Connected Vehicle Human-Machine Interface: Development and Assessment

Mohamed M. Ahmed, Ph.D., P.E.
Associate Professor
Civil and Architectural Engineering

UNIVERSITY OF WYOMING
COLLEGE OF ENGINEERING
AND APPLIED SCIENCE

The Problem

- 37,461 traffic fatalities in 2016 (US)
- 36% related to distraction and speeding
- Human factors are a leading cause of crashes

Table 1. Driver-, Vehicle-, and Environment-Related Critical Reasons

Critical Reason Attributed to	Estimated	
	Number	Percentage* ± 95% conf. limits
Drivers	2,046,000	94% ±2.2%
Vehicles	44,000	2% ±0.7%
Environment	52,000	2% ±1.3%
Unknown Critical Reasons	47,000	2% ±1.4%
Total	2,189,000	100%

*Percentages are based on unrounded estimated frequencies
(Data Source: NMVCCS 2005–2007)

Table 2. Driver-Related Critical Reasons

Critical Reason	Estimated (Based on 94% of the NMVCCS crashes)	
	Number	Percentage* ± 95% conf. limits
Recognition Error	845,000	41% ±2.2%
Decision Error	684,000	33% ±3.7%
Performance Error	210,000	11% ±2.7%
Non-Performance Error (sleep, etc.)	145,000	7% ±1.0%
Other	162,000	8% ±1.9%
Total	2,046,000	100%

*Percentages are based on unrounded estimated frequencies
(Data Source: NMVCCS 2005–2007)

Critical Reason is "the last failure in the causal chain of events leading up to the crash"

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USDOT CV Pilot Project

- **Using Connected Vehicle (CV) Technology to enable equipped vehicles to transmit and receive data to other equipped vehicles and roadside infrastructure.**

- **New York City, Tampa, and Wyoming selected as pilot deployment sites**
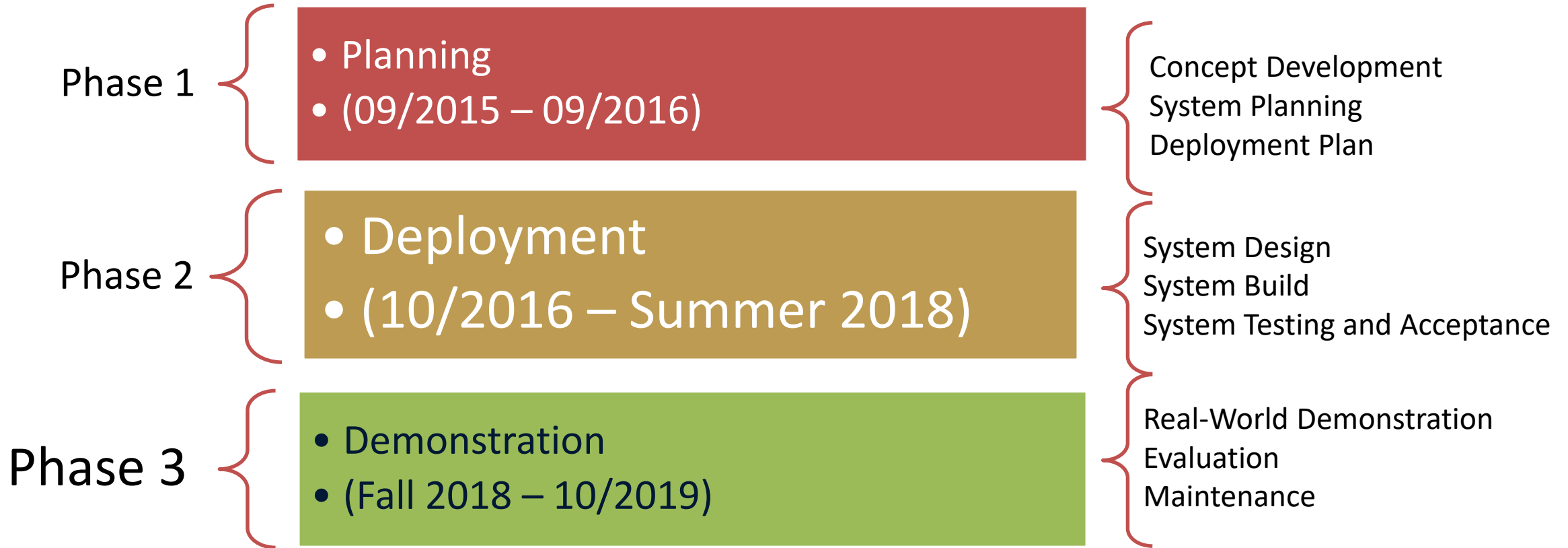
Wyoming Connected Vehicle Pilot

- **Competitive grant opportunity**
- **About $6 million funded 80% by the USDOT**
- **Freight focused**
- **DSRC based**
- **Intended to reduce the number and severity of crashes while improving mobility on the I-80 corridor**
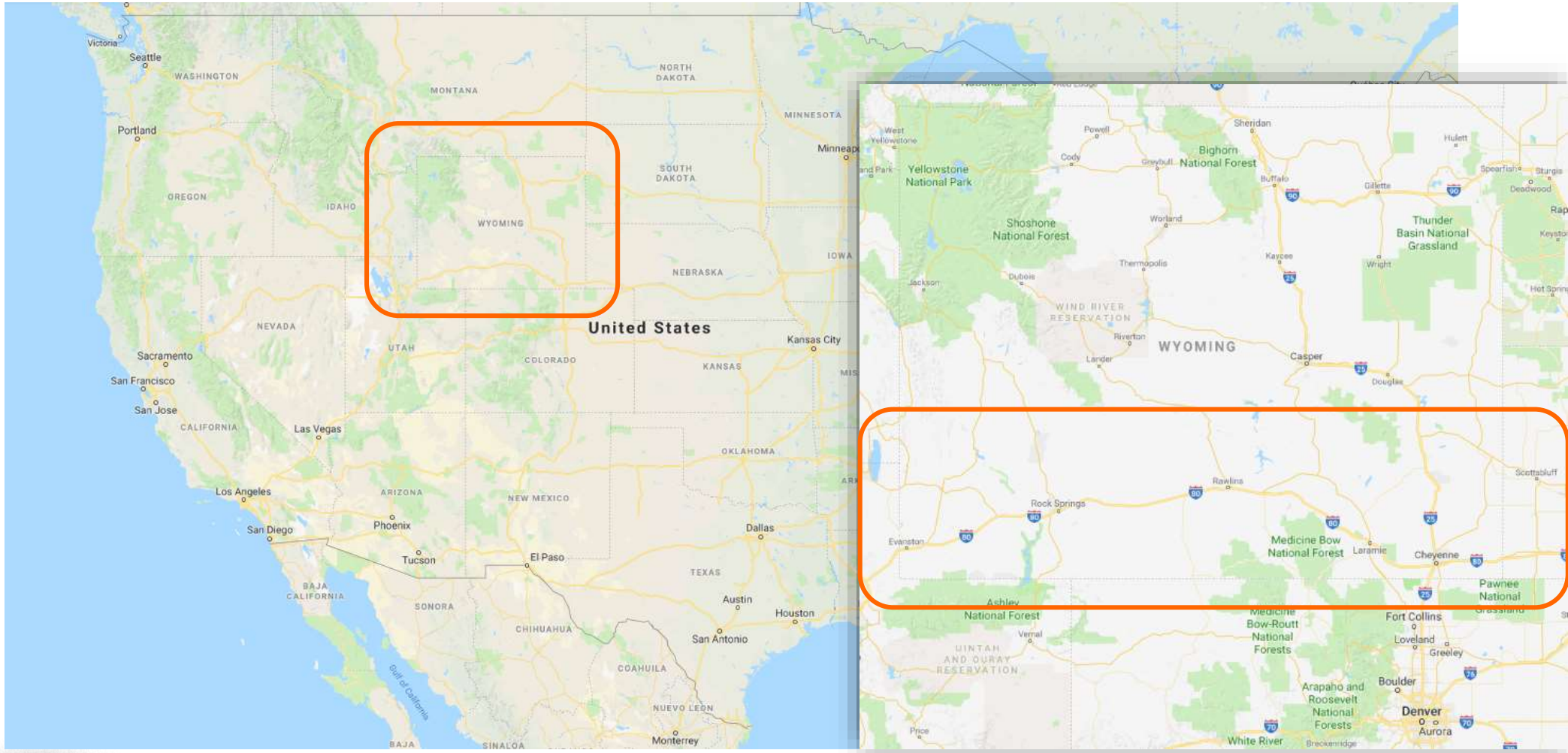
Connected Vehicle Pilot: Next Steps

Phase 1

- Planning
- (09/2015 – 09/2016)

Concept Development
System Planning
Deployment Plan

Phase 2

- Deployment
- (10/2016 – Summer 2018)

System Design
System Build
System Testing and Acceptance

Phase 3

- Demonstration
- (Fall 2018 – 10/2019)

Real-World Demonstration
Evaluation
Maintenance

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Wyoming's I-80 Corridor

Wyoming's I-80 Corridor

Heavy Freight Traffic
- Major E/W freight corridor
- Freight = over half of annual traffic

Severe Weather Conditions
- Roadway elevation
- Heavy winds, heavy snow and fog
- Severe blowing snow and low visibility

Adverse Impacts on Trucks
- **Higher than normal incident rates**
- **Multi-vehicle crashes**
- **Fatalities**

Source: WYDOT (Dec 17, 2015)

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I-80 Corridor

One of the most heavily instrumented rural corridors in the United States

136 Variable Speed Limit Signs
supported by 94 speed sensors

54 Electronic Message Signs

44 Weather Stations

52 Webcams

Interstate 80 Corridor

Interstate 80 Corridor

https://www.youtube.com/watch?v=Pe83hj8nUhI

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On I-80 in Wyoming

IN 1 YEAR PERIOD ALONE

700 COMMERCIAL VEHICLE ACCIDENTS

906 NON-COMMERCIAL VEHICLE ACCIDENTS

1,552 HOURS ROAD CLOSURES

1600+ CRASHES IN 1 YEAR

18 FATALITIES

271 INJURIES

1,317 PROPERTY DAMAGE

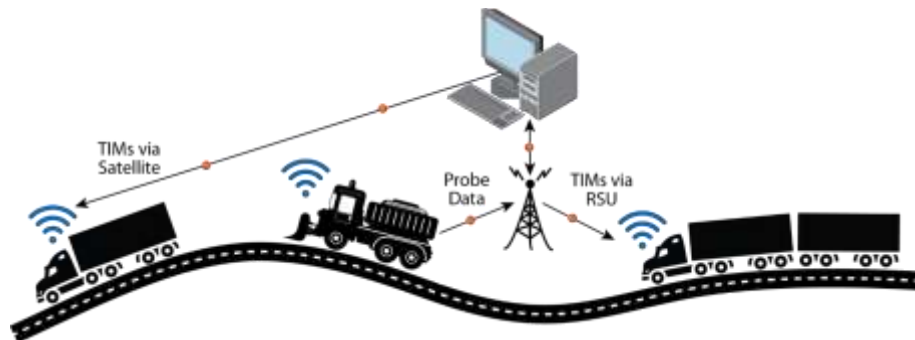## GOAL

Reduce crashes and crash severity on I-80.

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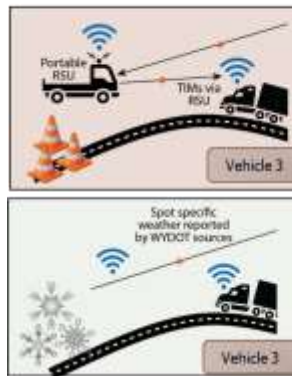
Wyoming Connected Vehicle Pilot

- Wyoming is paving the way for rural Connected Vehicle Applications

- Need for Effective Design for CV and ADAS

- Designing a safe implementable and Effective CV HMI for all Wyoming CV stakeholders
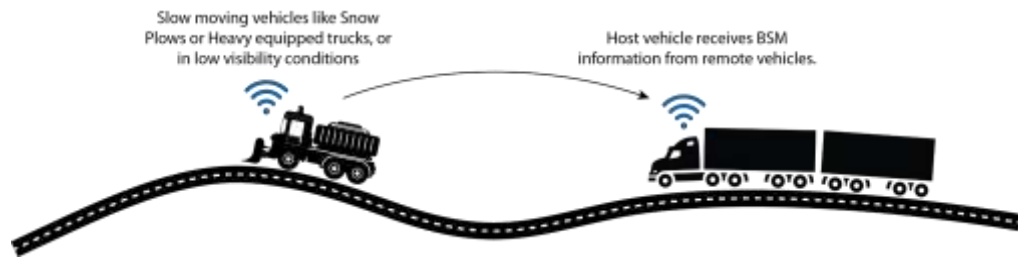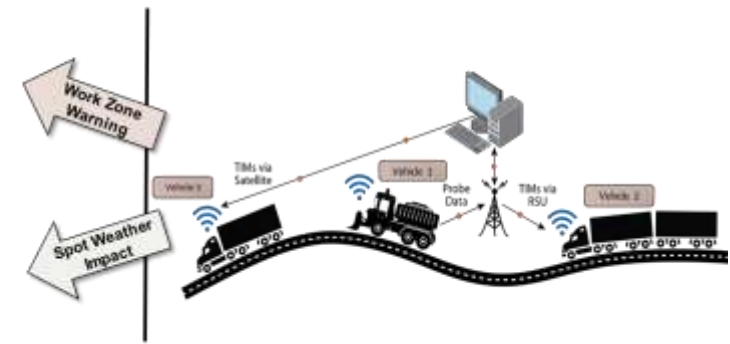

V2V Forward Collision Warning

I2V / V2I Situational Awareness (WZW, SWIS)

I2V / V2I Situational Awareness (TIM)

Distress Notification

Source: WYDOT CV Pilot

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Human Machine Interface

Forward Collision Warning
(FCW) – **V2V**

Situational Awareness
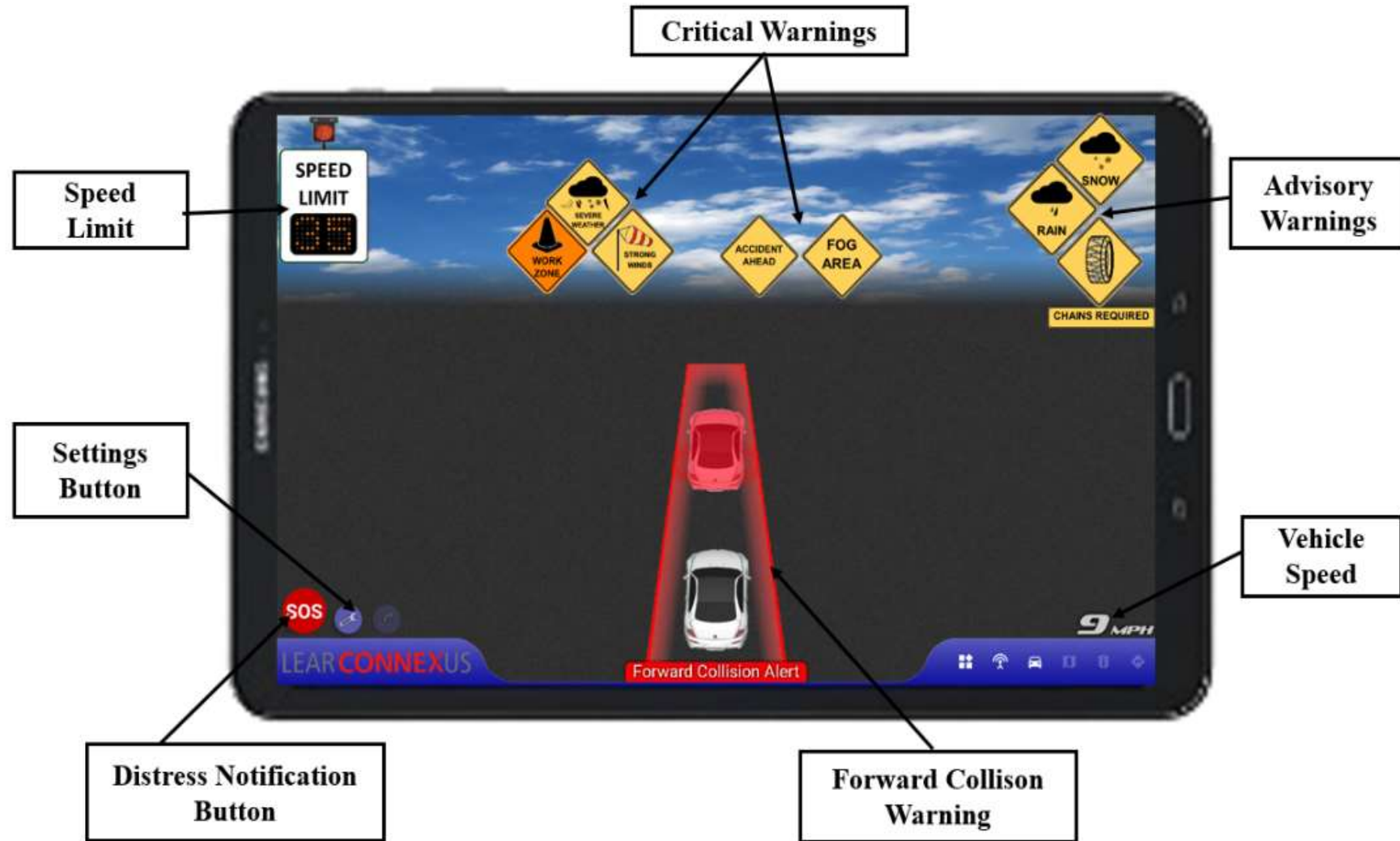(SA) – **I2V**

Distress Notification
(DN) – **V2I & V2V**

Spot Weather Impact Warning
(SWIW) - **I2V**

Work Zones Warning
(WZW) – **I2V**

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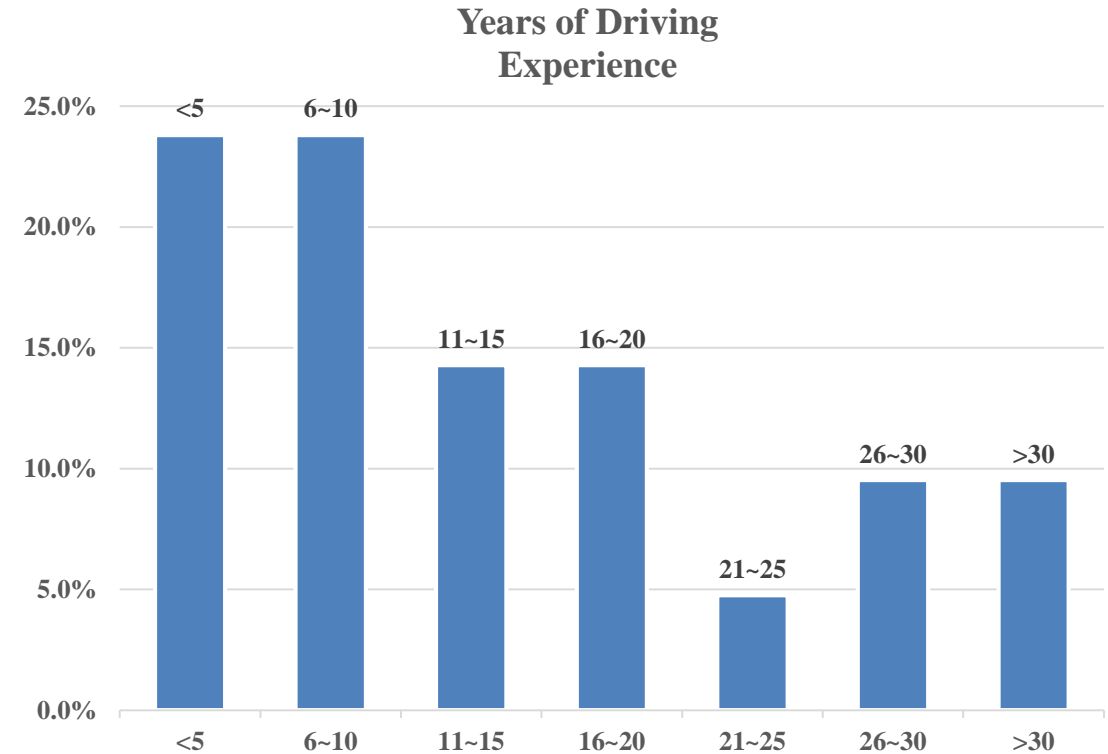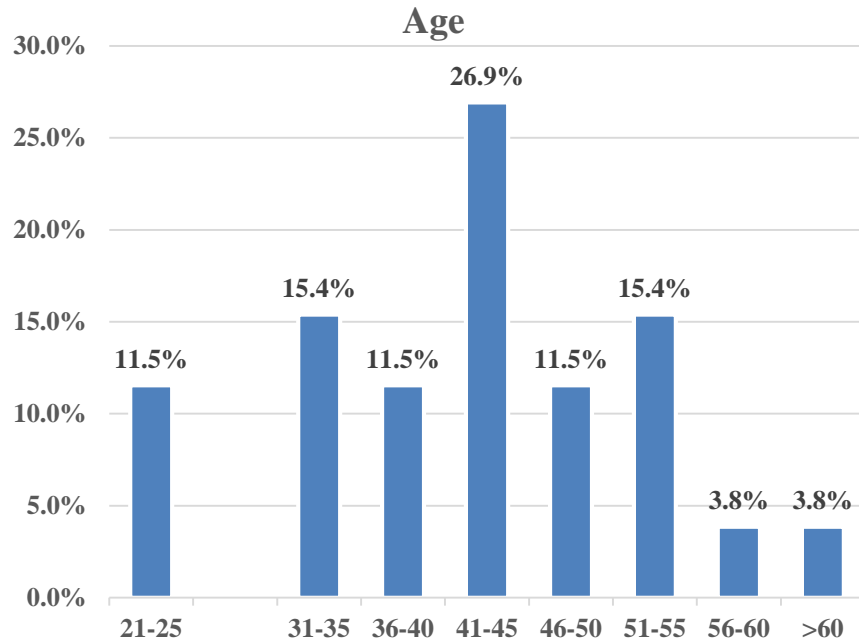
Human Machine Interface

Driving Simulator (UW)

University of Wyoming Simulation and Human Factors Lab (WYOSAFE SIM)

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Participants

23 WYDOT professional snowplow and truck drivers; all the participants were MALE.

58% High School, 34% College, 8% Postgraduate.

Age — bar chart showing: 21-25: 11.5%, 31-35: 15.4%, 36-40: 11.5%, 41-45: 26.9%, 46-50: 11.5%, 51-55: 15.4%, 56-60: 3.8%, >60: 3.8%

Years of Driving Experience — bar chart showing: <5: ~23.7%, 6~10: ~23.7%, 11~15: ~14.3%, 16~20: ~14.3%, 21~25: ~4.5%, 26~30: ~9.6%, >30: ~9.6%

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Work Zone & FCW

Scenario #1: *Work zone with Forward Collision Warning in fog*

CV Applications tested: *WZW & FCW*

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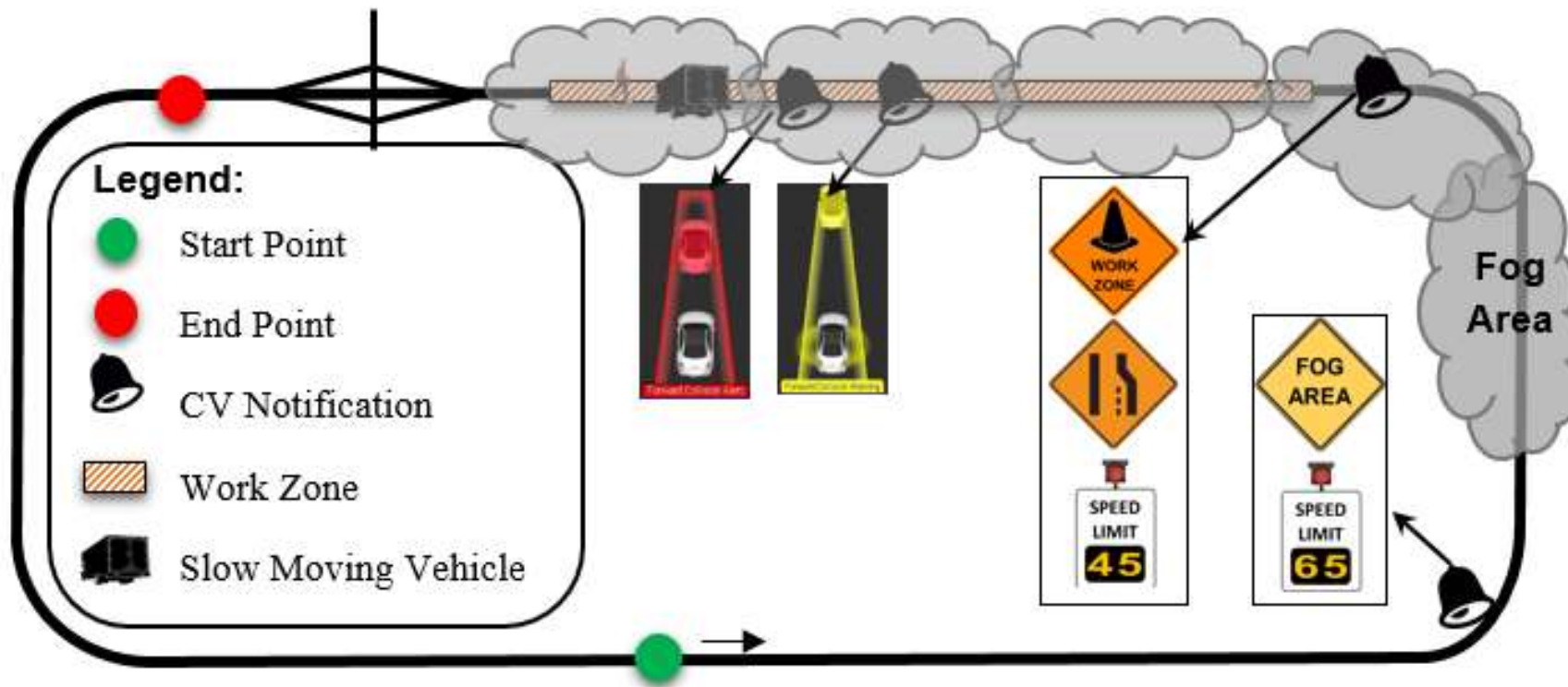
Adverse Weather

Scenario #2: *Slippery Road Surface due to snowy weather*

CV Applications tested: *SWIW & DN*

Legend:
- **Start Point** (green circle)
- **End Point** (red circle)
- **CV Notification** (bell)
- **Icy Road** (green bar)
- **Distressed Vehicle**

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Road Closure and Re-routing

Scenario #3: *Road Closure due to accident in severe weather*

CV Applications tested: *SWIW & SA*

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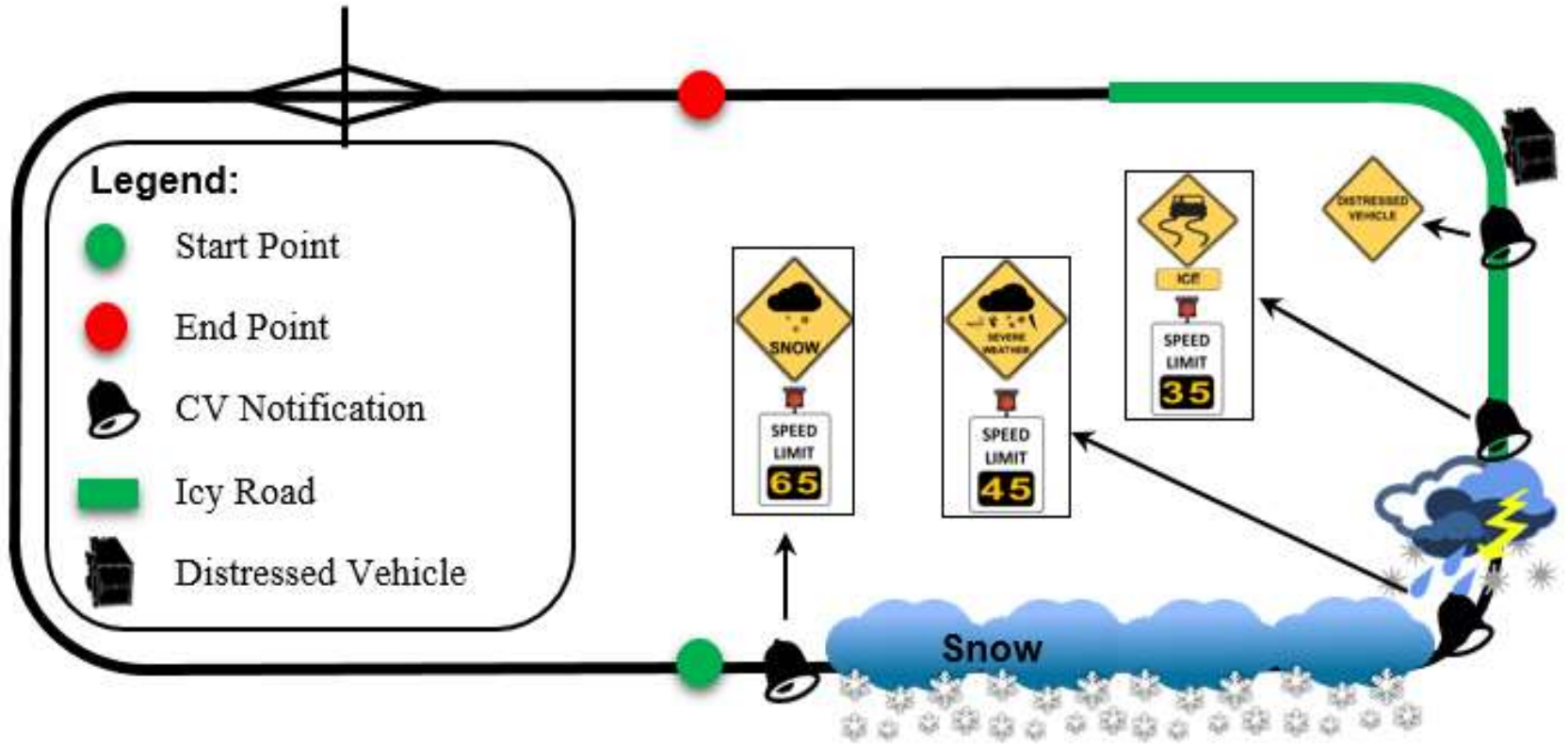
Work Zone in Fog Scenario
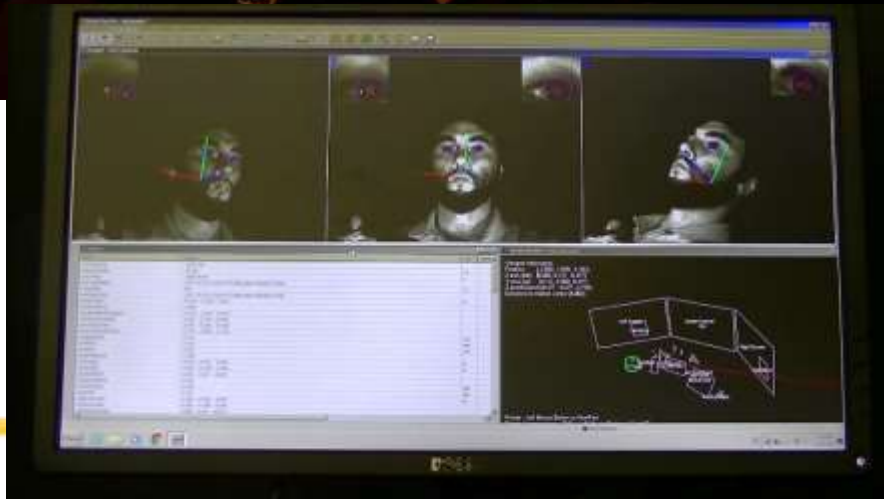
Usefulness of CV under Various Driving Conditions

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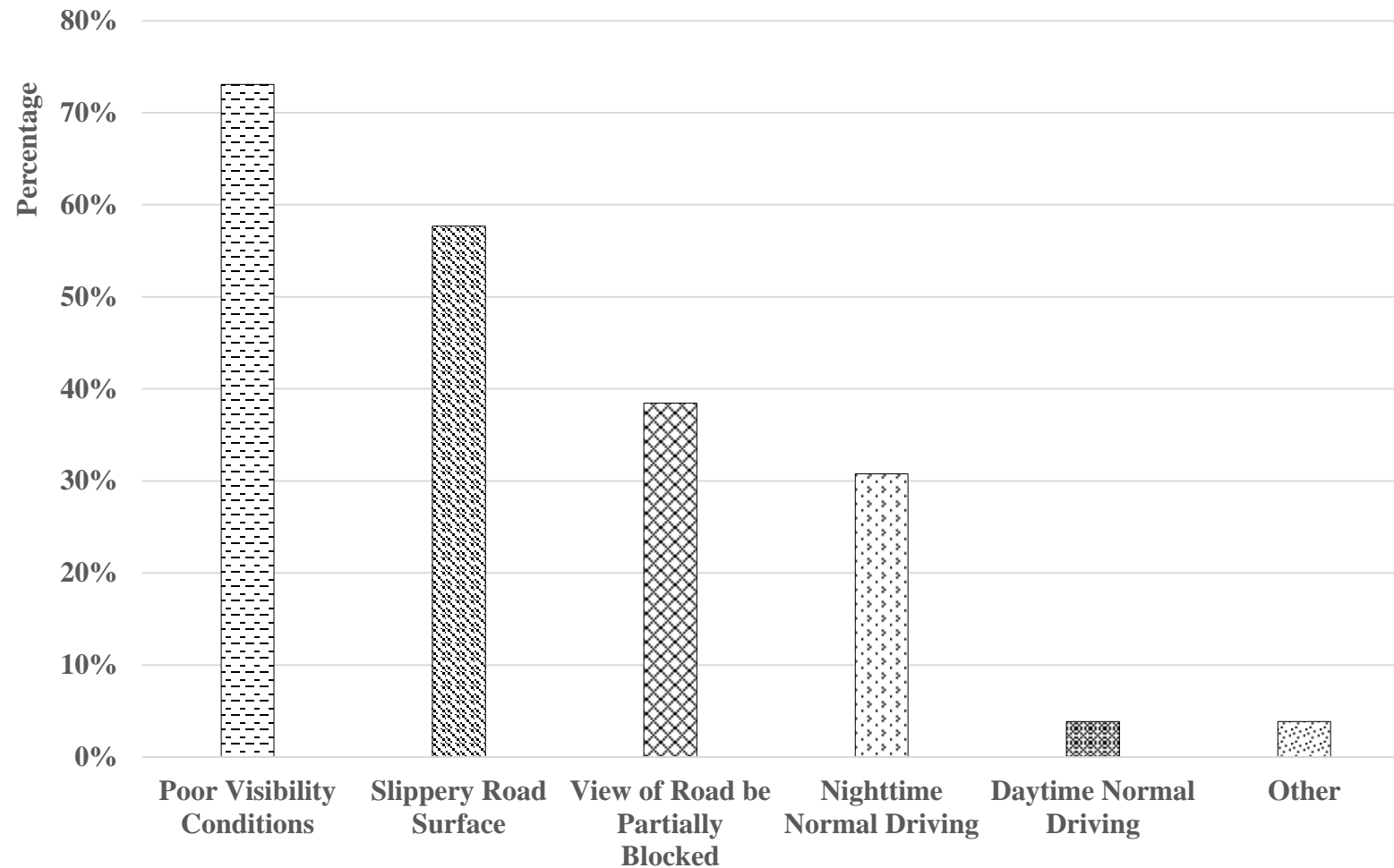
Participants Assessment of CV HMI

Scale Items	Mean	SE	Positive	Neutral	Negative
(a) Readability of CV Warnings (~84% Positive)					
CV warnings easy to understand?	6.1	0.80	96.2%	3.8%	0%
CV warnings are NOT confusing?	5.5	0.95	80.8%	19.2%	0%
CV warnings are NOT distracting?	5.2	1.37	**73.1%**	15.4%	11.5%
CV warnings clear conveyed messages?	5.7	0.93	84.6%	15.4%	0%
(b) Usefulness of CV Technology (~71% Positive)					
CV system provided improved roadway information?	5.8	1.14	85.7%	9.5%	4.8%
CV applications increased traffic safety?	5.9	1.14	88.5%	7.7%	3.8%
Dependent on the CV applications?	4.2	1.61	**42.3%**	30.8%	26.9%
Desirability of CV system?	4.8	1.67	**65.4%**	23.1%	11.5%

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Participants Assessment of Specific CV Apps

CV Applications	Readability					Usefulness				
	Mean	SE	Positive	Neutral	Negative	Mean	SE	Positive	Neutral	Negative
FCW	5.9	0.99	84.6%	15.4%	0%	6.1	1.03	88.5%	11.5%	0%
DN	6.0	1.11	88.5%	7.7%	3.8%	5.7	1.12	84.6%	11.5%	3.8%
Road Surface	6.1	0.80	96.2%	3.8%	0%	5.7	1.08	84.6%	11.5%	3.8%
Re-Routing	6.1	1.13	92.3%	3.8%	3.8%	6.0	1.10	84.6%	15.4%	0%
WZW	6.2	0.97	88.5%	11.5%	0%	5.8	1.24	80.8%	15.4%	3.8%
SWIW	5.9	0.91	92.3%	7.7%	0%	5.5	1.27	73.1%	19.2%	7.7%

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Preliminary Findings

➢**Summary of Preliminary Participants Assessment**

  ✓CV technology was most favorable under poor-visibility driving conditions

  ✓FCW and Re-Routing were the most useful CV applications

  ✓Approximately a quarter of the participants indicated that CV HMI might introduce distraction.

➢**Recommendations**

  ✓Some CV warnings should be provided during adverse weather or limited visibility conditions only (WZW).

  ✓User Customization Capability.

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Ongoing Work

- Eye Tracking and Driving Data
- HMI/ Warning Modality (i.e., visual, auditory (voice message, beeps), or a combination of visual and auditory)
- Optimum Number of Alerts
- Early Warnings and Duration
- Warning Prioritization
- Real-world Assessment

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Wyoming CV Pilot Team

STAY CONNECTED

Mohamed M. Ahmed
Associate Professor of Civil and
Architectural Engineering
University of Wyoming
mahmed@uwyo.edu

Contact for CV Pilots Program/Site AORs:
- Kate Hartman, Program Manager, Wyoming DOT Site AOR;
  Kate.hartman@dot.gov

Visit CV Pilot and Pilot Site Websites for more Information:
- CV Pilots Program: http://www.its.dot.gov/pilots
- Wyoming DOT: https://wydotcvp.wyoroad.info/