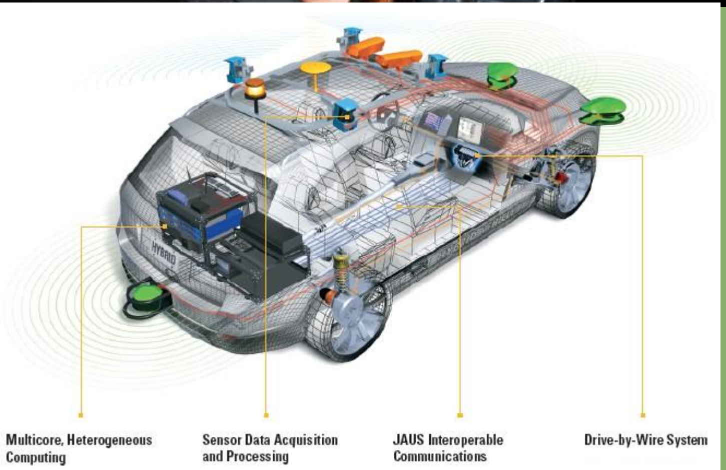

Autonomous Vehicle Implementation Predictions

Implications for Transport Planning

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Victoria Transport Policy Institute

Workshop 188

Activity-Travel Behavioral Impacts and Travel Demand Modeling Implications of Driverless Cars

TRB Annual Meeting

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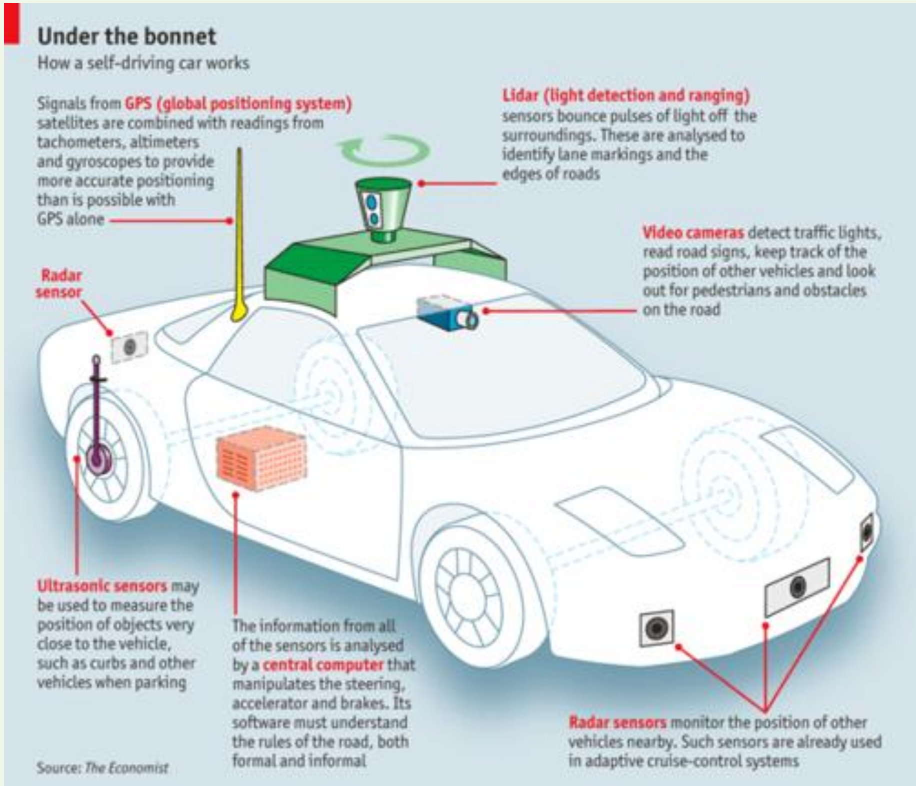
Practical Impacts

How will autonomous vehicles affect people's lives, and transport planning issues such as roadway and parking supply requirements, and crash rates?

Benefits	Costs/Problems
Reduced driver stress. Reduce the stress of driving and allow motorists to rest and work while traveling.	*Increases costs.* Requires additional vehicle equipment, services and maintenance, and possibly additional roadway infrastructure.
Reduced driver costs. Reduce costs of paid drivers for taxis and commercial transport.	*Additional risks.* May introduce new risks, such as system failures, be less safe under certain conditions, and encourage road users to take additional risks (offsetting behavior).
Mobility for non-drivers. Provide independent mobility for non-drivers, and therefore reduce the need for motorists to chauffeur non-drivers, and to subsidize public transit.	*Security and Privacy concerns.* May be vulnerable to information abuse (hacking), and features such as GPS tracking and data sharing may raise privacy concerns.
Increased safety. May reduce many common accident risks and therefore crash costs and insurance premiums. May reduce high-risk driving, such as when impaired.	*Induced vehicle travel and increased external costs.* By increasing travel convenience autonomous vehicles may induce additional vehicle travel, increasing external costs of parking, crashes and pollution.
Increased road capacity, reduced costs. May allow platooning (vehicle groups traveling close together), narrower lanes, and reduced intersection stops, reducing congestion and roadway costs.	*Social equity concerns.* May have unfair impacts, for example, if they lead to reduced convenience and safety of other modes.
More efficient parking, reduced costs. Can drop off passengers and find a parking space, increasing motorist convenience and reducing total parking costs.	*Reduced employment and business activity.* Jobs for drivers should decline, and there may be less demand for vehicle repairs due to reduced crash rates.
Increase fuel efficiency and reduce pollution. May increase fuel efficiency and reduce pollution emissions.	*Misplaced planning emphasis.* Focusing on technological solutions may discourage communities from implementing conventional but cost-effective transport projects such as pedestrian and transit improvements, and demand management strategies.
Supports shared vehicles. Could facilitate carsharing (vehicle rental services that substitute for personal vehicle ownership), which can provide various savings.	

Equipment Requirements

- Automatic transmissions.
- Diverse and redundant sensors (optical, infrared, radar, ultrasonic and laser) capable of operating in diverse conditions (rain, snow, unpaved roads, tunnels, etc.).
- Wireless networks. Short range systems for vehicle-to-vehicle communications, and long-range systems to access to maps, software upgrades, road condition reports, and emergency messages.
- Navigation, including GPS systems and special maps.
- Automated controls (steering, braking, signals, etc.)
- Servers, software and power supplies with high reliability standards.
- Additional testing, maintenance and repair costs for critical components, such as automated testing and cleaning of sensors.



Shared Vehicles (Autonomous Taxis)

Many motorists may prefer to own their vehicles for identity.

Self-driving taxis prices will probably be somewhere between that of carsharing ($0.60- $1.00 per vehicle-mile, which reflect the average costs to own and operate vehicles, plus some administrative costs) and human-operated taxis ($2.00-3.00 per vehicle-mile, which include vehicle ownership, operation, administration, plus dispatch and driver labor costs).

Self-driving taxis are likely to incur, at least sometimes, the following additional costs:

- *Additional vehicle travel to trip origins.*

- *Cleaning and vandalism.* Assuming that vehicles make 200 weekly trips, 5-15% of passengers leave messes with $10-30 average cleanup costs, and 1-4% vandalize vehicles with $50-100 average repair costs, these costs would average between $200 and $1,700 per vehicle-week.

- *Reduced comfort and privacy.* To minimize vandalism self-driving taxis will probably have less comfort (no leather upholstery or carpeted floors), fewer accessories, and less reliability (for more frequent cleaning and repairs) than personal vehicles.

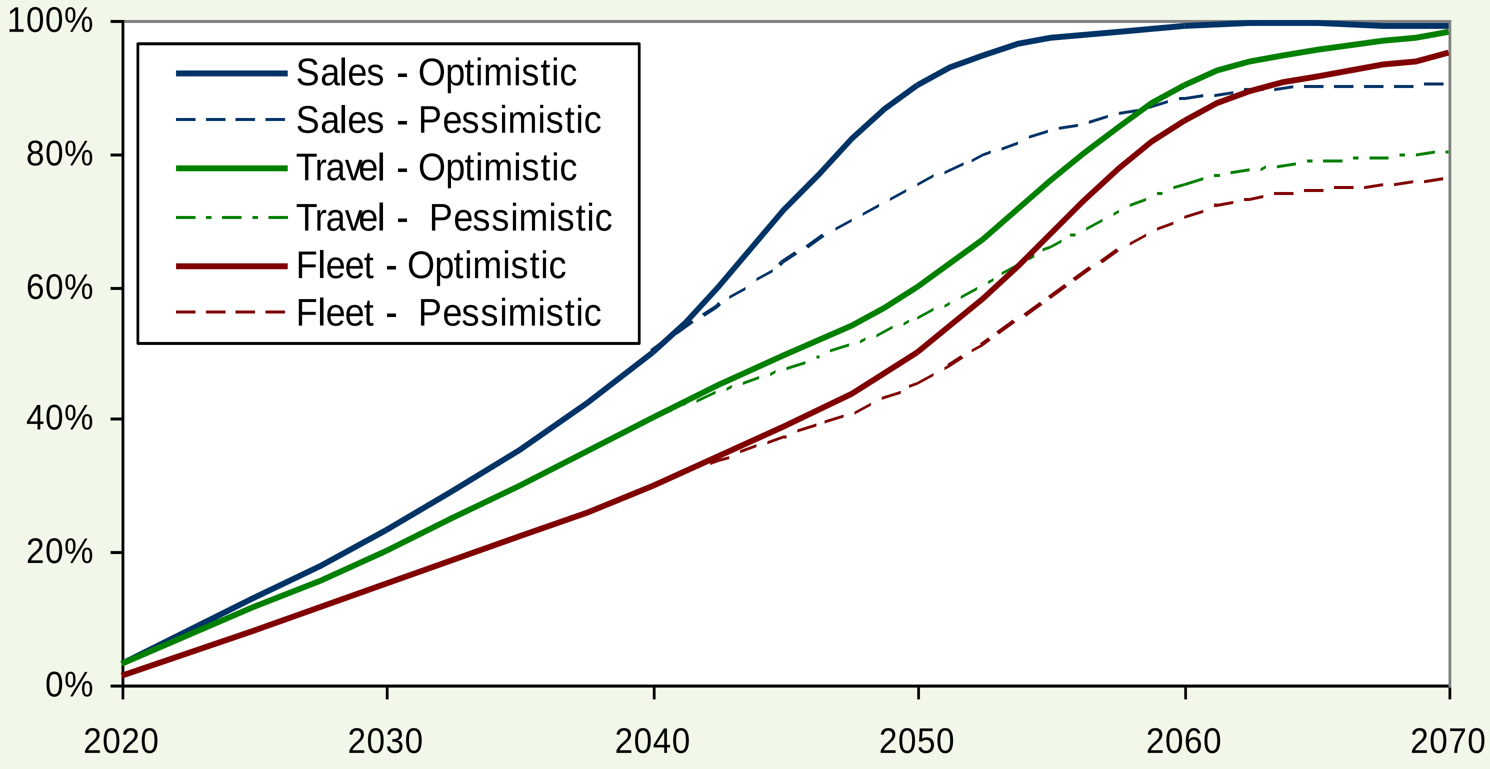
Stage	Notes
Level 2 – Limited automation (steering, braking and lane guidance)	This is the current state of art, available on some new vehicles.
Coordinated platooning	Currently technically feasible but requires vehicle-to-vehicle communications capability, and dedicated lanes to maximize safety and mobility benefits.
Level 3 – Restricted self-driving	Currently being tested. Google experimental cars have driven hundreds of thousands of miles in self-drive mode under restricted conditions.
Level 4 – Self-driving in all conditions	Requires more technological development.
Regulatory approval for automated driving on public roadways.	Some states have started developing performance standards and regulations that autonomous vehicles must meet to legally operate on public roads.
Fully-autonomous vehicles available for sale.	Several companies predict commercial sales of "driverless cars" between 2018 and 2020, although their capabilities and prices are not specified.
Autonomous vehicles become a major portion of total vehicle sales.	Will depend on performance, prices and consumer acceptance. New technologies usually require several years to build market acceptance.
Autonomous vehicles become a major portion of vehicle fleets.	As the portion of new vehicles with autonomous driving capability increases, their portion of the total vehicle fleet will increase over a few decades.
Autonomous vehicles become a major portion of vehicle travel.	Newer vehicles tend to be driven more than average, so new technologies tend to represent a larger portion of vehicle travel then the vehicle fleet.
Market saturation.	Everybody who wants an autonomous vehicle has one.
Universal	All vehicles operate autonomously.

Previous Vehicle Technologies

Name	Deployment Cycle	Typical Cost Premium	Market Saturation Share
Air bags	25 years (1973-98)	A few hundred dollars	100%, due to federal mandate
Automatic transmissions	50 years (1940s-90s)	$1,500	90% U.S., 50% worldwide
Navigation systems	30+ years (1985-2015+)	$500 and rapidly declining	Uncertain; probably over 80%.
Optional GPS services	15 years	$250 annual	2-5%
Hybrid vehicles	35+ years (1997-2003+)	$5,000	Uncertain. Currently about 4%.

Experience with previous technologies can provide a guide to deployment cycles and market saturation rates of autonomous vehicles.

Implementation Projections



Stage	Decade	Vehicle Sales	Veh. Fleet	Veh. Travel
Available with large price premium	2020s	2-5%	1-2%	1-4%
Available with moderate price premium	2030s	20-40%	10-20%	10-30%
Available with minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature included on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation (everybody who wants it has it)	2060s	?	?	?
Required for all new and operating vehicles	???	100%	100%	100%

Many Factors Affect Future Demands

Demographic Trends

Aging population

More working at home

Reduced youth drivers' license

Price Changes

Rising fuel prices

Efficient road & parking pricing

Improved Travel Options

Better walking and cycling

Improved public transit

Telework and delivery services

Carsharing

Changing User Preferences

Less driving

Shared rather than personal vehicles

More walking & cycling

More urban living

Intelligent Transport Systems (ITS)

Improved user information/navigation

Electronic pricing

Autonomous vehicles

Planning Innovations

Expanded objectives

Systems operations

Demand management

Transport Planning Prediction Timeline

2010s

Develop performance and data collection requirements for autonomous vehicles operating on public roadways.

2020s

Support large-scale autonomous vehicle testing. Evaluate their benefits and costs under actual operating conditions.

2030s

Study, and where appropriate support, autonomous vehicle implementation for specific applications such as taxi, carsharing and demand response services.

2040s

If autonomous vehicles prove to be effective and common, consider dedicating some highway lanes to their use.

2050s

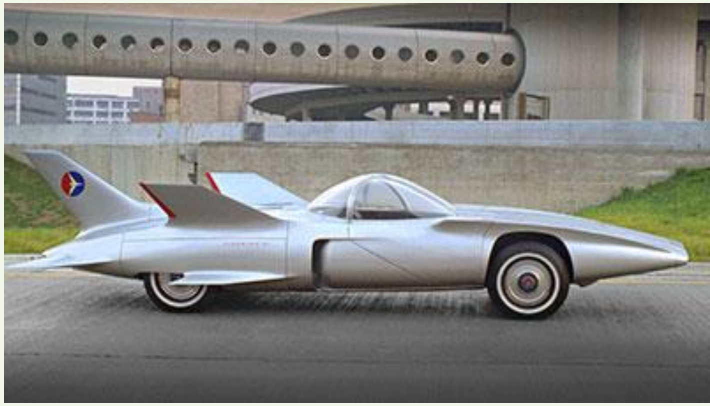
If autonomous vehicles prove overall beneficial and are the majority of vehicles, it may be possible to change roadway design and management practices.

2060s+

If autonomous vehicles prove to be very beneficial, it may be appropriate to restrict human-driving.

Conclusions - Deployment

- This analysis suggests that autonomous vehicles will have only modest impacts on transport planning issues such as road and parking supply, and public transit demand for the next few decades.
- If they follow previous vehicle technology development and deployment patterns, they will initially be costly and imperfect.
- During the 2020s and perhaps the 2030s, they are likely to be expensive novelties with limited abilities. It will probably be the 2040s or 2050s before middle-income families can afford to purchase autonomous vehicles that can safely chauffeur non-drivers, and longer before they are affordable to lower-income households.
- It is possible that a significant portion of motorists will prefer to drive their vehicles so traffic will mixed, creating new roadway management problems.



Conclusions – Deployment Costs

- Vehicle innovations tend to be implemented more slowly than for other technological change due to their high costs, strict safety requirements, and slow fleet turnover.
- Automobiles typically cost fifty times and last ten times as long as much as personal computers and mobile phones, so consumers seldom purchase new vehicles simply to obtain a new technology.
- Large increases in new vehicle purchase, expenditure and scrappage rates would be required for most vehicles to be autonomous before 2050.

Conclusions – Benefits and Costs

- There is considerable uncertainty concerning autonomous vehicle benefits, costs and travel impacts.
- They will require additional equipment, services and maintenance that will probably increase user costs by hundreds or thousands of dollars per vehicle-year.
- Advocates may exaggerate net benefits by ignoring new costs and risks, *offsetting behavior*, *rebound effects*, and harms to people who do not to use the technology, such as reduced public transit service.
- Benefits are sometimes double-counted by summing increased safety, traffic speeds and facility savings.

Conclusions – Planning Issues

- Whether they total vehicle travel increases or declines. It could go either way.
- The degree potential benefits can be achieved when only a portion of vehicle travel is autonomous. Some benefits, such as improved mobility for affluent non-drivers may occur when autonomous vehicles are relatively uncommon and costly, but many potential benefits require that most or all vehicles on a road operate autonomously.
- Whether this technology may harm people who do not use such vehicles, for example, if increased traffic volumes and speeds degrade walking and cycling conditions, conventional public transit service declines, or human-operated vehicles are restricted.

Victoria Transport Policy Institute

“Evaluating Non-Motorized Transportation Benefits and Costs”

“Autonomous Vehicle Implementation Projections”

“Transportation Cost and Benefit Analysis”

“New Transportation Planning Paradigm”

“The Future Isn’t What It Used To Be”

“Online TDM Encyclopedia”

and more…

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