Vehicle to Vehicle Retrofit Feasibility Analysis

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Scope

VII Consortium study for the U.S. Department of Transportation

- Analyze the opportunities and practical limitations of retrofitting DSRC devices into an existing vehicle fleet
- Conduct research through direct practical experience with retrofit devices
- Do retrofit DSRC devices add value?
Retrofit Assumptions

Retrofit: install DSRC system in a production vehicle that was not designed for DSRC

Retrofit systems are designed and implemented by or with OEMs

- Devices without connections to vehicle networks (aftermarket devices) may not support hard safety applications where vehicle data is essential and were excluded from this study
- A dealer or other authorized merchant is required for installation and certification
Tasks

Create taxonomy for retrofit solutions and assess support for applications

Assess sample of existing DSRC product specifications for retrofit suitability and develop general retrofit solution specs

Assemble hardware components for selected solutions

Install and document installation procedures for selected retrofit solutions

Test and evaluate communications coverage

Project management and final report
Retrofit Solutions Taxonomy

Retrofit solutions were classified based on design decisions that affect installation

- Each path in the taxonomy represents a possible retrofit solution alternative
Retrofit Solution Alternatives Chosen

Four alternatives were selected for further analysis based on

- What makes sense to implement
- Anticipated viability

Vehicle-Based Data Connection

Diagnostics Port (OBD-II)

Interior

- Stand Alone
- Integrated w/ Vehicle HMI

Exterior

- Stand Alone
- Integrated w/ Vehicle HMI

Vehicle Network (CAN)

Interior

- Stand Alone
- Integrated w/ Vehicle HMI

Exterior

- Stand Alone
- Integrated w/ Vehicle HMI

GPS and DSRC Antenna Placement

HMI Implementation

Alternative A

Alternative B

Alternative C

Alternative D
Application Selection Process

Evaluated applications from CAMP CICAS-V and VSC-A projects as well as VII-C Applications

Chose representative set of applications to highlight differences in retrofit solutions

Removed applications where performance requirements or required vehicle data were similar
## Retrofit Support for Applications

Four retrofit solution alternatives were assessed for expected application support based on:

- Vehicle data access
- DSRC antenna coverage

### Retrofit Solutions

<table>
<thead>
<tr>
<th>DSRC-Based Applications</th>
<th>Retrofit Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td><strong>I2V</strong></td>
<td></td>
</tr>
<tr>
<td>Traffic Signal Violation Warning</td>
<td></td>
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<tr>
<td>Stop Sign Violation Warning</td>
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<tr>
<td>Stop Sign Movement Assistant</td>
<td></td>
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<tr>
<td><strong>V2V</strong></td>
<td></td>
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<tr>
<td>Intersection Collision Warning</td>
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<tr>
<td>Forward Collision Warning</td>
<td></td>
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<tr>
<td>Emergency Electronic Brake Lights</td>
<td></td>
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<tr>
<td>Lane Change Warning</td>
<td></td>
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<tr>
<td>Blind Spot Warning</td>
<td></td>
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<tr>
<td>Highway Merge Assistant</td>
<td></td>
</tr>
<tr>
<td>Do Not Pass Warning</td>
<td></td>
</tr>
<tr>
<td>Control Loss Warning</td>
<td></td>
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<tr>
<td><strong>Sign Extension</strong></td>
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</tr>
<tr>
<td>In-Vehicle Signage Warning</td>
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<tr>
<td>Low Parking Structure Warning</td>
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<tr>
<td>Work Zone Warning</td>
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</tr>
<tr>
<td><strong>V2I</strong></td>
<td></td>
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<tr>
<td>SOS Services</td>
<td></td>
</tr>
<tr>
<td>Free-Flow Tolling</td>
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<tr>
<td>Intelligent Traffic Flow Control</td>
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</tr>
</tbody>
</table>

- **DSRC-Based Applications**
  - I2V: Inter-Vehicle
  - V2V: Vehicle-to-Vehicle
  - V2I: Vehicle-to-Infrastructure

- **Retrofit Solutions**
  - A: Commonly supported by vehicles and this retrofit solution type
  - B: OBD-II limits performance
  - C: Requires vehicle system that is typically optional equipment
  - D: Internal antenna significantly limits performance
OBD-II Performance Limitations

OBD-II vehicle diagnostics port, no real-time, high speed data

Reliability and speed of data over OBD-II can vary significantly, depending on the vehicle as well as the load placed on the network

The OBD-II data set is a subset of the total data available on vehicle networks and also varies by make and model
At the time of the study, Denso and Cohda had the most suitable DSRC products for retrofit solutions.

<table>
<thead>
<tr>
<th></th>
<th>Denso</th>
<th>Cohda</th>
<th>NEC</th>
<th>Savari</th>
<th>ITRI</th>
<th>Renesas</th>
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<tbody>
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<td>external</td>
<td>integrated</td>
<td>integrated</td>
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<tr>
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<td>✔ ✔</td>
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<td>X</td>
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<td>X</td>
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<td>Retrofit support</td>
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</tbody>
</table>
Test Vehicle Hardware Installation

Typical Alternative C implementation: DSRC device (incl. GPS receiver), OEM rooftop antenna, standalone touchscreen (incl. speaker), coaxial, data, and power cables
Retrofit Installation Assessment

Performed vehicle installations and recorded elapsed times

### Installation Time (Hours)

- Alternative C in MB Sedan
- Alternative C in Audi SUV
- Alternative B in VW Compact Hatch
- Alternative A in MB Sedan
Antenna Placement

Three antenna configurations used

- External OEM antenna
- External COTS antenna
- Internal COTS antenna
Antenna Assessment Scenarios

Developed test scenarios to quantify basic communication performance and verify functionality and interoperability of the 2 retrofit vehicles.

Scenario 1

Scenario 2

Scenario 3

Receiving Vehicle
Transmitting Vehicle
Antenna Placement vs. Performance

Compared test results of interior antenna and exterior COTS and OEM antennas

Measured Packet Error Rate and Received Signal Strength Index

- COTS antenna on roof center
- COTS antenna on dashboard
- OEM antenna on roof rear
- Direction of travel (moving vehicle)
Conclusions

Retrofit solution types exhibited considerable variations in functionality, performance, development, and installation.

Increases in retrofit solution performance required significant increases in installation time.

Integrating retrofit HMI with original vehicle HMI is unlikely to be cost effective.

DSRC products surveyed are suitable for research only.

There is potential to provide some DSRC functionality to a broad range of post-production vehicles that would otherwise have none.

Careful consideration of design, development, and installation is needed to make retrofitting viable.