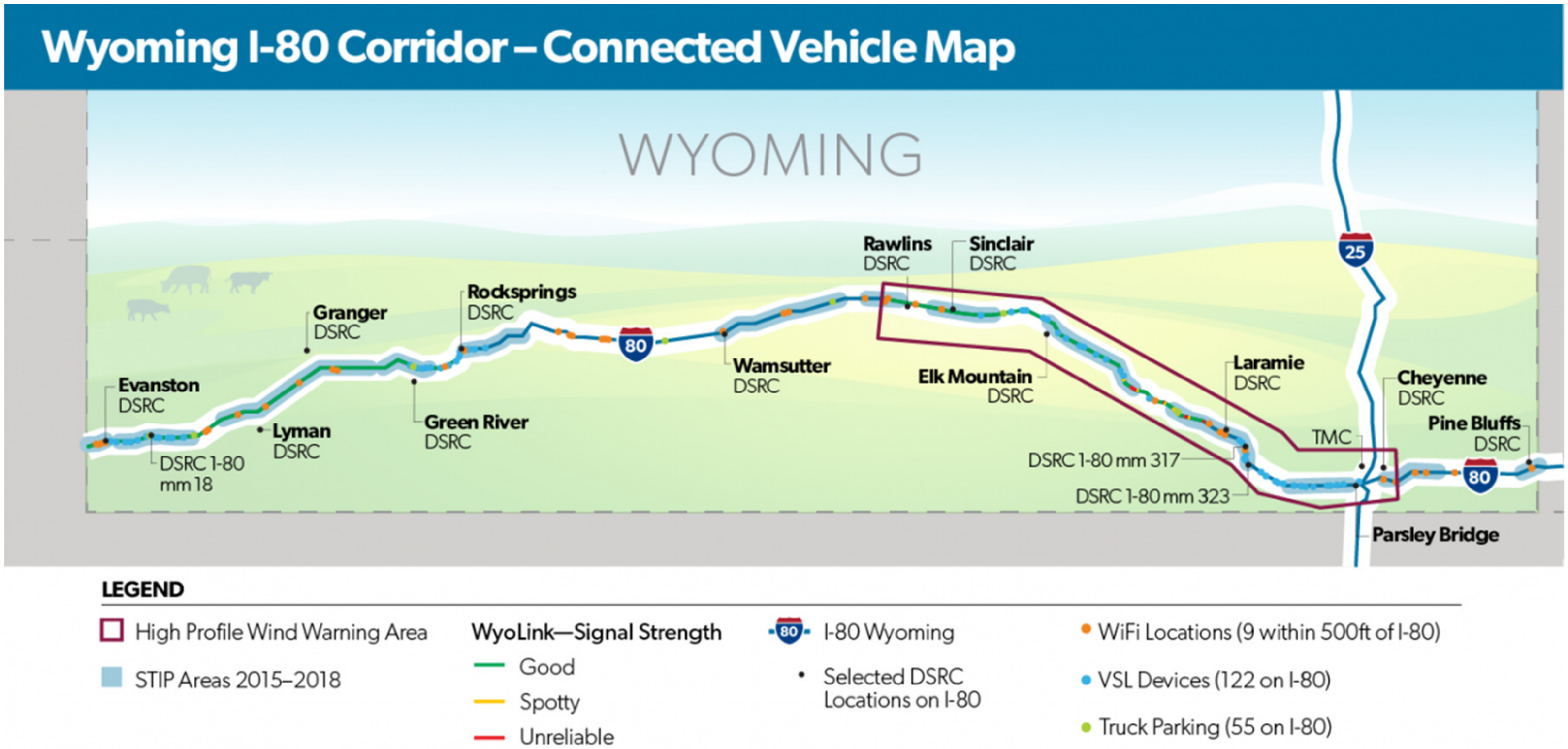



Acceleration and Yaw Rate for Following Vehicle Synchronized with Trajectories of Following, Leading, and Surrounding Vehicles for Swerving Event

# Lessons Learned

- The high resolution trajectory-level (microscopic) results from Phase 2 are timely for improving safety and mobility on freeways in Wyoming.
- Identifying trips in various weather conditions was achievable using novel 3 complementary methods.
- Within the identified trips, ML using video and vehicle kinematics provided promising results to identify trajectory-level road weather conditions.
- Transferability assessment of the SHRP2 Results needs more investigation.
- Moving forward with CAV, this will help in identifying the level of data needs.

# PHASE 3: Connected Human-in-the-loop Variable Speed Limit and ATIS



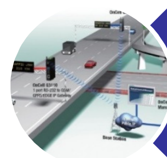



Source: https://www.transportation.gov/connections/connecting-vehicles-and-infrastructure-wyoming

# PHASE 3: Connected Human-in-the-loop Variable Speed Limit and ATIS


**Wyoming Department of Transportation**


Weather/ Driver Behavior & Performance - Based Variable Speed Limit



Advanced Traveler Information System

Connected Vehicle Weather Application

**Develop a VSL Guidelines**

# Phase 3 Tasks

**WYDOT Weather-based VSL and CV Integration**

1. Collect Wyoming VSL Baseline Data.
    a) Adjust driver behavior models to Wyoming Conditions.
2. Add CV Speeds to the VSL logic.
    a) Update microscopic traffic and driver parameters in microsimulation models for Wyoming (Driving Sim Integration).
3. Update VSL logic using adjusted results from SHRP2 Phase 2.
4. Identify and model deviation from Normal Driving (Critical Safety Events) on I-80 based on calibrated models from SHRP2.
5. Account for variation between SHRP2 and CV data in identifying Critical Safety Events.
6. Integrate within the CV Pilot Corridor.
7. Integrate the new system into the TMC's IRIS winter 2018-19.
8. Develop a VSL Guidance.

# Publications

1. Ahmed, M.M. and Ghasemzadeh, A. "The impacts of heavy rain on speed and headway Behaviors: An investigation using the SHRP2 naturalistic driving study data." **Transportation Research Part C: Emerging Technologies, Vol 91. 2018.pp 371-384, 2018.**

2. Ali Ghasemzadeh*, Britton Hammit*, Mohamed Ahmed, Rhonda Young, Using Parametric Ordinal Logistic Regression and Non-Parametric Decision Tree Approaches for Assessing the Impact of Weather Conditions on Driver Speed Selection Using Naturalistic Driving Data. **Transportation Research Record: Journal of the Transportation Research Board**, **2018.**

3. Ali Ghasemzadeh*, Mohamed Ahmed. Utilizing naturalistic driving data for in-depth analysis of driver lane-keeping behavior in rain: Non-parametric MARS and parametric logistic regression modeling approaches. **Transportation Research Part C: Emerging Technologies**. Vol 90. 2018. pp 379-392, 2018.

4. Ali Ghasemzadeh*, Mohamed Ahmed, Driver's Lane Keeping Ability in Inclement Weather Conditions: Preliminary Investigation using the SHRP2 Naturalistic Driving Study Data, **Transportation Research Record: Journal of the Transportation Research Board**, Volume 2663, pp. 99-108, https://doi.org/10.3141/2663-13, **2017**.

5. Britton Hammit*, Ali Ghasemzadeh*, Mohamed Ahmed, Rhonda Young, Evaluation of Weather-Related Freeway Car-Following Behavior using the SHRP2 Naturalistic Driving Study, Proceedings of the **Transportation Research Board 97th Annual Meeting**, **2018**.

6. Ali Ghasemzadeh*, Britton Hammit*, Mohamed Ahmed, Hesham Eldeeb, Complementary Methodologies to Identify Weather Conditions in Naturalistic Driving Study Trips: Lessons Learned from the SHRP2 Naturalistic Driving Study & Roadway Information Database, Proceedings of the **Transportation Research Board 97th Annual Meeting**, **2018**.

7. Md Nasim Khan, Ali Ghasemzadeh*, Mohamed Ahmed, Investigating the Impact of Fog on Freeway Speed Selection Using the SHRP2 Naturalistic Driving Study Data, Proceedings of the **Transportation Research Board 97th Annual Meeting**, **2018**.

# Publications

8. Anik Das*, Ali Ghasemzadeh*, Mohamed Ahmed, A Comprehensive Analysis of Driver Lane-Keeping Performance in Fog Weather Conditions Using the SHRP2 Naturalistic Driving Study Data, Proceedings of the **Transportation Research Board 97th Annual Meeting**, **2018**.

9. Ali Ghasemzadeh*, Mohamed Ahmed, Sherif Gaweesh*, Multivariate Adaptive Regression Splines and Logistic Regression Models to Identify the Impact of Rainy Weather on Driver Lane-keeping Performance Considering Driver Demographics and Roadway Characteristics Using SHRP2 Naturalistic Driving Data, Proceedings of the **Transportation Research Board 97th Annual Meeting**, **2018**.

10. Mohamed Ahmed, Ali Ghasemzadeh*, Exploring the Impacts of Adverse Weather Conditions on Speed and Headway Behaviors Using the SHRP2 Naturalistic Driving Study Data. Proceedings of the **96th Transportation Research Board Annual Meeting, 2017**.

11. Ali Ghasemzadeh*, Mohamed Ahmed, A Probit-Decision Tree Approach to Analyze the Effects of Adverse Weather Conditions on Work Zone Crash Severity Using the Second Strategic Highway Research Program Roadway Information Dataset. Proceedings of the **96th Transportation Research Board Annual Meeting, 2017**.

12. Ali Ghasemzadeh*, and Mohamed Ahmed, "Investigating the Feasibility of Using SHRP2 Naturalistic Driving Study to Support Data Requirements of VSL Decision Making Algorithms and its Application in Connected Vehicle". Proceedings of the **23rd Intelligent Transportation Systems World Congress (ITSWC), 2016**.

13. Ali Ghasemzadeh*, and Mohamed Ahmed, "Estimating the Impacts of Adverse Weather Conditions on Work Zone Crash Severity using the SHRP2 Roadway Information Database". Proceedings of the **14th World Congress of Transport Research, 2016**.

14. Britton Hammit*, Mohamed Ahmed, and Rhonda Young, "Feasibility of Using Connected Vehicle Data for Rural Roadway Weather Conditions in Wyoming". Proceedings of the **95th Transportation Research Board Annual Meeting, 2016**.

# Questions?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Federal Highway Administration

American Association of State Highway and Transportation Officials
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