Connected, Automated, and Connected & Automated Vehicles

CAV initiatives from OEM perspective

AASHTO Subcommittee on Traffic Engineering (SCOTE)
June 7, 2016

Toyota Motor Engineering & Manufacturing North America
Toyota Technical Center
Hideki Hada
Toyota’s Efforts on Cooperative ITS (V2X)

Motivation
Cooperative ITS support driving and aim to prevent traffic accidents by notifying drivers of information, which cannot be detected by a vehicle’s own sensors, through communications between vehicles and infrastructure, or among vehicles.

Collaborative R&D
Toyota commercialized certain functions of Cooperative ITS in 2009 after participating in proving tests held by government agencies and automotive industries, which began in 2006.

Cooperative ITS Products
Electronic Toll Collection & ITS Spots
Driving Safety Support Systems
Vehicle Information & Communication System

New V2V & V2I Products (available in 2015)

http://www.toyota-global.com/innovation/intelligent_transport_systems/infrastructure/
Use an appropriate communication means for certain goals

**Risk Avoidance**
- Cellular, WiFi, etc.

**Risk Mitigation**
- 5.9GHz DSRC

**Collision Avoidance**
- Radar, Laser, Vision
Cooperative ITS with 5.9GHz DSRC

5.9GHz DSRC
Long Distance: 300m
Omni-directional: 360 deg.
Enables Forecast: 2-way data exchange

DSRC enables expansion of safety horizon

On-Board Sensor
Collision Mitigation → Collision Avoidance

Risk Mitigation → Risk Avoidance

Current On-Board Sensor
Limited distance (150m), Limited field of view (30deg), 1-way sensing

https://www.youtube.com/watch?v=W9fl5M6_XVk
V2X Concepts

Vehicle to Infrastructure (V2I)

Vehicle to Vehicle (V2V)

Vehicle to Pedestrian (V2P)

http://www.toyota-global.com/innovation/intelligent_transport_systems/infrastructure/
Toyota’s Contributions to V2X Technology R&D in US

Technical Contributions to US Government-Industry Research Projects (5.9GHz DSRC)

V2V Safety
V2I Safety
V2I Mobility
V2V Operational Test

CAMP Projects
VSC, EEBL, VSC-A, V2V-I, V2V-Security, V2V-AEB

CAMP Project CICAS-V

VIIC Project
Vehicle Infrastructure Integration
Proof of Concept

CAMP Projects
Safety Pilot Driver Clinic
Safety Pilot Model Deployment

DSRC Industry Standard Development

SAE J2735, SAE J2945
IEEE 802.11p, IEEE 1609

Government Industry Discussions

VII Consortium (V2X Policy)
V2V Deployment Coalition
VII Executive Leadership Team

Realization of V2X in the United States
V2X Products

V2I services have been available in Japan: ITS Spot, Driving Safety Support Systems

http://www.toyota-global.com/innovation/intelligent_transport_systems/infrastructure/
## ITS Connect V2X Products – V2V

<table>
<thead>
<tr>
<th>V2V</th>
<th>Emergency Vehicle Notification</th>
<th>V2V Advisory</th>
<th>Cooperative Adaptive Cruise Control (C-ACC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle-to-vehicle communication</td>
<td>Helps the driver recognize an approaching emergency vehicle</td>
<td>Indicates the direction which another vehicle with V2X function comes from</td>
<td>Makes ACC control smoother by getting information of vehicle in front</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>V2I</th>
<th>Right Turn Collision Caution</th>
<th>Red Light Caution</th>
<th>Signal Change Advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle-to-infrastructure communication</td>
<td>Alerts driver to oncoming vehicles and pedestrians during turning right</td>
<td>Alerts driver to red light when there is a possibility of going through a red light</td>
<td>Indicates remaining time till green light to promote prompt start to avoid excessive idling</td>
</tr>
</tbody>
</table>

ITS Connect Promotion Consortium

Government-Industry Partnership for V2X Coordination & Management

Board Members

Regular Members

Special Members

Government Agencies
National Police Agency
Ministry of Internal Affairs and Communications
Ministry of Economy, Trade and Industry
Ministry of Land, Infrastructure, Transport and Tourism

Industry Associations

About 12

https://www.itsconnect-pc.org/en/
Toyota’s Approach for Automated Driving

Human driver and vehicle systems support each other for safer and more efficient vehicular mobility.

Automated Highway Driving Assist
ITS World Congress (Detroit, 2014)

Driving Intelligence
Connected Intelligence
Interactive Intelligence

http://www.toyota-global.com/innovation/automated_driving/
Automated driving system uses signals from ADAS sensors

Automated Driving On-Board Sensors

Driver Assist On-Board Sensors

Vehicle & Pedestrian Pre-Collision System
Dynamic Radar Cruise Control
Lane Departure Alert
Auto High Beam

Toyota Safety Sense Lexus Safety System +

http://www.toyota-global.com/innovation/automated_driving/
http://www.toyota-global.com/innovation/safety_technology/toyota-safety-sense/
http://www.lexus.com/models/RX/packages#lexus-safety-system
Automated Highway Driving Assist – 2014 Demonstration

Safety enhancement with driving automation technologies

Driver Assist: On-Board Sensors

DRCC
Dynamic Radar Cruise Control

LTC
Lane Trace Control

Lateral and Longitudinal Control

Preview HMI

Driver Monitor HMI

Two-Way Driver-Vehicle Interaction

Integrated Safety
Infrastructure information for automation (map): an early alert about the road conditions where adequate support from the vehicle system may be limited.

A: Left Merge Preview
An uncommon merge from left is ahead

B: Exit Only Lane Preview
The AHDA vehicle needs to exit the highway if remains in this lane

C: Unsupported Scene Preview
Difficult to see lane markings by camera.

D: End of Highway Preview
The current highway ends.
Information from & about the road, traffic and other vehicles will enhance capabilities & performance of automated vehicle control systems.

V2X Communication

Automated Driving

Advanced Sensing

Better Driving Experience
Our goals are the same. We need each other. But… are we working together?

We have two sets of materials.

How should we set requirements for lane marker detection?

It is in Part 3 of MUTCD (90 pages). They are guidelines.

There are many faded lane markings. ("fix the road")

It is maintained based on our standards. ("make cars better")

It is a good time for us to work together.
What Vehicles can “See”

Sensing technologies have been improving significantly.

(sample images found through Google search “sensor image on-board car”)

http://spectrum.ieee.org/automaton/robotics/artificial-intelligence/how-google-self-driving-car-works

http://www.4erevolution.com/volvo-drive-me/

http://autonomos-labs.com/research/

http://www.linleygroup.com/mpr/article.php?id=11437

What Vehicles may not “See” well

There are still areas for improvements.

It cannot see it if it is not there.

https://www.fhwa.dot.gov/publications/research/safety/13048/004.cfm

It may not see everything


It may not see it if it is hard to see.


It may see something even it is not there.

And, also it is very dynamic…

Lane Detection and Tracking (https://www.youtube.com/watch?v=BadCBN48z1Y), Smartmicro 3DHD Automotive Radar (https://www.youtube.com/watch?v=QN87Bm-1KgE&list=PL52C8001562502C7D), Delphi Automotive Radar provided by AutonomouStuff (https://www.youtube.com/watch?v=OovcjSbbdBM)
Potential Areas for Collaborative Work

Personal thoughts...

Identify crash prevention countermeasures through crash causation and crash history studies?

Designate “auto drive capable” roads?

Avoid Smart Road – Smart Car Conflict

Joint Review of MUTCD?

Mapping Convention of Signs?

New Signs?


http://www.car-engineer.com/her PROVIDER OF REAL-TIME DIGITAL MAPS/
Summary

Vehicle Technology:
• Improvement of ADAS on-board sensor performance and availability enable enhancement of Advanced Driving Support Systems (ADAS) toward automated driving.
• V2X and data/map will serve as additional sensors.

Road-Vehicle Interaction:
• Inter-industry dialogue is essential for:
  – Ensuring good performance of vehicle systems on public highways
  – Avoiding potential conflict between smart cars and smart roads.
  – Setting roadmaps toward deployment of new technologies.
  – Sharing know-hows for improving traffic safety
• Talk between industry associations may be most efficient.
  – Than all OEMs trying to talk to all states separately.