Integrated Active Transportation System Operational Vision and Implementation Research Plan

Cogenia Partners, LLC
Transportation Sustainability Research Center
Introduction

• How an Integrated Active Transportation System (IATS) can be realized and incorporated into the US transportation system
• September 2010 to December 2012
• Team: UC Berkeley Transportation Sustainability Research Center and subcontractors Cogenia Partners, LLC
• Sponsored by FHWA
Presentation Overview

1. Scope Introduction
2. Motivation
   - The need for a new approach
   - The difference of IATS
3. Methodology
4. Project Findings
5. Deployment Strategy
6. Recommendations
7. Next Steps: Phase II
IATS Concept

- Maximize safety, and minimize congestion, energy and environmental impacts through active integrated management of the roadway relationships.
SCOPE INTRODUCTION

1.
Project Scope

• Examine history of advanced transportation to identify what exists, what works, what doesn’t work, and why
• Develop a research framework, including guidelines to support ongoing research decision making to facilitate realization of the IATS concept
• Apply systems engineering principles to identify viable approaches to integration, and to assess feasibility of technical implementation
• Develop deployment strategy that addresses barriers and exploits opportunities (technical, social, political and economic)
• Identify additional research needs and next steps
2. MOTIVATION
Motivations

• Safety
  – Lives lost
  – Cost
  – Collateral impacts

• Mobility
  – Delays
  – Cost (fuel and lost time)
  – Collateral impacts

• Energy and Environment
  – Fuel consumption
  – Greenhouse Gas Emissions

• Economic Growth
  – Efficient commerce
  – Business opportunities and Jobs

Create a leap in economic and environmental benefits similar to the leap in economic growth created by the interstate highway system
Safety

U.S. car accident cost: $164.2 billion
AAA report says crashes are 2-1/2 times more costly than traffic jams.

Critical Crash Reasons
- Vehicle: 2%
- Road/Weather: 3%
- Driver: 95%

Critical Crash Reasons Attributed to Driver
- Decision Error: 34%
- Recognition Error: 41%
- Non Performance Error: 7%
- Performance Error: 10%
- Other: 8%

NHTSA Motor Vehicle National Crash Causation Report to Congress NHTSA 2008

- Crashes are dominated by driver errors
In 1999, rear end (end of queue) crashes accounted for 29.5% (1.85 million) of all accidents, and 11.8% of fatal crashes (NTSB Special Investigative Report May 2001)

Owners of Acura and Mercedes models equipped with forward collision warning systems that automatically braked the car when a crash appeared imminent reported a 14% drop in claims per year of insurance coverage compared to owners of similar vehicles without the systems IIHS Study 2011
Mobility: Causes of Congestion

- Bottlenecks: 40%
- Traffic Accidents: 25%
- Weather: 15%
- Work Zones: 10%
- Special Events: 5%
- Signal Timing: 5%

Source: FHWA (http://www.fhwa.dot.gov/congestion/describing_problem.htm)
Congestion Projected to Grow

Collateral impacts on safety, environment and economy will continue to increase

FHWA Freight Analysis Framework 2011
Energy and Environment

Controlling vehicle behavior can reduce energy consumption and environmental impact, with a collateral improvement in mobility.

Affect of Speed on Emissions and Energy
(Source: Boriboonsomsin University of California Riverside)
Reduced accident losses, reduced congestion, and reduced energy consumption all provide a positive collateral economic impact.

- 1.9 billion gallons of fuel wasted. Enough to fill 38 super-tankers or 210,000 gasoline tank trucks
- 4.8 billion hours wasted in congestion
- $300M in property damage liability and medical costs

2010 Urban Mobility Report; Texas Transportation Institute; AAA
Project Hypotheses

• External management of macro vehicle behaviors can reduce congestion and environmental impact due to incidents and bottlenecks

• Autonomous management of micro vehicle behaviors can reduce accidents and provide mechanism for macro management

• Basic enabling technologies exist, but integration approach and social/political acceptance is uncertain
Project Assumptions

• Optimal management of the vehicle-road system can be achieved
  – Maximum safe flow at given capacity, without stop and go congestion
  – Optimal energy/economic balance

• Mixed mode vehicle automation is feasible
  – Progressive migration from active safety systems to mixed mode driverless/driver-independent vehicles

• Integration of systems is politically and economically feasible
  – Can obtain benefits quickly enough to motivate adoption
  – Benefits are significant enough to offset costs

• Travelers will cooperate
  – Suitable mechanisms can be identified to motivate travelers to use system and to accept the constraints it may impose
IATS Overview

• Integrated
  – IATS combines the current advanced transportation disciplines to provide a broad array of functions that work together to provide safer and more efficient operation of the transportation system

• Active
  – IATS assumes increasing automation, and from this, active management
  – IATS applications that take positive action to reduce congestion, reduce accidents, respond to incidents when they do occur both directly (e.g. emergency response) and globally through system controls
How is IATS Different from ITS?

- Draws heavily from existing ITS-related technologies
  - Crash Avoidance, Automation, Information, Traffic management
- Stresses cross-cutting integration to achieve substantially higher levels of system performance
- Addresses social, political and economic factors to surmount deployment barriers
- Assumes incremental progress, but it can be accelerated by disruptive events
3. METHODOLOGY
Historical Methodology

• Analysis of 450+ ITS programs
  – Categorized according to basic functional focus and cross-cutting integration content

• Identified representative technology developments
  – Cataloged strengths and weaknesses
  – Assessed reasons for adoption/non-adoption (e.g., post mortem reports, etc.)

• Engaged experts in a variety of topics to understand how to successfully realize IATS
  – Explored non-technical barriers and driver acceptance
Technical Methodology

• Literature review to identify associated work and existing applicable technologies

• High-level concept of operations to identify basic system components and functional needs

• Gap analysis to identify technical research needs

• Comparison with historical and social findings to develop practical realization strategy
Social Methodology

• Literature review of worldwide ITS programs
• Interviews with transportation experts
• Guided by steering committee
  – 7 experts
• Two, 2-day scenario planning workshops
  – 16 experts
• Nationwide transportation stakeholder survey
  – 106 stakeholders at the national, state, and regional levels
  – Key leadership from US DOT, all State DOTs, MPOs, COGs
  – Assess U.S. ITS capabilities and ability to implement IATS
4.

PROJECT FINDINGS
Historical Findings

• **Wide array of ITS programs undertaken over the last 20 years**
  – TMC systems (widespread, self-contained deployment)
  – Automated vehicles (limited sponsored work over past 15 years, hampered by deployment issues)
  – Vehicle Safety Systems (car maker lead, most successful are autonomous)
  – Navigation/Information (widespread but generally limited to vehicle or phone routing, parking, etc.)
  – Connected Vehicle systems (feasible but hampered by deployment issues)
• **Virtually no significant programs undertaken to study integrated aspects of original IVHS vision**
• **Social, political, and economic issues represent key barriers to realization**

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¹ Lack of space and insufficient knowledge on our part prevent discussion here of ‘evolution’ and ‘evaluation.’ In our opinion, such a discussion must be conducted within an analytical framework that reflects legal and other social institutions.

Smart Cars on Smart Roads: Problems of Control, P. Varaiya, 1993
Historical Roadmap of ITS
ITS Has Included Limited Cross-Discipline Activity
Technical Findings

• Technical assumptions appear to be valid
• Simulations and demonstrations by others indicate that:
  – Mixed mode automation is becoming increasingly feasible
    • Laws providing for automated operation are also emerging
  – Many autonomous safety features are emerging in the market (appears to be the preferred approach over warning systems)
  – System level flow control can avoid and mitigate congestion
  – Route control and road topology control are somewhat problematic (cost and scalability)
System Overview

System Control
(state, models, control rules, energy, emissions)

Equipped Vehicles
(increasingly automated)

Non-Equipped Vehicles

Routes, Speeds, etc.

Roadway Infrastructure
(topology, directionality, signaling, etc.)

Response Infrastructure

Road Data

Directives

Vehicle Data

Collateral Impact

Direct Impact
Key System Functions

• **System sensing of the global roadway state**
  – Vehicles (providing self and other vehicle(s) information)
  – Roadway sensors (providing vehicle and roadway information)

• **Vehicle sensing of the local road environment state**
  – Based on independent vehicle sensors, possibly supplemented using vehicle to vehicles
  – Models used to predict behavior of other roadway occupants (vehicles, bikes/peds, animals, etc.)

• **System determination and control of optimal changes in vehicle behavior**
  – Models used to determine what behaviors will yield the best system performance for any given state (e.g., speed, lane, etc.)

• **System determination of optimal changes in traveler behavior**
  – System may seek to guide travelers into alternate transport modes for a portion of their trip, based on origin and destination, the current system demand, and the available modes of transport
Key System Functions (Cont’d)

• **System determination of optimal changes in the road topology**
  – Beginning with existing mechanisms such as adaptive signal timing and metering lights
  – Evolving to more sophisticated dynamic control over illuminated lane markings, and virtual control over intersection flow (e.g., virtual roundabouts, free flow, etc.)

• **Vehicle determination of the optimal trajectory consistent with routing and tactical (e.g., speed and lane) suggestions or directives**
  – Progressively automated operation
  – Hierarchical control structure that seeks out the desired trajectory (path)

• **System response to incidents**
  – Identify incidents and dispatch support equipment as necessary
  – Identify appropriate roadway and vehicle control actions to shift from optimal system flow to optimal response time
  – e.g., routing vehicles off the road or into different lanes or creating new dynamic lanes to make way for emergency vehicles
Technical Example: ACC

- As proportion of ACC equipped vehicle rises, impact (extent and speed reduction) of bottlenecks declines.
Technical Examples: Automation

- Automatic Braking
- Automatic Parking
- DARPA Urban Challenge
  - Driverless operation in mixed mode urban scene
- Google Car
  - Mixed-mode operation on open roads
Technical Example: Behavior Model

• Rule based simulations of large populations of independent agents (pedestrians)
• Illustrates ability to accurately model dynamic behavior of agent interactions that represents large-scale macro behavior of the masses

Simulated Crossing

Actual Crossing
Technical Example: Dynamic Lanes

- Implemented changeable lane topology using extinguishable signage and variable striping (using in-pavement lights)
  - 30% reduction in crashes
  - 75% reduction in delays
IATS in 15-20 Years

**O-D Influenced Routing Based on Traffic Flow on Variable Network & Suggested Speeds, Increasingly Automated Piloting**

**Integrated Approach:**
- Vehicle manage their own local situation
- System manages overall vehicle behavior to produce optimal flow and optimal mobility
  - Speeds, lanes, routes, etc.
- System manages road topology to best support traveler demand
- System can create gaps in traffic, which let signaled intersections cycle to allow cross traffic without stopping the main flow
  - “green wave”

**Benefits**
- Maximal system throughput at any demand level
  - System approaches theoretical capacity
- Reduced congestion and delay
- Reduced accidents
- Reduced energy and environmental impact
- Transportation system acts as an economic enhancer instead of an economic drag
Social and Behavioral Research Findings: Context

- Expected population increase in the next 40 years
  - Primarily in urban areas (8B by 2030; 9B by 2050)
- Changing demographics
  - Increase in senior populations
- Changing mobility needs
  - Transportation systems need to adjust
- Must identify potential disruptive forces
  - Resource constraints
  - Natural disaster
  - Cyber-terrorism
  - Climate change
Social and Behavioral Research Findings: Summary

• Scenario planning workshops
  – Need distributed implementation model with near-term goals that provides immediate value
  – IATS addresses congestion and energy consumption concerns
  – Implementation methods shall depend upon future strength of government, economy, globalization, emissions, and resource costs
  – Important to align FHWA and IATS goals

• National survey
  – Technology to implement IATS exists or is in development
  – Suggested incremental implementation approach would be best
  – Implementation may be better managed in IATS-prepared regions, such as Mid- and South Atlantic first (per survey findings)
Scenario Planning
Workshop Outcomes

Three-stage scenario planning process

1) Initial steering committee discussion
   – OUTCOME: Identified driving forces and initial focal question for each scenario world

2) Scenario planning workshops
   – Experts represented the following disciplines
     – Transportation
     – Technology
     – Sociology
     – Economics
     – Energy
     – Policy
     – Planning
     – Freight transport
     – Futuristics
   – OUTCOME: Identified potential disruptive scenarios and leading indicators

3) Final steering committee session
   – OUTCOME: Recommended additional stakeholder survey at the national, state, and regional level
Experts Engaged

• Luca Delgrossi, Daimler
• Dorothy Glancy, SCU
• Garry Golden, Futurethink
• Greg Larson, CalTrans
• David Levinson, UMN
• Alexander Rose, Long Now Foundation
• Richard Bishop, Bishop Consulting
• Jake Dunagan, Institute for the Future
• Stuart Candy, Arup
• Jon Gustafson, Cascade Sierra Solutions
• Paul Laurenza, Dykema
• Scott McCormick, Connected Vehicle Trade Association
• Gerry Tierney, PerkinsWill/Redcar
• Hiroshi Tsuda, Nissan
• Harry Voccola, Navteq
• James Wright, AASHTO
<table>
<thead>
<tr>
<th>Scenarios and Key Signposts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meteorological conditions that result in many unpredictable disasters</td>
</tr>
<tr>
<td>Technology-based prediction systems</td>
</tr>
<tr>
<td>No additional signpost</td>
</tr>
<tr>
<td>Economic slowdown</td>
</tr>
<tr>
<td>Increase in the number of green businesses</td>
</tr>
</tbody>
</table>
Scenario Planning Workshops: Scenario Quadrant Findings

• **When energy resources are abundant**
  – Introduce truck-only lanes to expedite freight movement
  – Create an electricity metering system to collect taxes on electric vehicles to pay for transportation infrastructure growth and maintenance

• **When resources are constrained**
  – Shift the focus of ITS toward the streamlining of the nation’s freight system
  – Improve the efficiency of mass transportation systems

• **When government is fiscally challenged**
  – Discover unconventional funding sources to continue the development and deployment of ITS technologies (e.g., public-private partnerships, international collaboration, tax policy changes, incremental implementation)
  – ITS concepts and benefits must be marketed to the public
  – Make road sensor data more readily available to third parties to create new industries focused on optimized routing and mode choice information

• **When climate change occurs and natural disasters are common**
  – ITS technologies adapt to provide more efficient evacuation and rescue operations
Key Disrupters and Their Impacts

• Resource constraints
  – Limited availability of resources slows large-scale IATS deployment
  – IATS may be driven by wealthy private-sector individuals

• Natural disasters/climate change
  – More frequent replacement of infrastructure – IATS infrastructure could be upgraded more often
  – Automated vehicles could be preprogrammed with evacuation procedures

• Changing economies
  – Weak economy limits growth of IATS due to low vehicle turnover
  – Stronger economy facilitates development/deployment of IATS
  – Increased congestion creates an opportunity for centrally managed automated vehicles that increase road efficiency
This is not the time to talk about climate legislation.

This either.

Have it your way.
Stakeholder Survey

- Expert scenario planning workshops in 2011 provided substantial data on the future of technology and transportation system
- Collect data on the current status of U.S. ITS deployment
- Assess response to IATS by transportation stakeholders
- Assess regional capacity for deployment – short term and long term
- Probe uptake of key IATS building blocks in U.S. at present
# Number of Respondents by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of Respondents</th>
<th>Number of Contacts</th>
<th>Percent Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England</td>
<td>12</td>
<td>48</td>
<td>12%</td>
</tr>
<tr>
<td>Mid-Atlantic</td>
<td>5</td>
<td>17</td>
<td>29%</td>
</tr>
<tr>
<td>East North Central</td>
<td>14</td>
<td>56</td>
<td>25%</td>
</tr>
<tr>
<td>West North Central</td>
<td>15</td>
<td>58</td>
<td>26%</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>13</td>
<td>86</td>
<td>15%</td>
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<tr>
<td>East South Central</td>
<td>4</td>
<td>33</td>
<td>12%</td>
</tr>
<tr>
<td>West South Central</td>
<td>10</td>
<td>31</td>
<td>32%</td>
</tr>
<tr>
<td>Mountain</td>
<td>17</td>
<td>54</td>
<td>32%</td>
</tr>
<tr>
<td>Pacific</td>
<td>16</td>
<td>53</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>106</strong></td>
<td><strong>436</strong></td>
<td><strong>24%</strong></td>
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</tbody>
</table>
Census Classification Used for Stakeholder Survey

• Survey regions in line with census classification allows results to be compared against population, congestion, and other U.S. census information.

http://energyiq.lbl.gov/EnergyIQ/CensusMap.html
## Example of Existing ITS Regional Deployment

<table>
<thead>
<tr>
<th>Traffic/roadway management methods used</th>
<th>New England</th>
<th>Mid-Atlantic</th>
<th>East North Central</th>
<th>West North Central</th>
<th>South Atlantic</th>
<th>East South Central</th>
<th>West South Central</th>
<th>Mountain</th>
<th>Pacific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive traffic signals</td>
<td></td>
<td>Cyan</td>
<td>Green</td>
<td>Green</td>
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<tr>
<td>Dynamic HOV lane management</td>
<td>Cyan</td>
<td>Cyan</td>
<td>Green</td>
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<tr>
<td>Reversible lanes</td>
<td>Cyan</td>
<td>Cyan</td>
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<tr>
<td>Use of Shoulder lanes</td>
<td>Cyan</td>
<td>Cyan</td>
<td></td>
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<tr>
<td>Variable speed limits</td>
<td>Orange</td>
<td>Orange</td>
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<tr>
<td>Ready for system monitoring</td>
<td>Green</td>
<td>Green</td>
<td></td>
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<tr>
<td>Ready for automation</td>
<td>Orange</td>
<td>Orange</td>
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</table>
Scores demonstrate the level of acceptance for IATS implementation. States with higher levels of IATS acceptance are illustrated in red.
Individual Responses to IATS matched with IATS Score

“The State of Ohio does not have jurisdiction in urbanized areas for any roadways other than the Interstate system and rural routes.” – Ohio

“We have people in all the agencies who believe in the benefit of ITS, but there is no program dedicated to building it.” – Illinois

“Legal liability would prevent automation to fully be implemented.” – New Mexico

“People do not trust/like decisions made by others, they like information to make their own decisions.” – New Hampshire

“Americans love their automobiles, and the thought of drivers giving up control of their vehicles to an automated system may be disconcerting.” – Texas

“Anything that requires a change in established habits / expectations” [is the most difficult transportation infrastructure and technology to implement]. – Washington state

“As long as the information is used to the benefit of the individual and the information being gathered is anonymous, the public is less likely to object.” – Michigan
Current Long-Term ITS Deployment Plans

- 78% of responding regions had both 10- and 20-year plans
- 36% had the same plan for both time horizons
- Most common 10-Year plans:
  - Public transit (22%)
  - Improved traffic signalization (13%)
  - Introduction of alternative fuel infrastructure or vehicles (9%)
- Most common 20-Year plans:
  - Public transit (25%)
  - Improved traffic signalization (8%)
  - Connected vehicles (8%)
Anticipated IATS Deployment Timeline (2012)

How many years from now do you envision a system [like IATS] existing somewhere in the world and existing in your specific region?
5. DEPLOYMENT STRATEGY
High-Level Deployment Strategy

• In general, realization must take place incrementally
  – Step-by-step change consistent with technical, economic, social, and political constraints

• Overall strategy should also consider impacts of disruptive events
  – Events that cause significant changes in basic technical, economic, social, and political constraints
  – Exploit positive disruptions
  – Respond to negative disruptions
Punctuated Equilibrium Strategy

### Near Term
- Localized speed guidance
- Incentivize using social media and gamification

### 5-10 Years
- Reduced Federal Role, Mega Regions, Balkanized governance
- Migrate control to increasingly automated vehicles
- Introduce dynamic road controls (signals, lanes, etc.)

### 10-15 Years
- Privacy Backlash Cyberterrorism
- Extend scope of dynamic roadway and speed/lane control
- Introduce dynamic O-D based routing

### 15-20+ Years
- Extend scope of flow control to introduce gaps to allow non-stop flow in cross traffic

### System Performance
- Vehicle Automation Tech and Laws
- Energy Independence
- Mega Scale Computing

### Exploit Disruptions
- Energy Crisis
- Climate Crisis
- War

### Smart phones, Social Media, Games, etc
6. RECOMMENDATIONS
Policy Research Recommendations

• Systematic R&D process that includes economic, social, and legal aspects as well as technical (e.g., NEPA)
  – Broadly integrated technical solutions
  – Immediate value to users and stakeholders
• Clarification of roles of federal, state, and private stakeholders throughout the process
• Autonomous vehicle legislation/regulation
• Liability and insurance
• Privacy
• Governance and jurisdiction
Economic Research Recommendations

- **Model introduction of new features in existing markets**
  - With and without interdependence
  - Identify key barriers and enhancers

- **Quantify benefits on the basis of various assumptions of performance and deployment**
  - Benefits based on technical capability and social acceptance
  - Direct (e.g., congestion, fuel savings)
  - Direct + Indirect (GDP, efficiency savings, job creation)

- **Perform sensitivity analysis to identify key benefits drivers**
  - Develop priorities based on measure of technical difficulty vs/ economic benefits

- **Examine effects of possible disruptors**
  - Energy changes/crises
  - Technical breakthroughs
  - Social accelerators and decelerators
Social Research Recommendations

• Driver distraction
  – Focus groups in 4 U.S. regions (West, Midwest, South, Northeast)

• Methods to increase IATS use and acceptance
  – Perception vs. deployment
  – National public survey

• Impact of incremental development
  – In-depth stakeholder interviews

• Jurisdiction and control issues between levels of government
  – Informational webinars

• Legal barriers and liability concerns (e.g., insurance, AV legislation)
Long-Term Strategic Research Recommendations

• Create a comprehensive development process (e.g., NEPA)

• IATS name/ terminology

• Regionalism of ITS deployment
  – Better understand need and uptake

• ITS inventory (existing and planned) disaggregated by U.S. region (public and private monitoring)

• Monitoring external forces in light of strategic plan
7. NEXT STEPS
PHASE II: Non-Technical

- Outline of procedural framework for IATS deployment
- Process for stakeholder socialization and consensus
  - Naming of IATS and related terminology
  - Benefits and concepts
- Inventory of existing and planned ITS deployment (regional disaggregation) ‘industry outlook’
- Economic analysis (e.g., cost, forecasting, payback, benefits)
- Public perception of IATS (e.g., focus groups, surveys)
- Monitoring of related legislation/ regulation
  - Automated vehicles, etc.
- Formal risk analysis (e.g., cyber-terrorism, liability)
  - Exposure (quantifiable measure of risk)
  - Mitigation
- Insurance industry - expert forum
  - Cost exposure
- Can motivational tools (e.g., gaming) provide a mechanism for causing drivers to exhibit certain desirable behaviors or motivate them to adopt certain elements of the system that might not provide them with direct benefit but benefit the entire system
PHASE II: Technical

• Modeling of behaviors to support accurate and reliable predictions of near-term future behavior for automated and human controlled vehicles and for not vehicle roadway occupants, such as pedestrians, cyclists and animals

• Accurate predictive models of traffic flow and congestion combined with agent-based simulations and rules to allow dynamic determination of optimal control and management strategies

• Global sensing of the road network state to support the predictive models of traffic flow

• Roadway systems to support dynamic alteration of roadway geometries

• Standards roadmap for IATS