Activity-Travel Behavior Impacts of Driverless Cars

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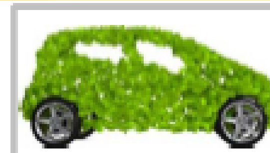
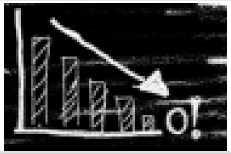
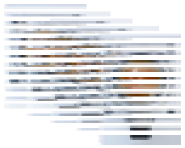
Outline

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

The Context

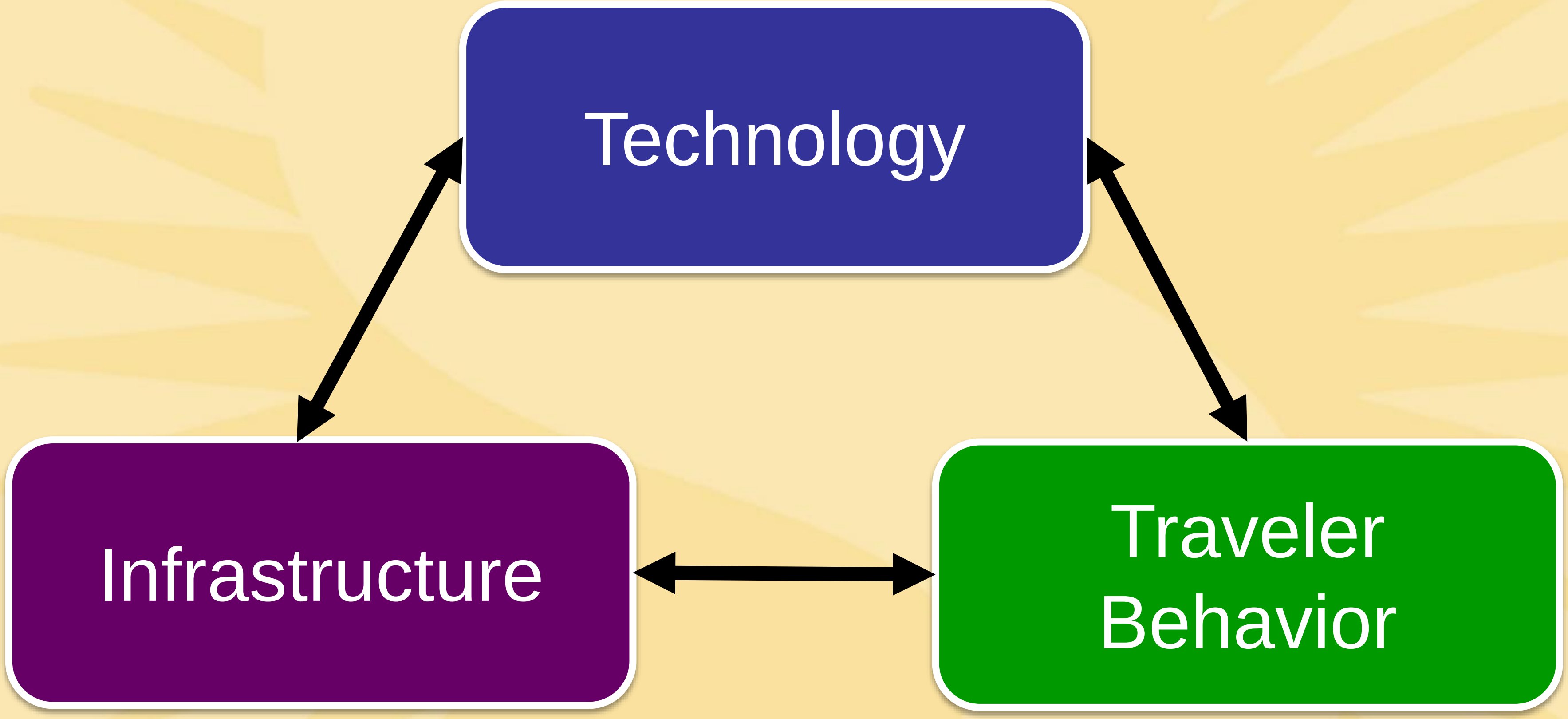
- Automated Vehicles: Vehicles that are able to guide themselves from an origin to a destination designated by the individual
- Individual yields near-full or partial control to artificial intelligence technology
  - Individual decides an activity-travel plan
  - The vehicle (or a central command) executes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

Motivation for Automated Driving

1	*Zero Emission*	- Optimization of traffic flow management - Reduction of fuel cons. and CO_2 emission	
2	*Demographic change*	- Support unconfident drivers - Enhance mobility for elderly people	
3	*Vision Zero*	- Potential for more driver support by avoidance of human driving errors	
4	*Increasing traffic density*	- Optimization of traffic flow management - Convenient, time efficient driving via automation	
5	*Economy*	- Ensure unique selling proposition - Attractive products by technological leadership	
6	*Maturity of driver assistance systems*	- Sensors are approved and cost-effective - Actuators (steering, …) in series production	

Source: *Bartels, 2013*

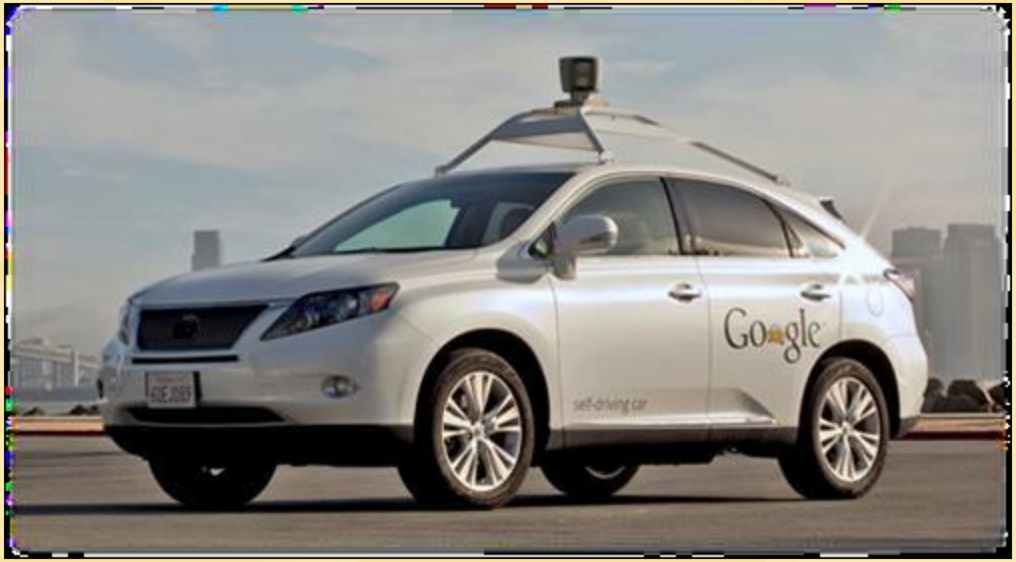
Automated Vehicles and Transportation



Two Broad Types of Technology

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

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

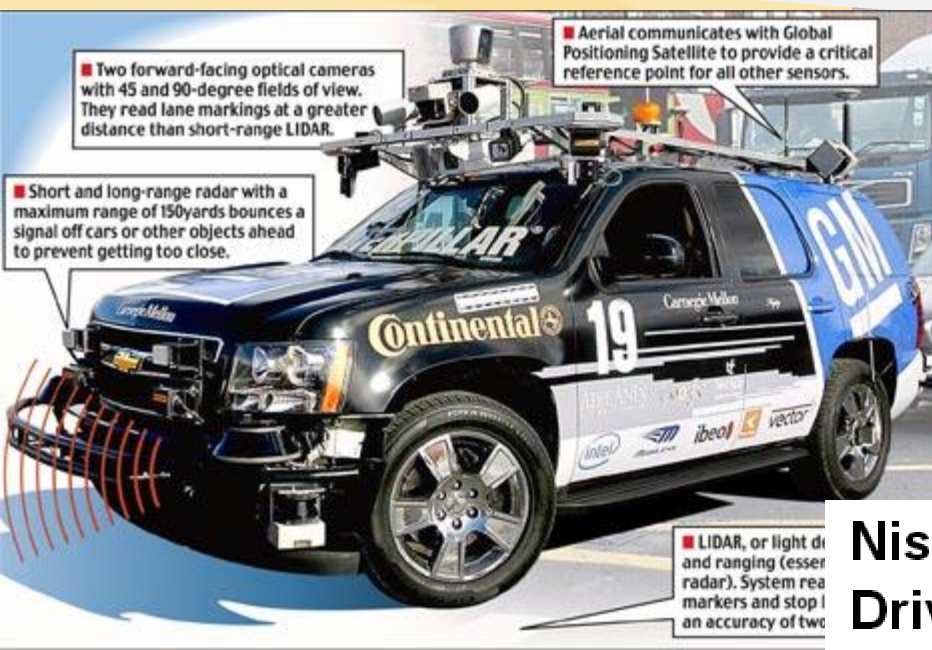
Google self-driving car takes legally blind man over 'carefully programmed route'

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.

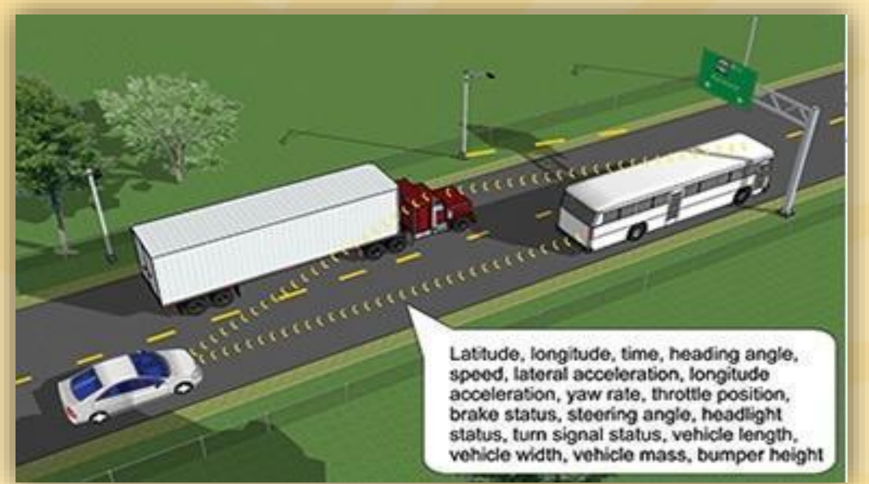
Volvo plans self-driving cars in 2014, envisions accident-free fleet by 2020



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

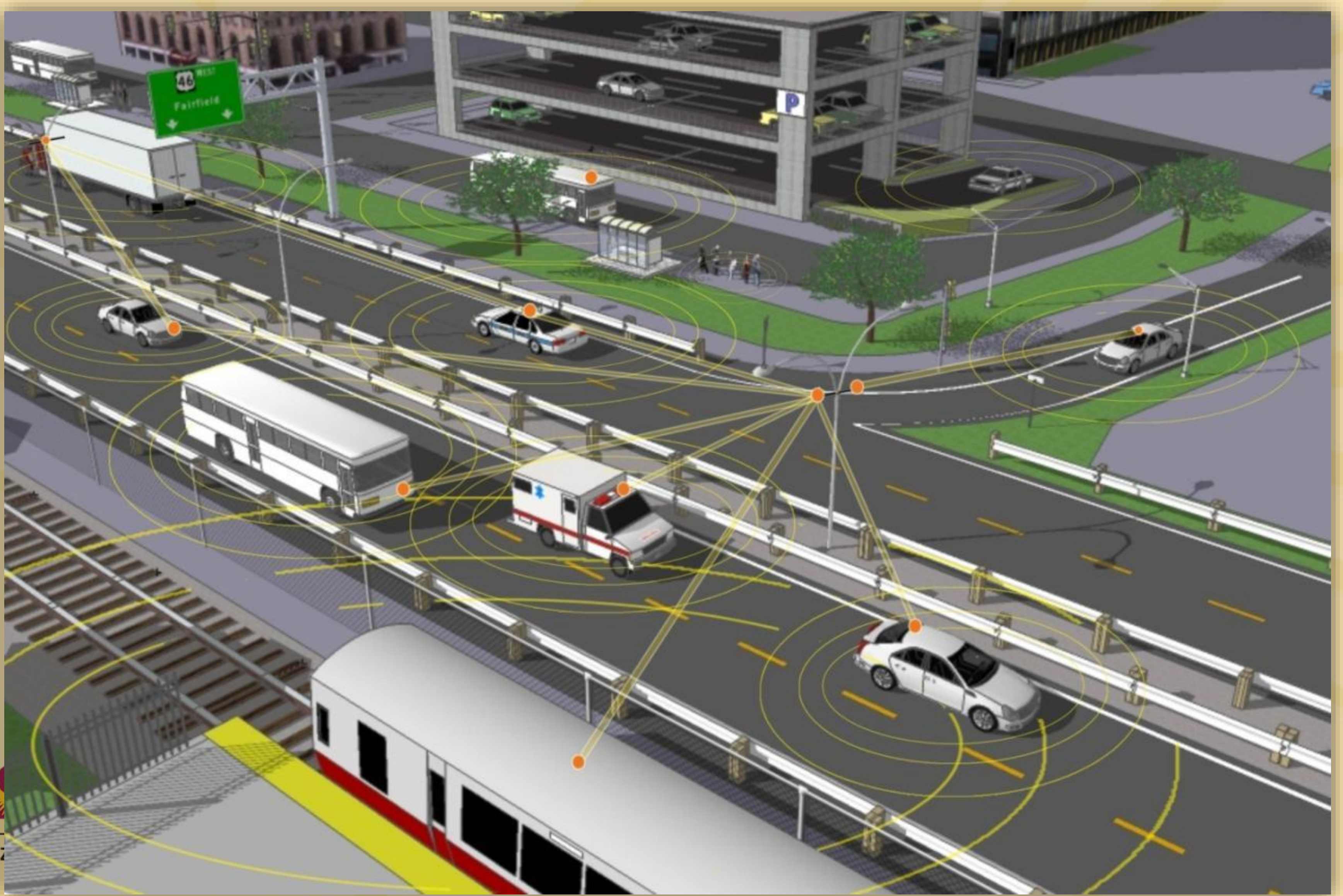
Connected Vehicle Research

- 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



An initiative of the USDOT
Intelligent Transportation Systems Joint Program Office

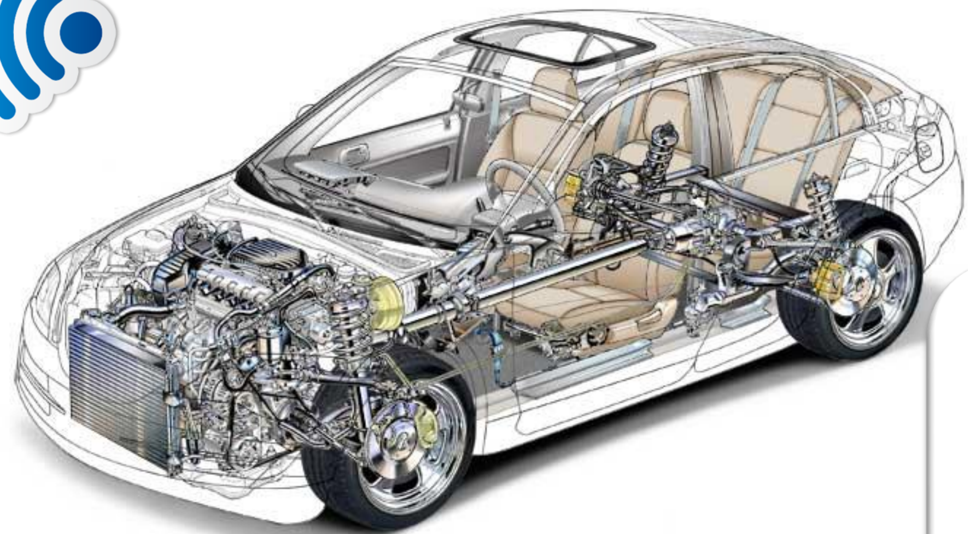
Connected Vehicle Research



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

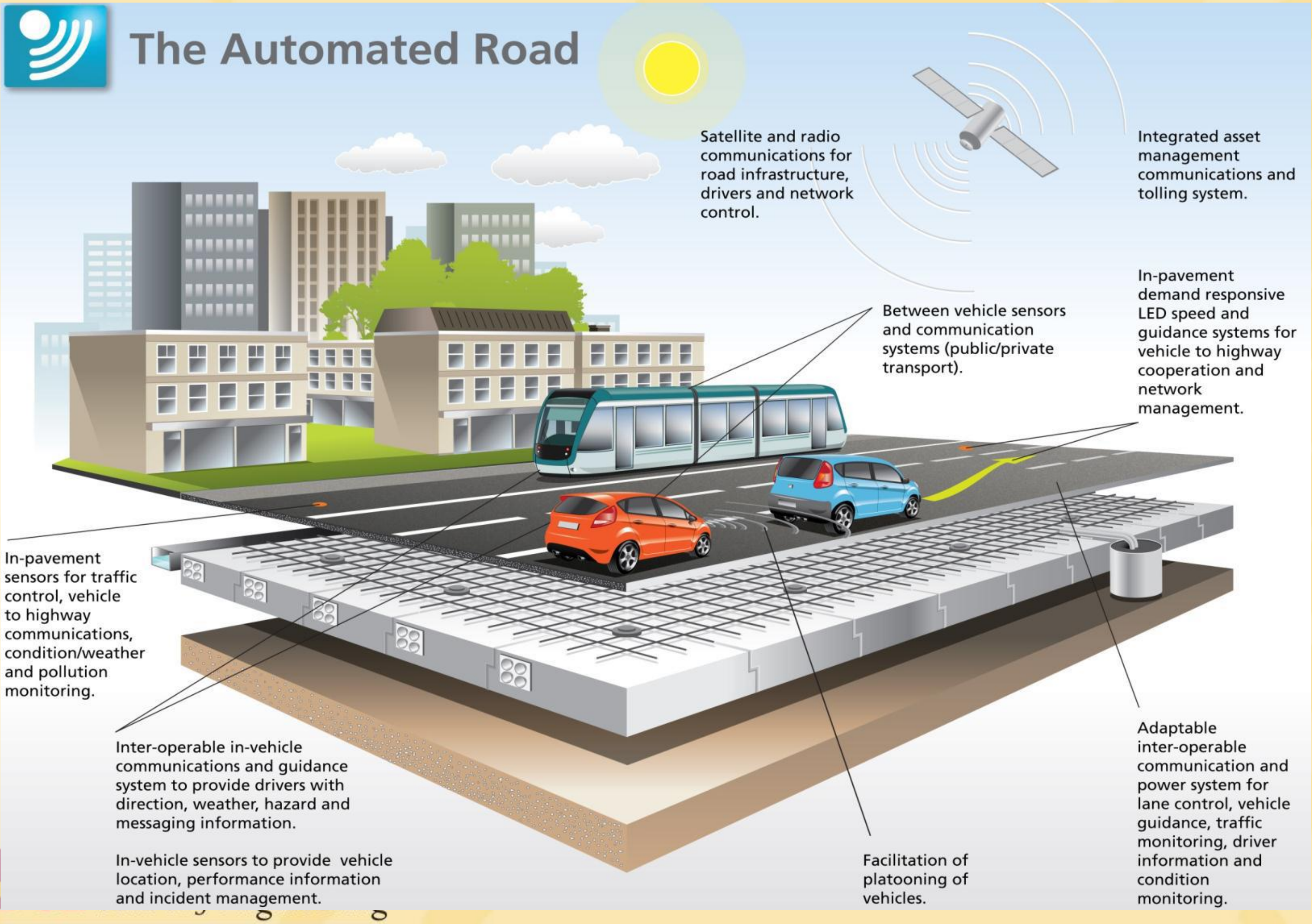
- Several states in the US passed legislative initiatives to allow self-driving cars to navigate roadways
  - California, Nevada, and Florida
- National Highway Traffic and Safety Administration Policy Statement
  - Policy guidance on licensing, safety, testing
- Autopilot Systems Council in Japan
-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

CityMobil2
CITIES DEMONSTRATING AUTOMATED ROAD PASSENGER TRANSPORT

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



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

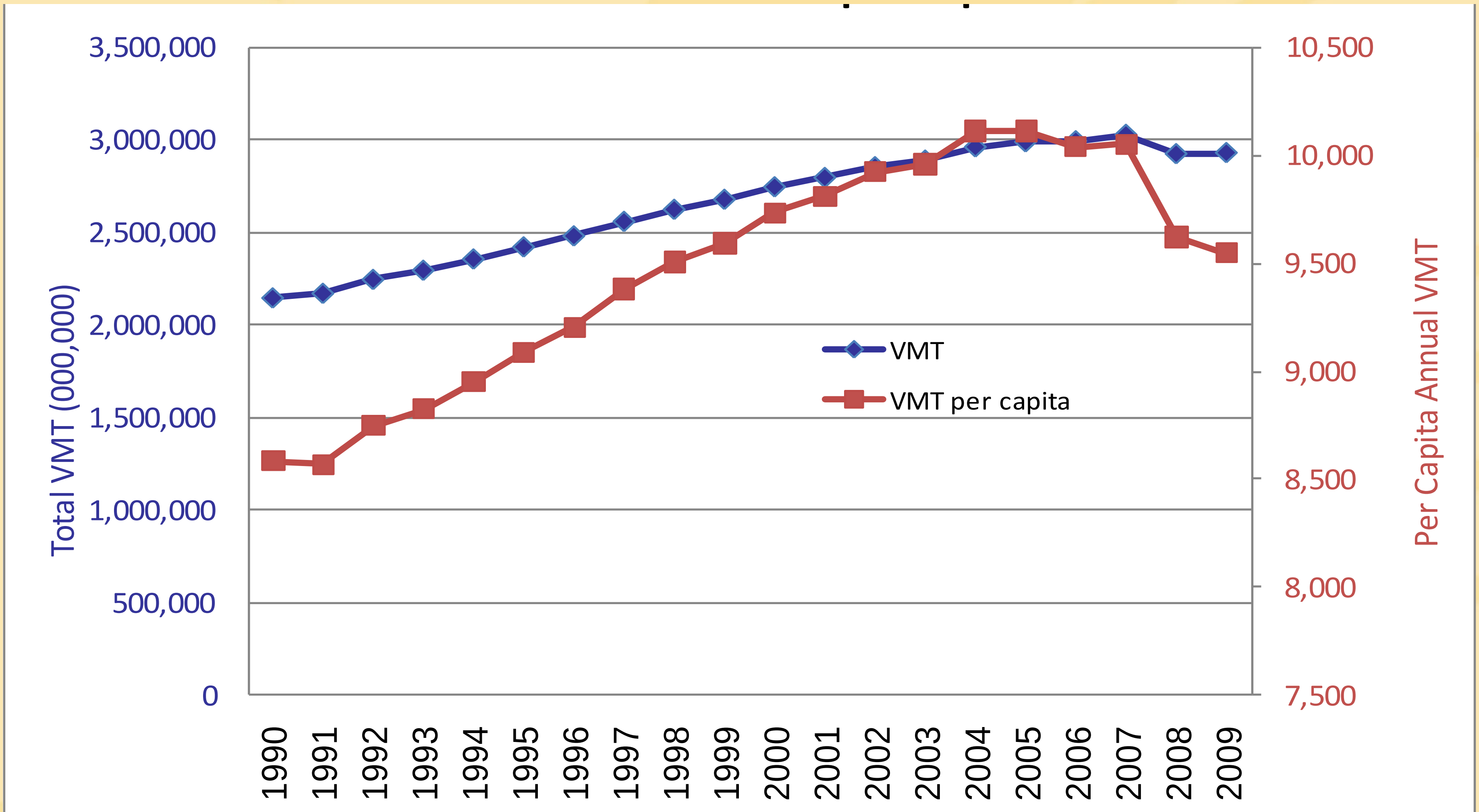
Mobility Implications

- 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

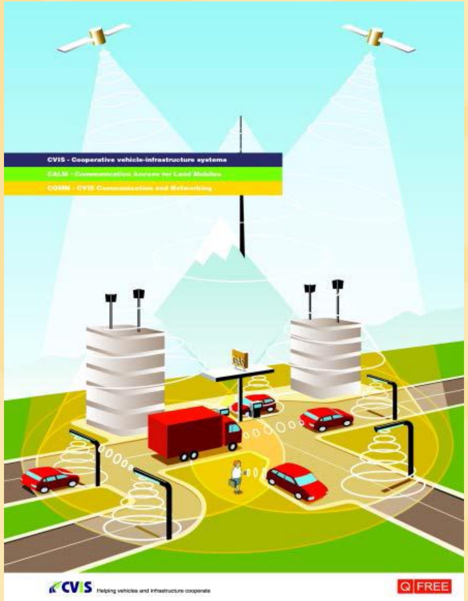
- Capacity enhancement
  - Vehicle platooning greatly increases density (reduced headways) and improves flow at transitions
  - Vehicle positioning (lateral control) allows reduced lane widths and utilization of shoulders; accurate mapping critical
  - Optimization of route choice, passage through intersections,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



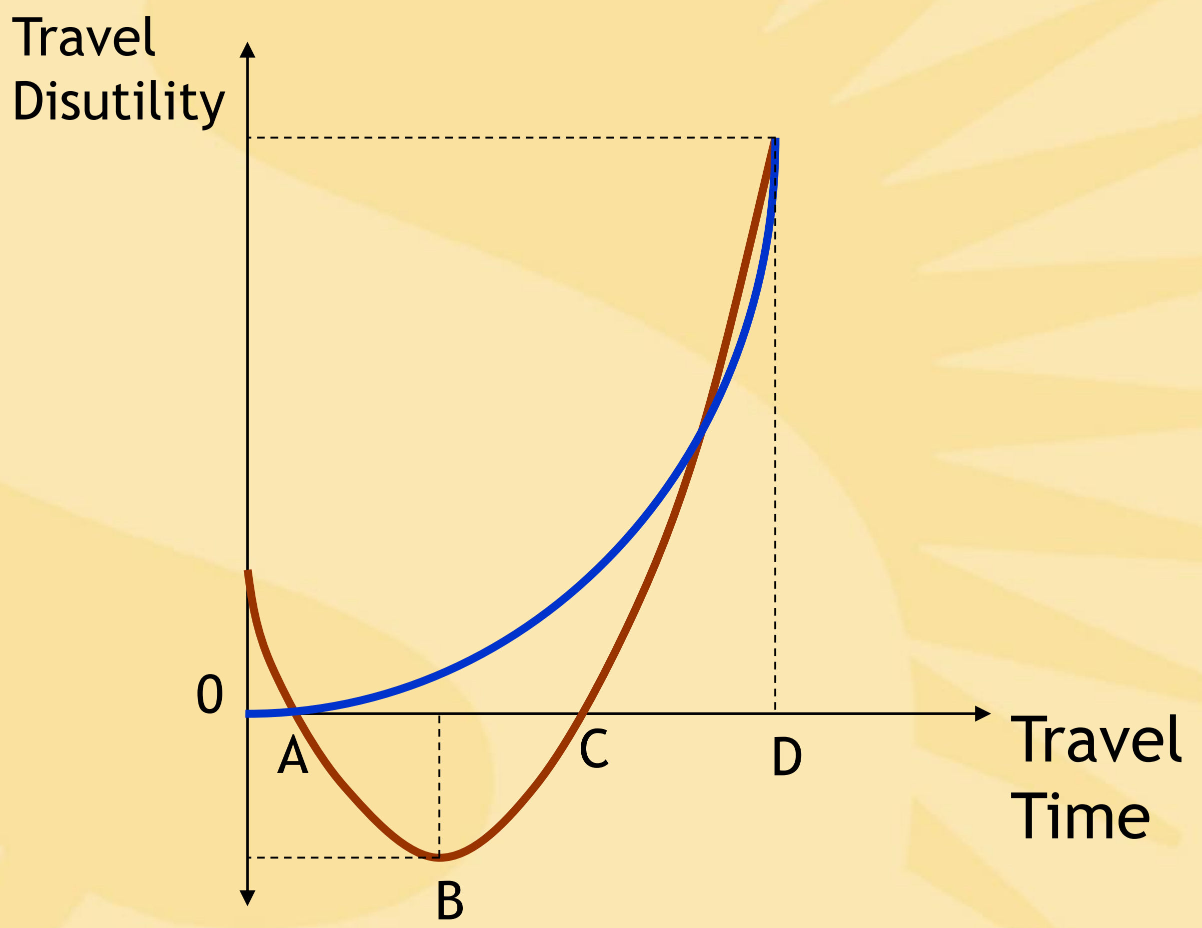
Location Choices

- 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

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