Activity-Travel Behavior Impacts of Driverless Cars

Ram M. Pendyala\textsuperscript{1} and Chandra R. Bhat\textsuperscript{2}

\textsuperscript{1}School of Sustainable Engineering \& the Built Environment
Arizona State University, Tempe, AZ

\textsuperscript{2}Center for Transportation Research
University of Texas, Austin, TX
Outline

- Motivation
- Automated vehicle technology
- Activity-travel behavior considerations
- Infrastructure planning and modeling implications
- Conclusions
The Context

- **Automated Vehicles**: Vehicles that are able to guide themselves from an origin to a destination designated by the individual.
- **Individual yields near-full or partial control to artificial intelligence technology**
  - Individual decides an activity-travel plan
  - The vehicle (or a central command) executes the plan (routing)
- **Individual retains ability to take back control and can make “on-the-fly” decisions regarding travel**
## Motivation for Automated Driving

<table>
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<tr>
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<th><strong>Zero Emission</strong></th>
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<tbody>
<tr>
<td>1</td>
<td>- Optimization of traffic flow management</td>
<td>- Reduction of fuel cons. and CO2 emission</td>
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<td>2</td>
<td><strong>Demographic change</strong></td>
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<td>- Support unconfident drivers</td>
<td>- Enhance mobility for elderly people</td>
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<td>3</td>
<td><strong>Vision Zero</strong></td>
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<td>- Potential for more driver support by avoidance of human driving errors</td>
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<td>4</td>
<td><strong>Increasing traffic density</strong></td>
<td></td>
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<tr>
<td></td>
<td>- Optimization of traffic flow management</td>
<td>- Convenient, time efficient driving via automation</td>
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<tr>
<td>5</td>
<td><strong>Economy</strong></td>
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<td>- Ensure unique selling proposition</td>
<td>- Attractive products by technological leadership</td>
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<tr>
<td>6</td>
<td><strong>Maturity of driver assistance systems</strong></td>
<td></td>
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<td>- Sensors are approved and cost-effective</td>
<td>- Actuators (steering, …) in series production</td>
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Source: Bartels, 2013
Automated Vehicles and Transportation

Technology

Infrastructure

Traveler Behavior
## Two Broad Types of Technology

<table>
<thead>
<tr>
<th>Self-Driving Vehicle (e.g., Google)</th>
<th>Connected Vehicle</th>
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<tr>
<td>AI located within the vehicle</td>
<td>AI wirelessly connected to an external communications network</td>
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<td>“Outward-facing” in that sensors blast outward from the vehicle to collect information without receiving data inward from other sources</td>
<td>“Inward-facing” with the vehicle receiving external environment information through wireless connectivity, and operational commands from an external entity</td>
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<td>AI used to make autonomous decisions on what is best for the individual driver</td>
<td>Used in cooperation with other pieces of information to make decisions on what is “best” from a system optimal standpoint</td>
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<td>AI not shared with other entities beyond the vehicle</td>
<td>AI shared across multiple vehicles</td>
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<td>A more “Capitalistic” set-up</td>
<td>A more “Socialistic” set-up</td>
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</table>
Autonomous (Self-Driving) Vehicle

- Google cars have successfully driven 500,000 miles
- Set 2018 as expected release date for self-driving car

Sight to behold: a blind man behind wheel of self-driving car

Google self-driving car takes legally blind man over 'carefully programmed route'
Autonomous (Self-Driving) Vehicle

Elon Musk: Tesla's driverless car will be street-ready in three years

Tesla raises the stakes with a bold about driverless cars.

Volvo plans self-driving cars in 2014, envisions accident-free fleet by 2020

Nissan Sets Goal of Introducing First Self-Driving Cars by 2020
Connected Vehicle Research

- Connected vehicle research addresses a suite of technologies and applications that use wireless communications to provide connectivity:
  - Among vehicles of all types
  - Among vehicles and a variety of roadway infrastructures
  - Among vehicles, infrastructure, and wireless consumer devices
Connected Vehicle Research
A “Connected” Vehicle

Data Sent from the Vehicle
Real-time location, speed, acceleration, emissions, fuel consumption, and vehicle diagnostics data

Data Provided to the Vehicle
Real-time traffic information, safety messages, traffic signal messages, eco-speed limits, eco-routes, parking information, etc.

Improved Powertrain
More fuel efficient powertain including: hybrids, electric vehicles, and other alternative power sources

Source: USDOT
Levels of Vehicle Automation

- **Level 0: No automation**
- **Level 1: Function-specific Automation**
  - Automation of specific control functions, e.g., cruise control
- **Level 2: Combined Function Automation**
  - Automation of multiple and integrated control functions, e.g., adaptive cruise control with lane centering
- **Level 3: Limited Self-Driving Automation**
  - Drivers can cede safety-critical functions; not expected to monitor roadway constantly
- **Level 4: Full Self-Driving Automation**
  - Vehicles perform all driving functions and can operate without human presence or intervention
Government Recognition

- Several states in the US passed legislative initiatives to allow self-driving cars to navigate roadways
  - California, Nevada, and Florida
- National Highway Traffic and Safety Administration Policy Statement
  - Policy guidance on licensing, safety, testing
- Autopilot Systems Council in Japan
- Citymobil2 initiative in Europe
Infrastructure Provision

- Increasingly complex activity-travel patterns
- Growth in long distance travel demand
- Limited availability of land to dedicate to transport infrastructure
- Budget/fiscal constraints
- Energy and environmental concerns
- Information and communication technologies (ICT) and mobile platforms can be leveraged
- **Autonomous vehicles leverage technology to increase flow without the need to expand capacity**
Smarter Infrastructure

The Automated Road

Source: http://www.foreveropenroad.eu/
Mobility Implications

- Infrastructure considerations tied to potential impacts of transport automation on mobility (people and freight)
- Safety enhancement
  - Virtual elimination of driver error (primary factor in 80 percent of crashes)
  - Enhanced vehicle control, positioning, spacing, and speed harmonization
  - How about offsetting behavior on part of drivers? Need to eliminate possibility of offsetting behavior...
  - No drowsy drivers, impaired drivers, stressed drivers, or aggressive drivers
  - Reduced number of incidents and network disruptions
Mobility Implications

- **Capacity enhancement**
  - Vehicle platooning greatly increases density (reduced headways) and improves flow at transitions
  - Vehicle positioning (lateral control) allows reduced lane widths and utilization of shoulders; **accurate mapping critical**
  - Optimization of route choice, passage through intersections, and navigation through and around **work zones**

- **Energy and environmental benefits**
  - Increased fuel efficiency and reduced pollutant emissions through vehicle operation improvement
  - **Clean-fuel vehicles**
  - Car-sharing provides additional benefits
Per Capita VMT Trend in USA

- Total VMT (000,000)
- Total VMT and VMT per capita
- VMT
- VMT per capita
Location Choices

- Live and work farther away
  - Use travel time productively
  - Access more desirable and higher paying job
  - Attend better school/college

- Visit destinations farther away
  - Access more desirable destinations for various activities
  - Reduced disutility impact of time and distance

- Changes in development patterns
  - More sprawled cities?
  - Impacts on community/regional planning and urban design
Activity-Travel Choices

- Undertake more activities (and trips) resulting in induced travel demand
  - Reduced disutility of travel
  - Positive utility of travel
- No more peak car effect?
Vehicle Ownership Choice

- Potential to redefine vehicle ownership
  - Nobody owns a vehicle; move towards car sharing enterprise where rental/taxi vehicles come to traveler, OR
  - Everybody has a vehicle including children, elderly, and disabled

- More efficient vehicle ownership and sharing scheme may reduce the need for additional infrastructure
  - Reduced demand for parking

- Desire to work and be productive in vehicle
  - Greater use of personal vehicle for long distance travel
  - Desire large multi-purpose vehicle with amenities to work and play in vehicle
  - Increase demand for infrastructure
Vehicle Ownership Choice
Mode Choice

- Automated vehicles combine the advantages of public transportation with that of traditional private vehicles
  - Flexibility, comfort, convenience, texting, talking, surfing, reading, gaming
- What will be the future of public transportation in an era of autonomous vehicles?
- What will be the future of walking and bicycling in an era of autonomous vehicles?
- If “TIME” is less of a consideration, then “COST” may be the major driver of travel choices
Mode Choice

- Driving personal vehicle more convenient and safe
- Finding parking space no longer onerous
- Traditional transit captive market segments now able to use auto (e.g., elderly, disabled)

- Reduced reliance/usage of public transit
- However, autonomous vehicles may present an opportunity for public transit
  - Reliable transit service
  - Lower cost of operation (driverless)
  - More personalized service - smaller vehicles providing demand-responsive transit service
Commercial Vehicle Operations

- Enhanced efficiency of commercial vehicle operations
- Driverless vehicles operating during off-peak and night hours reducing congestion
- Reduced need for infrastructure
Mixed Vehicle Operations

- Uncertainty in pace of technology availability, affordability, and adoption (market penetration rate)
- Need for mixed vehicle operations for considerable amount of time
- When will automated vehicles completely replace individual-driven vehicles?
- Need infrastructure that accommodates both manual and automated vehicles?
- Intelligent infrastructure with dedicated lanes for driverless cars
  - Managed lanes offer opportunity to accommodate self-driving vehicles (dedicated technology-equipped lanes)
Traveler Still Makes Choices

- Infrastructure use largely driven by user (departure time choice, origin-destination travel patterns, trip chaining)
- Provide information to traveler with incentives to bring about behavioral modification
- Combine driverless car technology with traveler information/incentives to optimize infrastructure utilization
Infrastructure Impacts

- Several opposing forces, making determination of net impacts uncertain
- Collect data and conduct focus groups to understand possible behavioral impacts and planning implications
- Recognize inter-dependent infrastructure systems
  - Information and communications technology, power, transport
- Travel models ill-equipped to handle “uncertainty”
  - Lessons learned from other technology innovations; develop scenarios and consider range of possible responses
You want to know the future?
You can’t handle the future!

Unless you have the right models

[ASU Ira A. Fulton School of Engineering]