BACKGROUND

- Problem Statement
  - Increased pedestrian fatalities.
  - V2P technologies designed to improve pedestrian safety.
  - Need for reliable approach to testing V2P system effectiveness.

- This project aimed to develop a generic assessment plan and V2P Test Bed to investigate the effectiveness of emerging V2P systems.
Outlines:

- Crash Trends.
- Available V2P Systems.
- Assessment Plan and V2P Test Bed.
- Findings and Suggestions.
Pedestrian and Bicyclist Fatalities (2007-2016)

Source: National Highway Traffic Safety Administration (NHTSA)
Factors known to increase risk of crashes:
- Environmental conditions (weather, lighting, and road surface).
- Infrastructure (road geometry, grade, crowded urban settings, and traffic control).
- Driver behavior-related (avoidance maneuver and speed).
- Road user characteristics (driver/pedestrian impairment, and distraction).
Proven solutions:
- Road diets.
- Medians, islands, and crossing refuge.
- Improved signal timing.
- Pedestrian crossing infrastructure such as Rectangular Rapid Flashing Beacon (RRFB) Pedestrian Hybrid Beacon (PHB).
- Reduced speed limits.

Connected Vehicle technology presents opportunities for new pedestrian safety applications.
V2P SYSTEMS

Vehicle-to-Pedestrian

- Detect at-risk pedestrians through external sensors.
  - May alert driver or pedestrian, and/or intervene driver to reduce crash risk or severity.

- Types of sensors include:
  - Optical camera/computer vision.
  - Direct wireless communications.
  - Radar.
  - Light detection and ranging (LiDAR).
PROJECT GOALS

- Establish a Test Bed for emerging V2P technologies at Turner-Fairbank Highway Research Center (TFHRC).

- Assess variety of V2P systems and document effectiveness.
INITIAL PHASE/PHASE I

2013 – 2016

Technology Scan:
- Identified 86 known V2P technologies.
- Very few mature, market-ready, and publicly accessible products.

Research Implementation Plan:
- Identified gaps and research needs for improving pedestrian safety.

Phase I Goal:
- Develop a test plan strategy and identify V2P systems currently available on the consumer market.
# US DOT V2P TECHNICAL SCAN SUMMARY

<table>
<thead>
<tr>
<th>Approach Number</th>
<th>Author / Manufacturer</th>
<th>Detection Method</th>
<th>Notification Method</th>
<th>Intervention Method</th>
<th>Stage of Development / Implementation</th>
<th>Time To Marketability (Estimated)</th>
<th>Technical Information Available</th>
<th>Cost Value (see individual sheets for specific information)</th>
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<td>7</td>
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<td>R&amp;D Concept</td>
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</tr>
</tbody>
</table>

**Free Download:**
PHASE I:
Assessment Plan

- Developed from common V2P features:
  - Technology accuracy.
  - Reliability.
  - Safety features.
  - Market readiness.
  - Accessibility.

- Identified four scenarios common to vehicle-pedestrian collisions:
  - STRAIGHT
  - PARALLEL
  - LEFT TURN
  - RIGHT TURN
PHASE II
2017 – PRESENT

- **Goal:** Use market-ready V2P systems to validate the test plan strategy from Phase I using the TFHRC V2P Test Bed.

- **Eligibility Criteria for Testing:**
  - Perform in at least 1 of the 4 test case scenarios.
  - Deliver measurable communication output to driver/vehicle or pedestrian/bicyclist.
  - Function within the environment provided (TFHRC or offsite).
PHASE II: Testing

- Three speeds: 10, 15, and 20 mph.
- Two locations at TFHRC V2P Test Bed:
  - Marked, signalized smart intersection with pedestrian crosswalks and pedestrian signal.
  - Marked mid-block crossing.
**V2P TEST BED**

**TFHRC**

- **Features:**
  - Variable speed.
  - Traffic and pedestrian volume control.
  - Signalized Smart intersection with pedestrian crosswalks.
  - Marked mid-block crosswalk.
  - Varying roadway curvature and grade.
  - Testing in different times of day and year.

---

CCTV: Closed-circuit television
RSU: Roadside unit
SPaT: Signal phase and timing
PHASE II: V2P Systems

- **Vehicle-Based**
  - **System 1: Camera-Based Aftermarket Safety Device.**
    - Equipment: Commercially available; installed in test vehicle.
  - **System 2: Camera- and Radar-Based Detection System.**
    - Equipment: Original equipment manufacturer (OEM).

- **Smartphone-Based**
  - **System 3: Smartphone-Based Pedestrian-to-Infrastructure Application.**
    - Equipment: Hardware, early-deployment software; installed at TFHRC.

- **Infrastructure-Based**
  - **Technology: Looking Forward.**
    - LiDAR-Based Pedestrian Detection.
SYSTEM 1:

Camera-Based Aftermarket Safety Device

- Forward-facing single-lens optical camera.
- Windshield-mounted driver interface.
- Driver notified via audiovisual alert.

Cautionary Alert  Emergency Alert
## SYSTEM 1:

Camera-Based Aftermarket Safety Device

<table>
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<tr>
<th>Location</th>
<th>Vehicle: Straight</th>
<th>Pedestrian: Perpendicular</th>
<th>Vehicle: Straight</th>
<th>Pedestrian: Parallel</th>
<th>Number of trials per speed per location</th>
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</thead>
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<tr>
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<td>Marked intersection</td>
<td>X</td>
<td>Marked intersection</td>
<td>X</td>
<td>10</td>
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<tr>
<td>Pedestrian</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Marked mid-block</td>
<td>X</td>
<td>Marked mid-block</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicyclist</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>X</td>
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<td>5</td>
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</table>
SYSTEM 1: Camera-Based Aftermarket Safety Device

- Reliable detection and alerts:

<table>
<thead>
<tr>
<th>Drivers stopped average distance</th>
<th>TTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian</td>
<td>5–10 ft</td>
</tr>
<tr>
<td>Bicyclist</td>
<td>5–10 ft</td>
</tr>
</tbody>
</table>

- Potential effect of roadway geometry:
  - Hills, gradations influenced detection.
SYSTEM 2: Camera- and Radar-Based Detection System

- Integrated with vehicle.
  - Radar and single-lens camera sensor.
  - Audiovisual dashboard alert.

- Assisted braking.
  - Supplemental braking.
  - Full automated braking.

- Pedestrian and bicyclist.
  - 10 trials at each speed.
  - Marked intersection only.
SYSTEM 2: Camera- and Radar-Based Detection System

- **Pedestrian:**
  - Reliable detection and alerts.
  - Generally earlier alerts at higher speeds.
  - Average stopping distance 5–10 ft; TTC 0.3–0.6 s.

- **Bicyclist:**
  - Less reliable detection and alerts.
  - Fewest alerts in 20 mph trials.
  - Average stopping distance 3–11 ft; TTC 0.3–0.6 s.

- **Intuitive and effective automated braking.**
  - More often deployed at higher speeds.

- **Detection limited by roadway elevation, curvature, and clothing contrast.**
SYSTEM 3:

Smartphone-Based Pedestrian-to-Infrastructure (P2I) Application

- Communicates with infrastructure to activate existing pedestrian crossing signal.
- Uses location estimation and geo-fencing to identify true location of crosswalk.
SYSTEM 3: SMARTPHONE-BASED P2I APPLICATION

- Relays pedestrian signal information with visual, haptic, text, and auditory messages.
  - Haptic information notifies user of misalignment with crosswalk during crossing.
SYSTEM 3: SMARTPHONE-BASED P2I APPLICATION

- Tested at 4 marked intersection crossings.
  - 10 trials per crosswalk, 5 in either direction.

- Reliable detection and accurate traffic signal status.
  - Lag between signal head and app.
  - Orientation sometimes misaligned with crosswalk.

- Further development for special populations and connected roadways.
  - Applications for pedestrians with visual and physical impairments.
  - Additional feature communicates pedestrian presence to nearby vehicles with OBU.
SYSTEM 4:

LiDAR-Based Pedestrian Detection

- Capable of automatic object detection, classification, and tracking.
  - Longer sensor range than most radars.
  - Constant scanning.
  - Susceptible to LiDAR shadows and obstruction by other objects.
  - High cost; redundant units needed for full coverage.

- Proposed for active traffic management systems and enforcement.
  - Potential to automatically trigger pedestrian signals or send alerts to equipped vehicles via RSU.
  - Potential to serve greater number of users being infrastructure-based.
OVERALL TECHNOLOGY SUMMARY

- Established a viable, adaptive V2P Test Bed at TFHRC.
  - Suited to variety of technologies and systems.

- Developed and implemented flexible test plan strategy.
  - Investigated multiple factors related to usability and effectiveness.

- Identified advantages and disadvantages of different technologies.
# OVERALL TECHNOLOGY SUMMARY

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<th>Systems</th>
<th>Accessibility</th>
<th>Effectiveness</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera-Based</td>
<td>Inexpensive; aftermarket; anyone can procure through certified vendors; compatible with most vehicle models</td>
<td>Older/intoxicated pedestrians Distracted driver Crowded urban settings</td>
<td>Speed &lt;31 MPH Light &amp; weather Road Grade Road curvature</td>
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<td>Free smartphone download; designed for people with disabilities</td>
<td>Low Light Road Grade Road curvature Crowded urban settings Mobility-impaired pedestrians</td>
<td>Smartphone Data/server connection Infrastructure</td>
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<td>Infrastructure-Based</td>
<td>All users at equipped location; independent of pedestrian state/action; possible communication with equipped vehicles</td>
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</table>
Looking Ahead….

- Document strengths and weaknesses of existing V2P technologies.
- Provide suggestions for the development of future pedestrian safety applications to maximize road user safety and mobility.
- Solicit feedback from stakeholders.
- Document techniques and technology features best suited for continued testing at the TFHRC V2P Test Bed.
- Explore effectiveness of the FHWA Smartphone-Based Mid-Block Pedestrian Crossing In-Vehicle Warning Application.