Evaluation of Connected Vehicle Warnings Effectiveness on Truck Drivers Behavior: Lessons Learned

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Overview of Wyoming I-80

- 402 mile stretch
- Vital freight corridor
- 30-55% Truck volume
- Difficult road & weather conditions
- 1552 hours of road closure yearly

Source: Wyoming Highway Patrol – April 2015
Wyoming DOT Connected Vehicle Pilot

- Freight-focused
- Improve travel reliability and safety on I-80 corridor

Source: WYDOT
Wyoming DOT Connected Vehicle Pilot

V2I + V2V = Human Machine Interface (HMI)

Source: Unex
Wyoming DOT Connected Vehicle Pilot

Suite of CV Applications

- FORWARD COLLISION WARNING
- 12V SITUATIONAL AWARENESS
- WORK ZONE WARNING
- SPOT WEATHER IMPACT WARNING
- DISTRESS NOTIFICATION

Source: WYDOT
## Wyoming DOT Connected Vehicle Pilot

### Pilot’s Performance Measures - Measuring Success

<table>
<thead>
<tr>
<th>No.</th>
<th>Performance Measure</th>
<th>Target</th>
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<tbody>
<tr>
<td>7</td>
<td>Effectively Disseminate and Receive V2V and V2V Alert/Advisory</td>
<td>Messages from the TMC 80% of vehicles likely took action based on alert</td>
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<td>Connected vehicles that likely took action following receipt of alert</td>
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<tr>
<td></td>
<td></td>
<td><strong>- Parked</strong> <strong>- Reduced speed</strong> <strong>- Came to a stop safely</strong> <strong>- Exit to</strong></td>
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<tr>
<td>12</td>
<td>Effectively Transmit and Receive V2V Messages</td>
<td>80% of vehicles took action based on V2V alert</td>
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<td>Connected vehicles that took action following receipt of a V2V alert</td>
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<td></td>
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<td><strong>- Parked</strong> <strong>- Reduced speed</strong> <strong>- Came to a stop safely</strong> <strong>- Exit to</strong></td>
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<tr>
<td>14</td>
<td>Improved Speed Adherence and Reduced Speed Variation</td>
<td>20% improvement over baseline of total vehicles traveling no more than 5 mph over posted speed during CV Pilot. Baseline will determine what percentage is traveling no more than 5 mph over posted speed prior to CV Pilot. Connected vehicles are 20% closer to posted speed</td>
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<td>Total vehicles traveling at no more than 5 mph over the posted speed (compare before and after CV Pilot)</td>
<td></td>
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<tr>
<td>16</td>
<td>Speed of applicable connected vehicles are closer to posted speed when compared to non-connected vehicles</td>
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Kitchener et al. (2015)
The Team
Objective – HMI/UX Design

Derive maximal safety benefits from real-life deployment
Approach

- Driving simulator experimentation
- Stakeholder engagement
Lesson #1: Prompt the Appropriate Driver Response
Keep It Easy & Simple

• Use familiar & standard signs - MUTCD

Existing Design
• Signs from/adapted from MUTCD

Our Findings
Keep It Easy & Simple

- Use familiar & standard signs - MUTCD

Existing Design
- Signs from/adapted from MUTCD

Our Findings

Not Easy at All to Understand  | Moderately Easy to Understand  | Very Easy to Understand
It’s All About Driver Response

Problems
- Late and forced merging behavior at work zones
- Truck drivers need early alerts

Existing Design
- Inform drivers of lane closures well in advance

Hallmark et al. (2011)
It’s All About Driver Response

Existing Design
• Inform drivers of lane closures well in advance

Our Findings

- Merged prior to road static lane merge sign
- Merged after road static lane merge sign
- Merged at taper zone

Early
It’s All About Driver Response

Problems

- Speed variability at work zones
- ~20% rear end crashes \textit{(FMCSA, 2018)}
- Blocked vision & presence of adverse weather
- Speeding of any kind ~ 7\% \textit{(FMCSA, 2018)}
It’s All About Driver Response
It’s All About Driver Response

Baseline Scenario

CV Scenario

Abrupt Reduction in Speed

Gradual Reduction in Speed
It’s All About Driver Response

Scenario Design
It’s All About Driver Response

Work Zone Warnings

Our Findings

Participants Speeds in Advance Warning Area

Legend:
- Notification Location
- Advance Warning Area
- Activity Area

Speed (mph)

baseline

CV

Scenario
It’s All About Driver Response

Work Zone Warnings

Our Findings

Participants Speeds in Advance Warning Area

- More harmonious speeds

Legend:
- Notification Location
- Advance Warning Area
- Activity Area
Lesson #2: Driver Safety is Above All
Do Not Distract Truck Drivers

Human Factors – Truck Drivers

- Challenging driving environment

Source: En.Wheelsage – Scania G450

Source: FleetOwner

Source: FleetOwner
Do Not Distract Truck Drivers

Our Findings

- 30% of simulator participants found CV moderately distracting
- Work Zone Warning application invoked notable distraction
Do Not Distract Truck Drivers

HMI Design Guidelines - NHTSA (2016)
In difficult driving conditions, filter out messages of lower safety relevance

Recommendations

Reduce message flow rate
Lesson #3: Build User Trust & Approval
Understand Truck Drivers’ Needs

Human Factors – Truck Drivers

• Low tolerance for nuisance
  ➔ Minimize redundancy with road static signs

Our Findings

• Higher approval for CV apps with marked safety/operational benefits
  ➔ Allow user customizability

Source: Fleet Owner (2017)
Communicate in a Balanced Way

Source: PohlTransportation

- Improve Situational Awareness
- Minimize distraction & Nuisance