Seminar #294: Transforming Transportation Through Connectivity

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Seminar #294:
Transforming Transportation Through Connectivity

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Inspired by Berkeley’s *Transportation Science Seminar*, originated by G.F. Newell, 1965

First seminar October 5, 2000, *Benefits of Archived ITS Data: Measuring Capacity at a Freeway Bottleneck*

Venue for student/faculty interaction

Strong involvement of transportation community
Transport Challenges

Safety
- 34,080 fatalities in 2012
- 1.10 fatalities per 100 MVMT in 2011
- 2.2 M injuries in 2011
- 5.3 M crashes in 2011
- $230 B total cost (including medical)
- Leading cause of death for ages 4 to 34

Accessibility, Reliability and Mobility
- 4.8B hours travel delay
- $115 billion cost of urban congestion

Household Market Basket
- Second biggest monthly expense, after housing

Sustainability
- 28% of GHG emissions (78% CO, 58% NO\textsubscript{x}, 36% VOCs)
- 29% of energy consumed (mostly petroleum)
- 70% of petroleum consumption (60% imported)
- 3.9 billion gallons of wasted fuel
- Half of Americans live in areas that exceed air quality standards for at least one pollutant.
## Evolution of U.S. ITS Program

<table>
<thead>
<tr>
<th>Congressional Legislation</th>
<th>Dates and Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Research and Development</td>
</tr>
<tr>
<td></td>
<td>- Operational Tests</td>
</tr>
<tr>
<td></td>
<td>- Technical assistance including architecture and standards</td>
</tr>
<tr>
<td></td>
<td>- Policy and Institutional Challenges to Deployment</td>
</tr>
<tr>
<td></td>
<td>- ITS Deployment Program (Congressionally designated)</td>
</tr>
<tr>
<td></td>
<td>- Model Deployment Initiatives</td>
</tr>
<tr>
<td></td>
<td>- Research</td>
</tr>
<tr>
<td></td>
<td>- Mainstreaming ITS</td>
</tr>
<tr>
<td><strong>Moving Ahead for Progress in the 21st Century (MAP-21)</strong></td>
<td>2012-2014</td>
</tr>
</tbody>
</table>
Deployed Technologies

- CCTV Cameras
- Traveler Information
  - DMS ~90% of freeways
  - Social Networking 40%
  - HAR 60%
  - Subscription 35%
  - Web 90%
  - Email 50%
  - Phone 20%
  - 511 70%
- Electronic Toll Collection
- Ramp Control
- Sensors/Loops
- Automated Enforcement
- Lane Management
- Archived Data
- Probe Vehicles
ITS By the Numbers

- **Years**: 20+
- **Funding**: $3B federal + $18B by 75 top metro areas
- **Market**: $48B ITS end-use products and services
- **Federal Programs**: 3 (ISTEA, TEA21, SAFETEA-LU)
- **Electronic Toll Collection**: 99% of plazas/94% of lanes
- **Transit Automatic Vehicle Location**: 77% of 117 fixed route bus agencies
- **Transit Smart Cards**: 16,000+ buses/451 rail stations
- **Commercial Vehicle Electronic Screening**: 40 states/360 weigh stations/70,000 companies/500,000 trucks
- **Professional Capacity Building**: 2,500 participants in 2010
- **Standards Participation**: 106 published since 1995
- **Traffic Management Centers**: 266
- **Freeway Miles Under Surveillance**: 7,700 roadside/4,500 probe vehicles/54% of freeways in 75 metropolitan areas
- **Arterial Miles Under Surveillance**: 2,500 roadside/1,700 probe vehicles/50% of intersections in 75 metropolitan areas
- **511 Coverage**: All or part of 38 states (70% of population)
- **Dynamic Message Signs**: 4,200/109 freeway management agencies post information/36 of 40 metro areas post travel times
Intelligent Vehicle in 1990

- 1990 Honda Accord
  - Automatic shoulder belts
  - CD player
  - No ABS or airbags
  - EPA 19 mpg city, 26 mpg highway (combined 22 mpg)
- San Francisco – emphasis on earthquake safety
Intelligent Vehicle in 2014

- 2014 Ford Focus
  - $21,900
  - EPA Rating 22 City/34 Highway
  - Adaptive Cruise Control with Forward Collision Warning
  - Blind Spot Information System (BLIS) with Cross-Traffic Alert
  - Rear View Camera
  - Lane-Keeping System
  - Active Park Assist
  - 911 Assist
  - Traffic Sign Recognition
  - Driver Alert
  - Pedestrian Alert Kit and Active City Stop
Data Revolution

From a desert…

…to an ocean!
Data is Power

SOURCES

TRAVELER
- LOCATION
- DECISIONS

VEHICLE
- TRANSIT
- LIGHT VEHICLE
- FREIGHT

INFRASTRUCTURE
- LOOP
- RADAR
- OTHER

USES

ECO-DRIVE

ENVIR.

MOBILITY

VARIABLE SPEED LIMITS

SAFETY

PERFORMANCE MEASUREMENT

TRAVELER INFORMATION

QUEUE WARNING

OTHER

CURRENT STATE

TRAVELER
- "nearly zero"

VEHICLE
- "a few"

INFRASTRUCTURE
- "some"

POTENTIAL END STATE

TRAVELER
- "some"

VEHICLE
- "nearly all"

INFRASTRUCTURE
- "where needed"
Data Environment Evolution

Current State
- TRAVELER: "nearly zero"
- VEHICLE: "a few"
- INFRASTRUCTURE: "some"

Potential Interim States
- TRAVELER
- VEHICLE: "nearly all"
- INFRASTRUCTURE: "where needed"

Potential End State
- TRAVELER: "some"
- VEHICLE
- INFRASTRUCTURE
Connected vehicles can help.

They use wireless communication between vehicles and infrastructure to help prevent crashes, make travel easier, and curb pollution.
All vehicles, regardless of type, will communicate with each other using a wireless technology called Dedicated Short-Range Communications (DSRC).
Connected vehicles have the potential to address up to 81% of unimpaired crash scenarios.
Connected vehicles will provide drivers with warnings to help them avoid crashes.
Imagine your car informing you of available parking on the next block, your cell phone telling you a cab or bus or train is approaching, or your car helping you find a rideshare partner.
Consider the ways in which increased travel information can help the environment. Connected vehicles can help.

http://www.youtube.com/watch?v=Zuf2VNWGMnY
What is DSRC?

- “Dedicated Short Range Communications”
- Short to medium range communications service
- FCC authorized spectrum at 5.9 GHz for safety applications in 1999
- Europe allocated 5.9 GHz and Japan uses the 5.8 GHz
- Key ingredients: **standardization** and **interoperability**
- Other applications and other wireless technologies can be accommodated
- Older DSRC systems such as toll tags operate at 900 MHz: no standard, several proprietary systems are in place
- Both vehicle to infrastructure and vehicle to vehicle communication environments
- **Complementary** to cellular communications
- Very high data transfer rates & minimal latency
- Range up to 1000 m
- Data Rate – 6 to 27 Mbps
- Channels – 7 Licensed Channels
Communications Technologies

Latency in seconds

<table>
<thead>
<tr>
<th>Communications Technologies</th>
<th>Latency (in seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial Digital Radio &amp;</td>
<td>WiFi 802.11 (3–5 sec)</td>
</tr>
<tr>
<td>Satellite Digital Audio Radio</td>
<td>Cellular (1.5 – 3.5 sec)</td>
</tr>
<tr>
<td></td>
<td>WiMax (1.5 – 3.5 sec)</td>
</tr>
<tr>
<td>Two-Way Satellite</td>
<td>(60+ sec)</td>
</tr>
<tr>
<td>5.9 GHz DSRC</td>
<td>(0.0002 sec)</td>
</tr>
</tbody>
</table>

Active Safety Latency Requirements (sec)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Latency (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Signal Violation Warning</td>
<td>0.1</td>
</tr>
<tr>
<td>Curve Speed Warning</td>
<td>1.0</td>
</tr>
<tr>
<td>Emergency Electronic Brake Lights</td>
<td>0.1</td>
</tr>
<tr>
<td>Pre-Crash Sensing</td>
<td>0.02</td>
</tr>
<tr>
<td>Cooperative Forward Collision Warning</td>
<td>0.1</td>
</tr>
<tr>
<td>Left Turn Assistant</td>
<td>0.1</td>
</tr>
<tr>
<td>Lane Change Warning</td>
<td>0.1</td>
</tr>
<tr>
<td>Stop Sign Movement Assistance</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Least Stringent Latency Requirement for Active Safety (1.0 sec)

Most Stringent Latency Requirement for Active Safety (0.02 sec)

Note: y-axis not to scale for illustration purposes
Data source: Vehicle Safety Communications Project – Final Report
Original Vision

Vehicles

Infrastructure
Vision for Connected Future

Drivers and Operators

Rail

Maritime

Vehicles and Fleets

Wireless Devices

Infrastructure
Vision for Connected Future

Drivers and Operators

Rail

Maritime

Vehicles and Fleets

Wireless Devices

Infrastructure
Multi-modal surface transportation system—connectivity as its core.
Vehicles (cars, trucks, buses, fleets of all kinds) ↔ Drivers and operators ↔ Infrastructure ↔ Mobile Devices
Leverage technology to maximize safety, mobility and the environment—enabled through wireless communications—in all modes.
First priority is safety: crash and injury prevention (80% of crash scenarios).
Solutions for 80% of Crashes

- Rear End Warning 28%
- Lane Departure 23%
- Intersection 25%
- Lane Change 9%
- Opposite Direction 2%
- Backover 2%

SAE J2735 Basic Safety Message

- Temporary ID
- Time
- Latitude
- Longitude
- Elevation
- Speed
- Heading
- Acceleration
- Brake System Status
- Vehicle Size
“Here I Am” / Where’s My Bus/Carpool?

“Here I Am” / What is the Fastest Route to my Delivery Point

latitude, longitude, time, heading angle, speed, lateral acceleration, longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, headlight status, wiper status, external temperature, turn signal status, vehicle length, vehicle width, vehicle mass, bumper height

“Here I Am” / I am Full
Safety Pilot 2011-2013

- Major field test and real world implementation
  - Multiple vehicle types: cars, fleets, trucks, buses
  - Fully integrated systems & aftermarket devices
  - Prototype security mechanisms
  - Certification processes
- Goals
  - Support real world V2V & V2I applications with data rich environment
  - Establish benefits data in support of NHTSA 2013 Agency Decision
  - Public awareness & determine user acceptance
- Outcomes
  - Benefits and user acceptance data for supporting future federal actions
  - Archived road network data for supporting mobility, environmental, and other research
  - Multiple supplier sources for devices and infrastructure
  - Better understanding of the operational policy issues associated with the deployment of V2V and V2I
Safety Pilot – 2836 Vehicles

V2V
Forward Collision Warning
Emergency Electronic Brake Light
Intersection Movement Assist
Blind Spot Warning/Lane Change Warning
Do Not Pass Warning
Left Turn Across Path/Opposite Direction
Right Turn in Front

V2I
Signal Phase and Timing
Curve Speed Warning
Railroad Crossing Warning
Pedestrian Detection

Informed NHTSA Decision February 2014
# Model Deployment Fleet

<table>
<thead>
<tr>
<th>Connected Vehicle Device</th>
<th>Vehicle Type</th>
<th>Vehicle Source</th>
<th>Total Units in Model Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Devices</td>
<td>Light Vehicles</td>
<td>CAMP</td>
<td>64</td>
</tr>
<tr>
<td>Integrated Devices</td>
<td>Commercial Trucks</td>
<td>Battelle Team</td>
<td>3</td>
</tr>
<tr>
<td>Vehicle Awareness Devices</td>
<td>Light Vehicles</td>
<td>UM, Ann Arbor</td>
<td>2200</td>
</tr>
<tr>
<td>Vehicle Awareness Devices</td>
<td>Local Truck Fleets</td>
<td>Con-Way, Arbor Springs</td>
<td>50</td>
</tr>
<tr>
<td>Vehicle Awareness Devices</td>
<td>Heavy Duty</td>
<td>University Fleet</td>
<td>100</td>
</tr>
<tr>
<td>Vehicle Awareness Devices</td>
<td>Transit Vehicles</td>
<td>AATA</td>
<td>100</td>
</tr>
<tr>
<td>Aftermarket Safety Devices</td>
<td>Light Vehicles</td>
<td>UM, Ann Arbor</td>
<td>300</td>
</tr>
<tr>
<td>Retrofit Devices</td>
<td>Local Truck Fleets</td>
<td>Con-Way, Sysco</td>
<td>16</td>
</tr>
<tr>
<td>Retrofit Devices</td>
<td>Transit Vehicles</td>
<td>UM Buses</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>2836</strong></td>
</tr>
</tbody>
</table>
Vehicle Examples

Fully Integrated Safety Devices (ISD)
- 64 cars
- 3 trucks

Vehicle Awareness Device (VAD)
- 2200 cars
- 150 trucks
- 100 buses

Retrofit Safety Devices (RSD)
- 16 trucks
- 3 buses

Aftermarket Safety Device (ASD)
- 300 cars
Mobility Program

Real-time Data Capture & Management

- Vehicle Status Data
- Weather Data
- Truck Data
- Transit Data
- Infrastructure Status Data
- Location Data

Data Environment

Mobility Applications

- Enable Advanced Traveler Information System (Enable ATIS)
- Response Emergency Staging & Communication Uniform Management & Evacuation (RESCUME)
- Multimodal Intelligent Traffic Signal Systems (MMITSS)
- Freight Advanced Traveler Information System (FRATIS)
- Intelligent Network Flow Optimization (INFLO)
- Integrated Dynamic Transit Operations (IDTO)

- 65 mph
- Brakes on...
- Two passengers...
High Priority Mobility Applications

Legend:
- DMA PROGRAM FUNDED
- DMA SUPPORTED (NOT FUNDED), OPEN TO OTHER PROGRAMS AND RESEARCHERS

*JOINTLY FUNDED BY DMA AND PUBLIC SAFETY PROGRAMS
Dynamic Mobility Applications

- Enable Advanced Traveler Information System (EnableATIS)
- Freight Advanced Traveler Information Systems (FRATIS)
- Integrated Dynamic Transit Operations (IDTO)
- Intelligent Network Flow Optimization (INFLO)
- Multi-Modal Intelligent Traffic Signal Systems (MMITSS)
- Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.)
AERIS Program

- Low Emission Zone
- Eco-integrated Corridor Management
- Eco-Signal Operations
- Eco-Lanes
- Support Alternative Fuel Vehicle Operations
- Eco-Traveler Information
Multimodal Data Set for Portland Oregon Region
Test Data Set for the FHWA Connected Vehicle Initiative
Real-Time Data Capture and Management Program

The Portland State University Multimodal Test Data Set submitted on this web site consists of Freeway, Transit and Arterial data for the I-205 Corridor in Portland, Oregon. The selected corridor ranges along the I-205 Freeway from Sunnyside Road near Interstate 5 to the end of the extension, near the Oregon/Washington State line. The Grater Portland Transportation Council's (GPTC)'s Connected Vehicle Test Data Set includes access to two arterials, the I-205 Freeway and I-5 Freeway. Data, which is available in the data set summary. The data set contains Freeway Loop Detector data, weather data, incident data, arterial coordinate data, and traveler data. The data set also includes data from the two arterials in the selected corridor. Freeway I-205 is the major north-south Freeway in the corridor and 82nd Avenue is the primary north-south arterial. Transit service consists of routes running along and across 82nd Avenue and major arteries that run along the I-205 Freeway. The data set provides a two-month multimodal data set for use in testing Connected Vehicle Applications.

**Arterial**
- **Documentation**
  - Arterial Data Documentation.pdf
  - 82nd Avenue Timing Plans.xlsx
- **Data**
  - ArterialData.zip
  - ArterialPhaseTimingData.zip

**Freeway**
- **Documentation**
  - Freeway Data Documentation.pdf
  - RefillWaterFlowChart.xlsx
  - AggregationAnalysis.pdf
- **Data**
  - IncidentWeatherData.zip
  - FreewayData.zip

**Transit**
- **Documentation**
  - Transit Data Documentation.pdf
- **Data**
  - TransitBusData.zip
  - TransitLightRailData.zip
Autonomy vs. Cooperation

Degree of autonomy

- Autonomous Unmanned Military Vehicles
- Autonomous Adaptive Cruise Control
- Platooning
- Automated Highway Systems (AHS)

Information/Warning

- Autonomous Warning Systems
- Electronic Emergency Brake Light
- Cooperative Collision Warning System

Control

- Intelligent Speed Adaption
- Intersection Movement Assist

Degree of cooperation

Key: Indicates DOT focus application for connected vehicles
# Levels of Automation

<table>
<thead>
<tr>
<th>NHTSA level</th>
<th>SAE level</th>
<th>SAE name</th>
<th>SAE narrative definition</th>
<th>Execution of steering and acceleration/deceleration</th>
<th>Monitoring of driving environment</th>
<th>Backup performance of dynamic driving task</th>
<th>System capability (driving modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Non-Automated</td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Assisted</td>
<td>the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Partial Automation</td>
<td>the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automated driving system (“system”) monitors the driving environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Conditional Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>High Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Full Automation</td>
<td>the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>
Autonomy + Connectivity

Sensor-Based Solution Only
- Cannot sufficiently mimic human senses
- Not cost-effective for mass market adoption
- Lack of adequate 360° mapping of environment in urban grids

Connected Vehicle Solution Only
- DSRC does not currently work with pedestrians, bicyclists, etc.
- DSRC-based V2I might require significant infrastructure investment
- V2V requires high market penetration to deliver value reliably

Converged Solution
- Convergence will facilitate adequate mimicking of human senses
- Convergence will reduce need for an expensive mix of sensors and reduce the need for blanket V2I investment
- Convergence will provide the necessary level of functional redundancy to ensure that the technology will work 100 percent of the time
Predictions

- 2015: Audi plans to market vehicles that can autonomously steer, accelerate and brake at lower speeds, such as in traffic jams.
- 2015: Cadillac plans vehicles with "super cruise": autonomous steering, braking and lane guidance.
- 2015: Nissan expects to sell vehicles with autonomous steering, braking, lane guidance, throttle, gear shifting, and, as permitted by law, unoccupied self-parking after passengers exit.
- Mid-2010’s: Toyota plans to roll out near-autonomous vehicles dubbed Automated Highway Driving Assist with Lane Trace Control and Cooperative-adaptive Cruise Control.
- 2016: Tesla expects to develop technology that operates autonomously for 90 percent of distances driven.
- 2018: Google expects to release their autonomous car technology.
- 2020: Volvo envisages having cars in which passengers would be immune from injuries.
- 2020: Mercedes-Benz, Audi, Nissan and BMW all expect to sell autonomous cars.
- 2025: Daimler and Ford expect autonomous vehicles on the market.
Policy Issues

- Liability
- Implementation
- Privacy
- Cyber/Security
- Governance
- Risk
- Certification
- Data
- Legislation
- Deployment Approach
- Financing
- Sustainability
- Organized by graduate students?
- More social interaction before/after?
- More point/counterpoint?
- We’re open to other ideas!
- More modes of transportation?
- Other topics we haven’t covered?
Thank You for Your Attention

Let knowledge serve the city

Portland State University