I-35 Traveler Information During Construction

Connected Work Zone Applications
- Work Zone Warning
- Queue Warning

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Other Key Team Members

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- Leonard Ruback

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Objective

Testing and verification of the Southwest Research Institute (SwRI) OBU application that provides in-vehicle work zone and queue warning information to drivers in a connected vehicle environment.

Specific Tasks:

- Test Plan Development
- Conduct Tests and Collect Data
- Review results and make recommendations for future refinement needs and/or enhancements.
- Capture information related to Lonestar™ integration and ways to automate this process.
Work Zone Warning

Queue Warning
Work Zone Warning

Generate Road Safety Message (RSM)
Geo-fenced Warning Zone

- Unique ID
- Message Start Time
- Message Duration (min)
- Message Type
- Message Text (3 lines)
- Approach Polygon
- Heading
- +/- Tolerance for heading
- Broadcast frequency (Hz)
- Message Priority (1-7)

Send RSM to Upstream Roadside Unit (RSU)

Work Zone Information
- Direction of travel
- Lane closure boundaries
- Start & end time
- Closure type

Connected Vehicle

RSU
Work Zone Warning with LoneStar™ Integration

Lane Closure Data XML

LoneStar™
- Get Work Zone Information
  - Direction of travel
  - Lane closure boundaries
  - Start time & end time
  - Lane closure type
- Generate RSM
  - WZ map
  - heading +/- tolerance
  - warning message
- Assign RSM to Appropriate RSU
  (RSU -> RSM Mapping)
- Transmit RSM to Designated RSU

Connected Vehicle OBU
- Vehicle data
  - position
  - speed
  - heading

RSU

CWZ Application
(warning message generation)

Driver-Vehicle Interface
(in-vehicle display/tablet)
Work Zone Warning with LoneStar™ Integration
Starting point of CWZ warning area

Connected vehicle (CV) trajectory
- OBU of CV does not generate warning
- OBU of CV generates CWZ warning

Geo-fenced region of CWZ warning area defined by RSM
OBU application generates a warning if a connected vehicle’s

[position coordinates are within approach polygon ]

AND

[heading is within a specified value for heading +/- tolerance]
Laptop to get data from OBU & run test application

Laptop to send RSM to RSU

In-Vehicle Display

OBU

GPS Antenna

Wireless Modem

RSU
RSUs on I-35 in Temple, TX
Work Zone Lane Closure Scenarios
**Northbound Lane Closures**

<table>
<thead>
<tr>
<th>Lane</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB-1</td>
<td>“Right lane closed”</td>
</tr>
<tr>
<td>NB-2</td>
<td>“Left lane closed”</td>
</tr>
<tr>
<td>NB-3</td>
<td>“Left two lanes closed ahead”</td>
</tr>
<tr>
<td>NB-4</td>
<td>“Left two lanes closed”</td>
</tr>
<tr>
<td>NB-5</td>
<td>“Right lane closed”</td>
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</table>

**Lane Closure Scenarios Tested**
<table>
<thead>
<tr>
<th>Southbound Lane Closures</th>
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<tbody>
<tr>
<td>SB-1 “Left lane closed”</td>
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<tr>
<td>SB-2 “Right lane closed”</td>
</tr>
<tr>
<td>SB-3 “Right two lanes closed ahead”</td>
</tr>
<tr>
<td>SB-4 “Right two lanes closed”</td>
</tr>
<tr>
<td>SB-5 “Left lane closed”</td>
</tr>
<tr>
<td>SB-6 “Right lane closed”</td>
</tr>
</tbody>
</table>

Lane Closure Scenarios Tested

- SB-1: “Left lane closed”
- SB-2: “Right lane closed”
- SB-3: “Right two lanes closed ahead”
- SB-4: “Right two lanes closed”
- SB-5: “Left lane closed”
- SB-6: “Right lane closed”
Work Zone Warning CV Application Field Tests

Drove Connected Vehicle in Various Test Scenarios

In different lanes

In opposite direction

On frontage road

On cross-road
Field Tests

Multiple test-runs

- Drove the connecting vehicle in different lanes.
- Stayed in selected lane & avoided lane change.

<table>
<thead>
<tr>
<th>Test Dates</th>
<th>Number of Test-Runs</th>
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<tbody>
<tr>
<td></td>
<td>Northbound</td>
</tr>
<tr>
<td>December 2, 2021</td>
<td>3</td>
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<tr>
<td>December 20, 2021</td>
<td>4</td>
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<tr>
<td>January 25, 2022</td>
<td>4</td>
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<tr>
<td>February 8, 2022</td>
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<td>February 17, 2022</td>
<td>7</td>
</tr>
<tr>
<td>February 22, 2022</td>
<td>5</td>
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</table>
Field Observations

• Messages displayed were continuously monitored
• Observation recorded using a CWZ Data collection Form.

- Warning was displayed correctly
- Warning was displayed incorrectly
  o appeared correctly but did not stay on
  o appeared late
  o was on-and off
Data Collection and Results

Data Collected:
- Vehicle trajectory data
- Message logs
- Locations and times when RSM was received from RSU

Findings:
- OBU received the appropriate RSM at the right location upstream of the lane closure.
- The generated warning message was occasionally lost. It typically occurred on curves when the connected vehicle got outside of the geo-fenced warning polygon.
- After making the following changes system worked as intended:
  - increased from 20 m to 25 m, and
  - revised the degree of +/- tolerance for headings
WZ warning message disappears when test-vehicle gets outside of the geo-fenced region

Test-vehicle receives WZ warning message

WZ warning message disappears when test-vehicle gets outside of the geo-fenced region

Connected vehicle (CV) trajectory

Geo-fenced region of work zone warning area
Lessons Learned

• The performance of CWZ Applications depends on the
  o Accuracy of the roadway map used to define the warning zone.
  o Expected positioning accuracy of connected vehicles that are driving in that area.
• Roadway map accuracy in construction areas is often questionable due to significant changes in roadway geometry.
• The width used for creating of the geofenced warning zone should be guided by the actual physical width of the roadway.
• Guidance needed on how many points should be used to define a warning zone/approach polygon based on the curvature of the roadway to ensure OBUs correctly match to the region along the entire path.
For further information contact:

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