Toyota’s Approach Toward the Realization of Sustainable Mobility

The 2008 Toyota Sustainable Mobility Seminar
September 23-24
Portland, Or

Chris Tinto - Vice President
Technical and Regulatory Affairs, Safety
Toyota Motor North America, Inc.
Toyota’s Approach Towards the Realization of Sustainable Mobility

• Agenda
  – Toyota’s Safety Approach
  – Intelligent Transportation Systems (ITS)
    • ITS – Safety
    • ITS – Environment
  – Summary
1. Safety
   Traffic accident

2. Environment
   Traffic Congestion, Environmental impact

3. Comfort
   Fun, Excitement, Comfort

“Minimize”

“Maximize”
Toyota’s Safety Approach
In Pursuit of Real World Safety

Accident Investigation/Analysis

Development/Evaluation  Computer Simulation/Analysis

Toyota Safety
Toyota Safety

Passive Safety

Energy Absorbing Body Structure

Occupant Restraint System

GOA (1995)

Seat belt with pre-tensioner & force limiter (1997)

SRS Curtain shield airbag (1998)

SRS Knee airbag (2002)
Toyota Safety

Passive Systems

LS460 (2007)

Passenger Twin-Chamber Airbag

IS250/350 (2006)
Toyota Safety

Active Systems

Vehicle Stability Enhancement

Accident Avoidance
Operation Support / Control

ABS (1971)
TRC (Traction control) (1987)
VSC (1995)
Pre-crash Safety (2003)
Toyota Safety

Active Systems – Evolution of Vehicle Dynamic Control System

VDIM: Vehicle Dynamics Integrated Management

+Steering Control

Vehicle Dynamics Integrated Management

VSC

TRC

ABS

Stand Alone Control

VDIM: Vehicle Dynamics Integrated Management

Saftey & Fun to drive
Toyota Safety

Pre-Crash Systems – Evolution

2004 Lexus LS430
(2003 Harrier in Japan)

Front
Millimeter-wave radar
Toyota Safety

Pre-Crash Systems – Evolution

2006 Lexus LS460
(2004 Crown Majesta in Japan)

Front camera

2004 Lexus LS430
(2003 Harrier in Japan)

Front Millimeter-wave Radar

Improved Warning & Control
Toyota Safety

Pre-Crash Systems – Evolution

2006 Lexus LS460 (2004 Crown Majesta in Japan)

Front Camera

2004 Lexus LS430 (2003 Harrier in Japan)

Front Millimeter-wave Radar

Lexus LS460/600H (2006 Lexus GS450h in Japan)

Driver monitoring camera

Improved Warning & Control
Toyota Safety

Pre-Crash Systems – Evolution

2006 Lexus LS460
(2004 Crown Majesta in Japan)

Front Camera

2004 Lexus LS430
(2003 Harrier in Japan)

Front Millimeter-Wave Radar

2006 Lexus LS460 (Japan)

Front Stereo Camera
Rear Millimeter-Wave Radar

Detection of Pedestrian
Evolution to Omni-Directional Detection & Higher Level

‘08 Lexus LS460/600H
(2006 Lexus GS450h in Japan)
Toyota Safety

All Driving Stages

Integration and Cooperation of Safety Systems

Integrated Safety Management Concept
Toyota Safety

Integrated Safety Management Concept

Recognition

Driver’s Condition (drowsy, etc.)

Vehicle Condition (Vehicle behavior)

Traffic Environment (Inter-vehicle distance, pedestrians, etc.)

Judgment

DSS computer

DSS: Driver Support System

Action

Driver Alert (Displays, sounds, vibrations, etc.)

Vehicle Control Support

Traffic Environment (Communication, lights, sounds, etc.)
Toyota Safety

Integrated Safety Management Concept

- Wheel speed sensor (on each wheel)
- Brake pressure sensor
- Stereo camera
- Yaw rate and acceleration sensor
- Steering angle sensor
- DSS (Driver Support System) ECU
- Driver-monitoring camera
- Brake pedal stroke sensor
- Millimeter-wave radar

Recognition

- Wheel speed sensor (on each wheel)
- Steering torque sensor
- Rear millimeter-wave radar

Toyota Safety Integrated Safety Management Concept Recognition
To demonstrate this concept, Toyota has identified the following components:

- **Wheel speed sensor** (on each wheel)
- **Brake pressure sensor**
- **Stereo camera**
- **Yaw rate and acceleration sensor**
- **Steering angle sensor**
- **Brake pedal stroke sensor**
- **Millimeter-wave radar**
- **DSS (Driver Support System) ECU**
- **Driver-monitoring camera**
- **Rear millimeter-wave radar**
- **Steering torque sensor**

In summary, Toyota’s Integrated Safety Management Concept Judgment includes these components to enhance safety and support the driver.
Stereo camera
Yaw rate and acceleration sensor
Steering angle sensor
DSS (Driver Support System) ECU
Driver-monitoring camera
Brake pedal stroke sensor
Millimeter-wave radar

Pre-crash Intelligent Headrest
Pre-crash Seatbelt
Suspension control
Steering control (VGRS)
Electric power steering
Brake actuator

Toyota Safety
Integrated Safety Management Concept Action

Toyota Safety Integrated Safety Management Concept Action
Toyota Safety

Pre-Crash Systems

Driver assistance through recognition technology

An Earlier Warning Becomes Possible for the Driver

Danger ↔ High Danger ↔ Unavoidable Collision

With Face Direction Sensor

Warning (When looking away)

Warning Brake

Intervention
Warning
Suspension
Brake Assist
Seat belt

With Stereo Camera

Warning (When looking away)

Warning Brake

Intervention
Warning
Suspension
Brake Assist
Seat belt
Steering Assist
Toyota Safety

Pre-Crash Systems – Demonstration

ENHANCED PRE-CRASH SAFETY SYSTEM
Toyota Safety
Rescue Systems

Automatic Notification upon Airbag Deployment
Toyota Safety
Integrated Management Safety Concept

Collision

Parking
- Reduction of driving burden
- Rader cruise control
- PA, IPA (Parking Assist, Intelligent Parking Assist)
- G-Book

Active Safety
- Accident avoidance operation support/control
- Vehicle distance alarm
- Lane Keeping Assist
- Lane-deviation alarm
- VDIM, BA (Brake Assist)
- Network linked Navigation system
- Blind corner monitor

Pre-crash Safety
- Damage reduction
- Pre-crash Safety System
  - PC-BA, PC-VGRS (Pre-crash Brake Assist, Pre-crash Variable Gear Ratio Steering)
- VSC, ABS (Anti-lock Brake System)

Passive Safety
- Passenger safety
- Seatbelts, airbags
- GOA (Global Outstanding Assessment)

Rescue
- HELPNET/Lexus Link
- Vehicle Infrastructure Cooperative Systems

GOA (Global Outstanding Assessment)
ITS Safety

Autonomous Safety Systems and Vehicle-Infrastructure Cooperative Systems

- Autonomous safety systems
- Vehicle-Infrastructure Cooperative Systems that support safe driving
- Increased awareness of people

Accident reduction

≈ 20XX
Vehicle’s and Driver’s Eyes

“Clairvoyance”

i.e. The power to perceive things that are not present to the senses

Autonomous Cooperative
In-vehicle signage (curve ahead, etc)

Off-board navigation completes on-board maps

Electronic payments for parking, gasoline, and toll roads

Traveler information (work zones, travel times, etc)

Infer travel times, volumes, etc from probe data for corridor planning assist and load balancing

Pothole detection

In-vehicle signage (curve ahead, etc)

Network management and probe data collection

Wireless communication (DSRC)

Stop sign violation warning

Traffic signal violation warning

Electronic payments for parking, gasoline, and toll roads

Lead vehicle emergency brake warning

Ramp metering

Signal timing optimization

Curve speed warning

Weather information (traveler notification, improved forecasting, winter maintenance, etc)

Road-Side Unit

Application type legend:

Safety

Mobility

Commercial

Network management and probe data collection

(*) VII program is sponsored by US DOT

References: "VII POC Applications Concept of Operations" document

TODAY for TOMORROW
ITS Safety
Effects of Vehicle-Infrastructure Cooperative Systems

Autonomous safety systems
Vehicle-Infrastructure Cooperative Systems that support safe driving

Reduction of deaths and injuries

Frontal collisions
Rear-end collisions
Solo vehicle accidents
Accidents at intersections
Accidents involving motorcycles/motorbikes
Accidents involving bicycles
Accidents involving pedestrians
ITS Safety

Communication Sensors

V-I System
- Road-sensing data unit
- Vehicle/Pedestrian recognition

V-I System
- Traffic control unit
- Light/Restriction recognition

V-V System
- Communication unit
- Hazardous vehicle recognition

Communication sensors

Situation recognition
ITS Safety
Vehicle-Infrastructure Cooperative System

Demonstration at Higashi-Fuji Technical Center
ITS Safety
Vehicle-Infrastructure Cooperative System – Vehicle to Vehicle
ITS Safety
Vehicle-Infrastructure Cooperative System – Vehicle to Infrastructure

- Detects pedestrian on crosswalk and warns car that is turning left
- Prevents collision with an oncoming vehicle
- Early lane change based on information about fallen object
ITS Safety

Vehicle-Infrastructure Cooperative System – Vehicle to Infrastructure

Smooth parking space search with help of parking lot information

Information Center
- Receives and transmits information on road conditions, public transit, information and parking lots
- Provides departure times for available trains based on estimated time of arrival at station

Receives traffic congestion information and takes a left-turn detour
Government-Industry Collaboration

DSSS Project (with National Police Agency)

Location: Toyota City, Japan
5 Dangerous Intersections
Vehicles: 100 Vehicles
(50 are equipped with IR-DSRC)

Phase 1: Warning Only

- Signal Violation
- Stop Sign Violation

Phase 2: Control Intervention

May be in Tokyo with OEMs
Government-Industry Project
Ministry of Land, Infrastructure and Transport & 14 OEMs (cars, trucks, motorcycles)

Inter-OEM Validation of V-V Safety Applications

- Common: Communication Media & Messages, Scenarios
- OEM-Unique Implementation, HMI, Algorithms

- Stop Sign Movement Assist
- Pedestrian Present
- Blind Spot Warning
- Lane Change Assist
- On-Coming Vehicle Warning

ITS Safety
Vehicle-Infrastructure Cooperative System Programs – ASV Project (Japan)
### ITS Safety

**U.S. Department of Transportation (DOT) ITS Projects**

<table>
<thead>
<tr>
<th>Year</th>
<th>98-04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
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<th>10</th>
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<th>16-20</th>
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<tbody>
<tr>
<td></td>
<td>5.9GHz DSRC allocation by FCC</td>
<td>World Congress on ITS (NY)</td>
<td>ITS World Congress (NA)</td>
<td>ITS World Congress (NA)</td>
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<td><strong>Major Projects</strong></td>
<td>Congestion Mitigate Initiative</td>
<td>IVBSS</td>
<td>SHRP-2</td>
<td>700MHz Re-allocation</td>
<td>NG911</td>
<td>Clarus</td>
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<td>US DOT VII Program</td>
<td>SAFE-TRIP21?</td>
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<tr>
<td><strong>CAMP</strong></td>
<td>CICAS-V</td>
<td>VSC-A</td>
<td>VSC-A (2)</td>
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**Note:**
- **SAFETEA-LU**: Safe Highways and Transit Investment Act of 2003
- **TEA-21**: Transportation Equity Act for the 21st Century
- **SHRP-2**: Strategic Highway Research Program 2
- **NG911**: Next Generation 911
- **CICAS-V**
- **VSC-A**: Vehicle Source Control Area

**Acronyms:**
- **CAMP**: Coordinated Approach to Making Products
- **POC**: Performance-Oriented Contracting
- **CICAS-V**: Coordinated Intelligent Critical Areas System
- **VSC-A**: Vehicle Source Control Area
- **SAFE-TRIP21**: Safe and Efficient Transportation Program for the 21st Century

**Image Source:**
- [Toyota ITS Project Diagram](#)
Public-Private Projects for Cooperative ITS Systems

USDOT’s RITA and automakers are conducting POC tests to assess 5.9GHz DSRC for V-I by using a network in Michigan.

Test item example:
- Signal Violation Warning
- Traveler Information
- Electronic Toll System etc

RITA will summarize the test result as part of its ‘Viability Assessment’ in late 2008.

Consortium Participants: GM, Ford, Chrysler, Mercedes, VW, BMW, Toyota, Honda, Nissan (9)
R&D for Technological Proof Test of Cooperative Signal Violation Warning

This application provides geometric data and signal phase info to vehicles via 5.9GHz DSRC and warns the vehicle when a possible violation is detected.

Proving the functionality of V-I communications via 5.9GHz DSRC within CICAS-V–enabled intersections in MI.

Next Step: a full-scale field test will be conducted later than this Fall.

CAMP Participants: GM, Ford, Mercedes, Toyota, Honda
ITS Safety

Test Scenarios

Traffic Signal Violation

Stop Sign Violation

Vehicle & Pedestrian Present

V-I Video Share
Potential Casualty Reductions with Cooperative Safety Systems

Towards “Minimize”

Passive Safety

Autonomous Systems

Vehicle-Infrastructure Cooperative Systems
ITS Environment
ITS Environment

Relationship between Travel Speed and Exhaust Emissions

CO₂ emissions
(CO₂ emissions ratio)

Base value for emissions at 10 km/h is 100

100
80
60
40
20
0
10km/h 30km/h 60km/h
(Traveling speed)

NOx emissions
(NOx emissions ratio)

Base value for emissions at 10 km/h is 100

100
80
60
40
20
0
10km/h 30km/h 60km/h
(Traveling speed)

*Speed measured in a state close to actual traveling conditions
Source: Japan Automobile Research Institute

TODAY for TOMORROW

TOYOTA
Traffic Flow Improvement (examples)

1. Smoother Flow
   Causes: Delayed start at intersection
   - Merging bottleneck
   - Lane departure / passing other vehicles
   - Congestion at ‘sag’ points
   Measure: Assist driver with smooth operation

2. Density Management
   Causes: staggered driving
   Measure: Running in line by ACC, forming a ‘group’

3. Crowd Dispersion
   Causes: Temporarily crowded area / time / season
   Measure: Provide traffic information to vehicle, with “TDM”

“TDM”: Traffic Demand Management
ITS Environment
Probe Technology

- Traffic Regulation
- Smoothness
- Accident
- Parking Info.
- Weather Info.
- Traffic Jam
- Skid Info.

Probe Information Center

Monitor Display

TODAY for TOMORROW
ITS Environment

Probe Technology
Summary
Summary

Minimize (Safety & Environment)

Maximize (User-friendliness)

Safety Systems

Passive Safety  Active Safety

Vehicle-Infrastructure Cooperative System

Sustainable Mobility

Probe Information System

Evolution I

201X ~

Evolution II

Integrated HMI

Navigation Cooperation

Car Navigation

Information and Telecommunication System

TODAY for TOMORROW
Summary

The 15th ITS World Congress Exhibitions and Demonstrations

http://www.itsworldcongress.org/about-world-congress.html

VII Bus Tours: Focus on Infrastructure-based demo (Test bed & the future Transportation Management Center (TMC))

Participants take a trip around the Center and experience cooperative demo on a closed public road (bus sends probe data to TMC)

11th Avenue Theater

Demonstrations by 6 automakers (Toyota will join)

11th Avenue Theater Participating OEMs: GM, Daimler, VW, Toyota, Nissan, Honda
Thank you for your attention!
ITS Environment

CO₂ and NOₓ emission reduction by congestion improvement

CO₂ Emission

<table>
<thead>
<tr>
<th>Average Vehicle Speed</th>
<th>CO₂ Emission Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>10km/h</td>
<td>100</td>
</tr>
<tr>
<td>20km/h</td>
<td>80</td>
</tr>
<tr>
<td>30km/h</td>
<td>60</td>
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</tbody>
</table>

NOₓ Emission

<table>
<thead>
<tr>
<th>Average Vehicle Speed</th>
<th>NOₓ Emission Index</th>
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</thead>
<tbody>
<tr>
<td>10km/h</td>
<td>100</td>
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<tr>
<td>20km/h</td>
<td>90</td>
</tr>
<tr>
<td>30km/h</td>
<td>80</td>
</tr>
</tbody>
</table>

Source: JARI
ITS Safety

Casualty Reduction with Cooperative Safety Systems

Autonomous

Cooperative

Casualties

Frontal Collision  Rear-end Collision  Single Car  Intersection  Motorcycle  Bicycle  Pedestrian

Education, Road Maintenance
The world’s first 5.9GHz DSRC infrastructure is deployed for VII projects.

VII POC created a common foundation for 5.9GHz DSRC cooperative infrastructure. Demonstrations utilizing this framework are expected during the 2008 ITS World Congress in New York.
ITS Safety

DOT ITS Projects – VII System at a Glance

Cooperative ITS Services (VII Applications)
- WiFi
- Cell Phone Network
- Satellite

VII Operation Center
- ITS Network
- Telematics Service Providers
- Traffic Management Center
- VII Operation Center
- VII Public Applications
- Payment System
- POC Test
- DSRC Mobility
- V-I
- Traffic Management Center
- VII Private Businesses
- VII Coalition
- VII Consortium
- CICAS-V
- CAMP VSC-2 Consortium

System R&D and Testing
- VII Architecture
- VII Network
- Interoperability among mobility applications

Business Deployment
- VII business Model
- VII Operation
- Partnership with related entities

Technological R&D and Testing
- Standardizing System Specifications
- DSRC Communications Protocol
- Interoperability among safety applications
“Minimize” symbolizes the vision and philosophy of our persistent efforts to minimize the negative aspects vehicles may have, such as traffic accidents, traffic congestion and environmental impact.
Toyota Safety

Active Systems – Direction

- Supports Series of Driver Behaviors as Much as Possible
- Attempts to Prevent Drivers from Approaching Critical Conditions

Monitoring of Surroundings
Omni-directional supervision / Driver monitor

Error types in Accidents with Injury

N = 825,683 persons
Source: 2002 ITARDA

Vehicle Infrastructure Cooperation System

Recognition
Action
Judgment

Driving support by autonomous system
Driving support by vehicle & road cooperation

Vehicle Dynamics Control
VSC・VDIM

Accident Avoidance Support
Pre-crash safety
# Toyota Safety
## Integrated Management Safety Concept

<table>
<thead>
<tr>
<th>Parking</th>
<th>Active Safety</th>
<th>Pre-crash Safety</th>
<th>Passive Safety</th>
<th>Rescue</th>
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</thead>
<tbody>
<tr>
<td>Reduction of driving burden</td>
<td>Accident avoidance operation support/control</td>
<td>Damage reduction</td>
<td>Passenger safety</td>
<td>Rescue</td>
</tr>
<tr>
<td>Rader cruise control</td>
<td>Vehicle distance alarm</td>
<td>Lane-deviation alarm</td>
<td>Pre-crash Safety System</td>
<td>Rear-end Pre-crash Safety System</td>
</tr>
<tr>
<td>PA, IPA (Parking Assist, Intelligent Parking Assist)</td>
<td>Lane Keeping Assist</td>
<td>VDIM, BA (Brake Assist)</td>
<td>PC-BA, PC-VGRS (Pre-crash Brake Assist, Pre-crash Variable Gear Ratio Steering)</td>
<td>VSC, ABS (Anti-lock Brake System)</td>
</tr>
<tr>
<td>G-Book</td>
<td>Blind corner monitor</td>
<td>Network linked Navigation system</td>
<td>Vehicle Infrastructure cooperation system</td>
<td>GOA (Global Outstanding Assessment)</td>
</tr>
<tr>
<td>Back guide monitor</td>
<td>Vehicle distance alarm</td>
<td>Lane-deviation alarm</td>
<td>Pre-crash Brake Assist, Pre-crash Variable Gear Ratio Steering</td>
<td>HELPNET/Lexus Link</td>
</tr>
</tbody>
</table>

**Safety Features:**
- Pre-crash Safety System
  - PC-BA, PC-VGRS
  - Rear-end Pre-crash Safety System
  - VSC, ABS
  - Vehicle Infrastructure cooperation system
- Passive Safety
  - Seatbelts, airbags
  - GOA (Global Outstanding Assessment)
- Rescue
  - HELPNET/Lexus Link

**Other Features:**
- Rader cruise control
- Lane Keeping Assist
- Lane-deviation alarm
- Blind corner monitor
- Network linked Navigation system
- Vehicle Infrastructure cooperation system
- GOA (Global Outstanding Assessment)
- HelpNet/Lexus Link