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Sustainable Transportation Solutions:

Can Automated Vehicles Help?

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Transportation

- personal mobility is an important part of a progressive society
- U.S.: the automobile has become essential element of life
- our mobility is often restricted due to limitations in transportation infrastructure
- resource management problem:
    - if resources (transportation infrastructure) are limited and demand is high, congestion occurs

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Major Transportation Issues:

- Safety
- Mobility (efficiency, throughput, congestion)
- Economics
- Environment, Energy (air quality, climate change)

Transportation Modes:

- moving people: walking, scooters, bicycles, cars & trucks (all sizes), buses, trains (+subways, monorail, etc.), ships, airplanes
- moving goods: walking, scooters, bicycles, cars & trucks (all sizes), buses, trains, ships, airplanes

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Transportation Safety:

- Unfortunately, approximately 34,000 people die annually on our roads today in the United States
- many more are injured
- equivalent to two major plane crashes per week
- the number of total miles driven continues to increase (VMT), but the deaths/injuries count remains about the same
- transportation in general is getting safer

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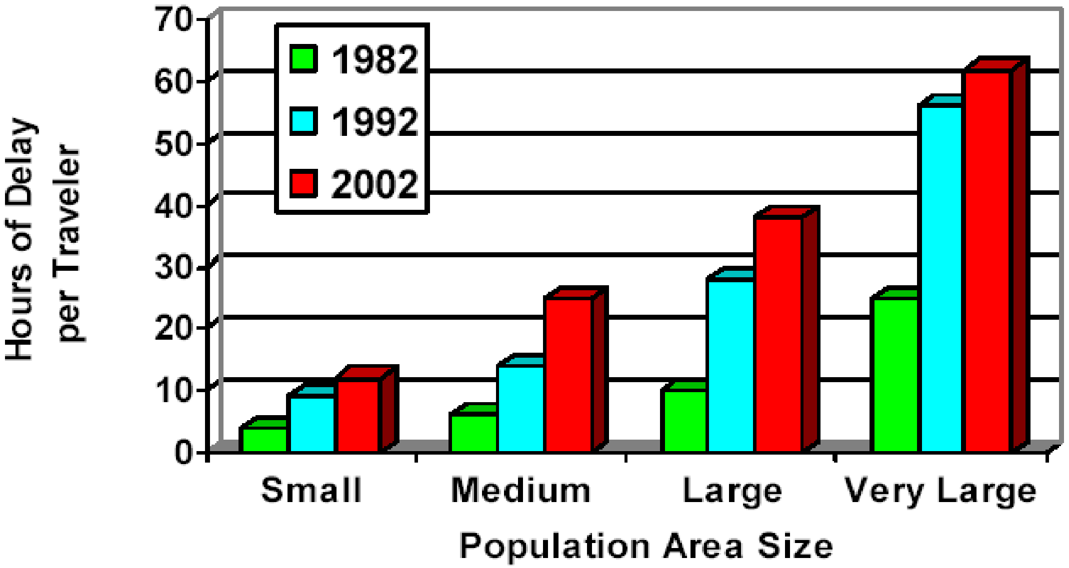
Roadway Congestion

- congestion has grown everywhere in cities of all sizes
- congestion occurs during longer portions of the day and delays more travelers and goods than ever before
- billions of gallons of fuel are wasted every year, more emissions
- Annual Mobility Study: http://mobility.tamu.edu/ums

“slow speeds caused by heavy traffic and/or narrow roadways due to construction, incidents, or too few lanes for the demand”



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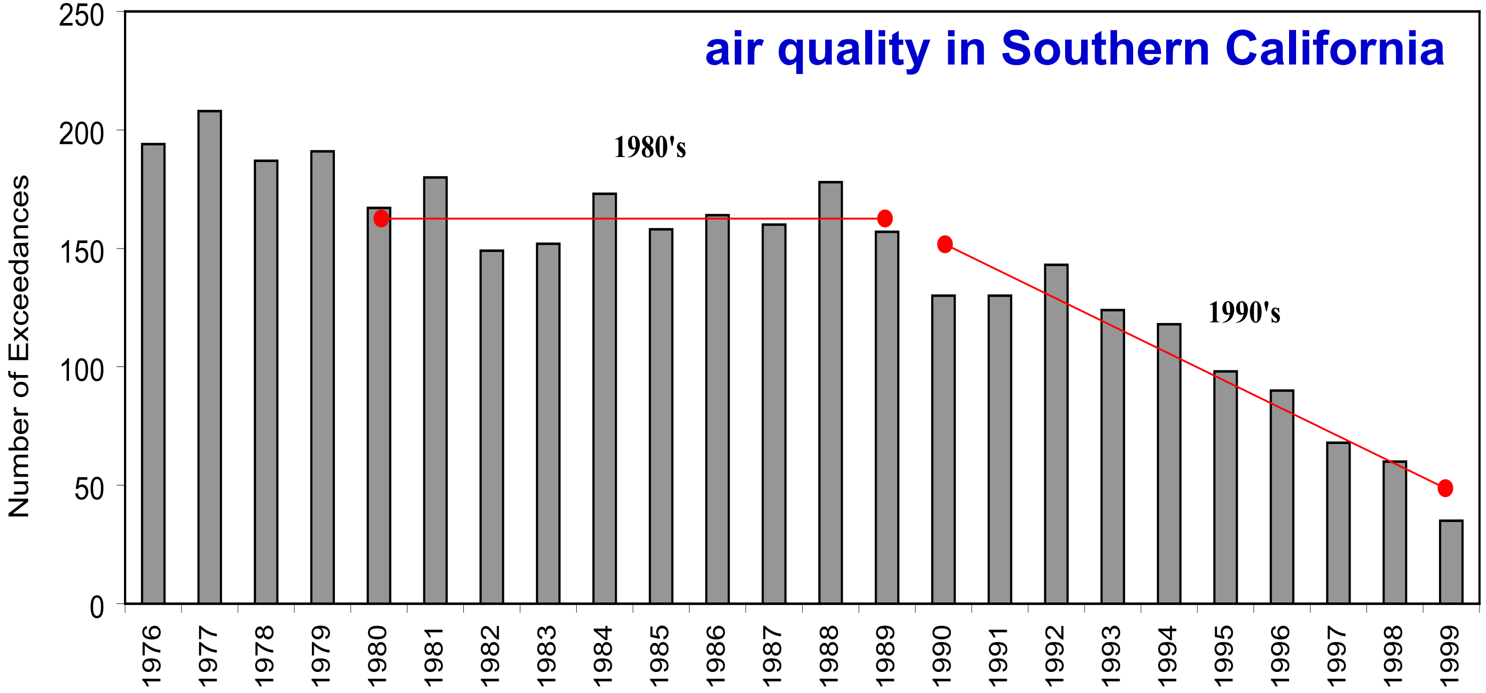
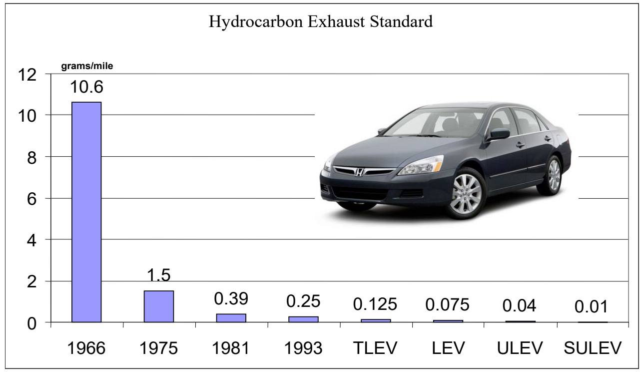
Air Quality





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Transportation: Energy and Greenhouse Gas Emissions

- **Increasing concern to stabilize greenhouse gases (GHG) to below levels emitted today (while still meeting energy needs)**
- **Transportation accounts for 40% of U.S. CO_2 emissions**
- **80% of transportation CO_2 comes from cars and trucks**

Primary Energy Carbon Intensity — **Efficiency** — **Total Demand**

$$\text{GHG Emission (MTCO2e per Year)} = \frac{\text{GHG (MTCO2e)}}{\text{Energy}} \times \frac{\text{Energy}}{\text{Mile}} \times \frac{\text{Miles}}{\text{year}}$$

Low Carbon Fuels — **Vehicle and Transportation Efficiency** — **Land Use, Transportation Planning**

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Approaches to Minimize Energy and Emissions Impacts of Transportation:

- **Build cleaner, more efficient vehicles:**
  - make vehicles lighter (and smaller) while maintaining safety
  - improve powertrain efficiency
  - develop alternative technologies (e.g., electric vehicles, hybrids, fuel-cell)

- **Develop and use alternative fuels:**
  - Bio and synthetic fuels (cellulosic ethanol, biodiesel)
  - electricity

- **Decrease the total amount of driving: VMT reduction methods**
  - Better land use/transportation planning
  - Travel demand management
- **Improve transportation system efficiency**
  - Intelligent Transportation System (ITS) technologies
  - Connected Vehicles → Vehicle Automation

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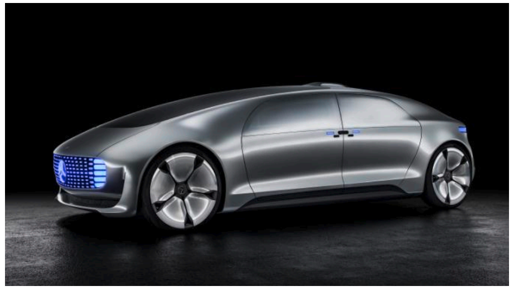
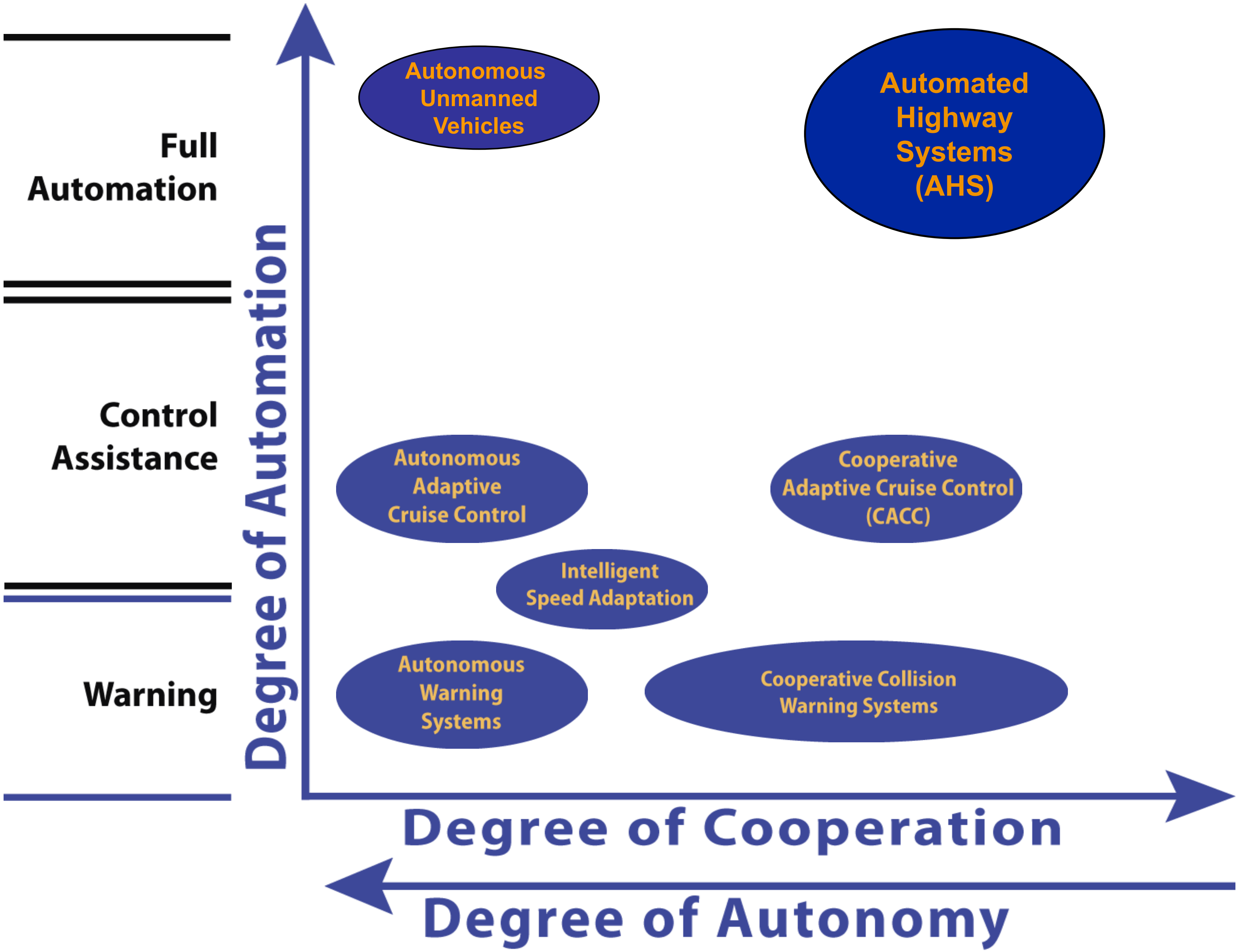
Automated/Autonomous Vehicle Technology

- **Automated/Autonomous vehicle**
  - **Capable of sensing its environment and navigation without human input, to fulfill the transportation needs of a traditional vehicle**
- **Sensing Technology**
  - **Radar, LiDAR, computer vision and sonar**
- **Control Systems Technology**
  - **Choosing speed and acceleration (longitudinal control)**
  - **Choosing lanes and turning (lateral control)**
- **Note that there are different levels of automation**



Automated versus Autonomous Vehicles



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Levels of Vehicle Automation

← driver — automated vehicle →

	0	1	2	3	4	5
	The driver constantly performs all aspects of the dynamic driving task. No systems intervene – only those that warn the driver.	The system can take over **either** steering **or** acceleration / deceleration. The driver must continuously carry out the other.	The system takes over **both** steering **and** acceleration / deceleration in a defined use case.	The system takes over both steering and acceleration / deceleration in a defined use case. It is capable of recognizing its limits and notifying the driver.	The driver can hand over **the entire driving task** to the system in a defined use case.	The system can take over the entire dynamic driving **task in all use cases**.
	The driver must constantly monitor the drive.	The driver must constantly monitor the drive. He must be ready to resume full control immediately.	The driver must constantly monitor the drive. He must be ready to resume control immediately.	The driver does not need to monitor the drive, but be ready to resume control within a given time frame if the system so requests.	The driver would not be required at all during these cases – neither for monitoring, nor as backup.	The driver is no longer required at all.

TERMINOLOGY

SAE (J3016)	No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
VDA*	Driver only	Assisted	Partly automated	Highly automated	Fully automated	Driverless
BASt	Driver only	Assisted	Partially automated	Highly automated	Fully automated	——
NHTSA**	0	1	2	3	3/4	

* used on this platform
** only roughly corresponding with the other taxonomies

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Vehicle Automation and Traffic System Operations

- In general, full or partial vehicle automation can help with traffic system operations
- Traffic operations with autonomous vehicles will not likely change much
  - Mobility and Environmental impacts will remain the same or could even get worse
  - Partial Automation Example: automated cruise control (ACC) has been shown to have negative traffic mobility impacts
- Traffic operations with connected automated vehicles will likely have a improved mobility and environmental impacts

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Mobility and Environmental Considerations of Connected and Automated Vehicles

Behavioral Effects: Explosion of Various Uses

- Likely to reduce the time cost of travel and thus increase vehicle travel and GHG emissions
- Engage in activities other than driving (e.g., work, entertainment, sleep, relax)
- Lowers physical and intellectual barriers to vehicle travel
- Young and disabled can travel alone
- Enables "passenger-less" travel (zero-occupancy vehicles)
- New empty vehicle relocation travel: return home, drop-off, pick-up
- Less on-street parking and increased roadway capacity

Mobility and Environmental Considerations of Connected and Automated Vehicles

Operational Effects:

- If done properly, there are several operational aspects that can decrease GHG emissions
- Potential congestion reductions
- Potential traffic smoothing
- Potential better speed management

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Driver's Behavior and Sensing
(and automation counterpart)

- Feeling
  - E.g. force of gravity, acceleration, deceleration (IMU)
- Seeing
  - Most important means of acquiring information on perceived objects and on traffic control messages (computer vision)
- Hearing (sensors and communications)
  - E.g. vehicle engine, tires, warning sounds.
  - Drivers having hearing problems can have 1.8 times more accidents than do driver with normal hearing.
- Smelling (sensors)
  - E.g. overheated engine, burning brakes, fires.

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Longitudinal Control

- No other cars: drive at a safe speed
- Other cars around: use Car-Following "Logic"
  - How does an individual vehicle follow another vehicle?
    - In a single stream of traffic
    - No overtaking
    - Maintains fail-safe distance
  - Generalized form (Gazis, 2002)

$$\ddot{x}_{n+1}\left(t+\Delta t_{n+1}\right)=\lambda\cdot\left[\dot{x}_{n+1}\left(t\right)\right]^{m}\cdot\frac{\left[\dot{x}_{n}\left(t\right)-\dot{x}_{n+1}\left(t\right)\right]}{\left[x_{n}\left(t\right)-x_{n+1}\left(t\right)\right]^{l}}$$

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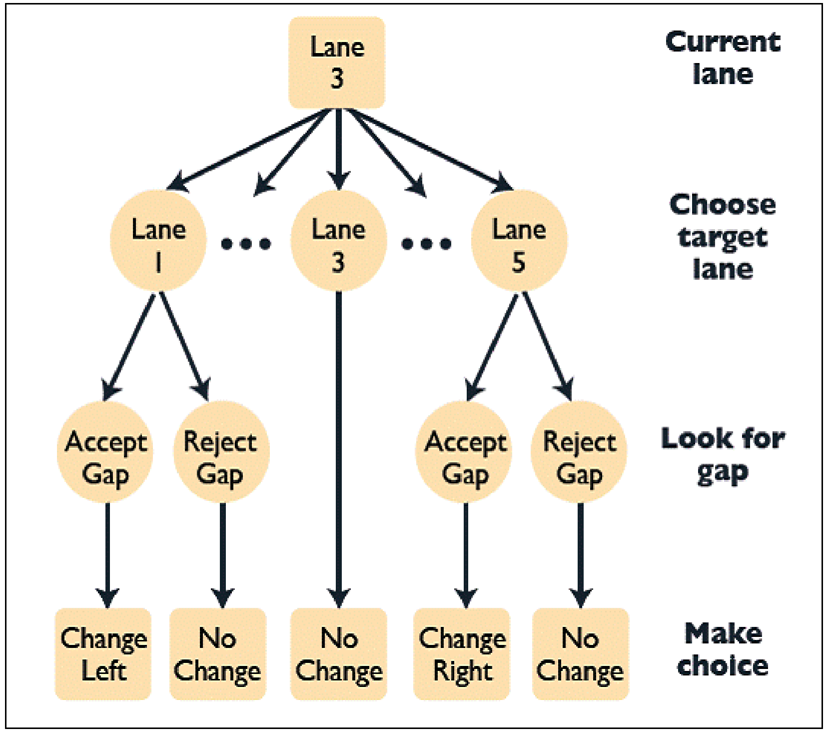
Lateral Control:

- Follow lanes on road
- Make turns at intersections
- Change lanes when necessary
- Lane change decisions:
  - Is it necessary?
  - Which lane?
  - Is it possible?: gap acceptance decision



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