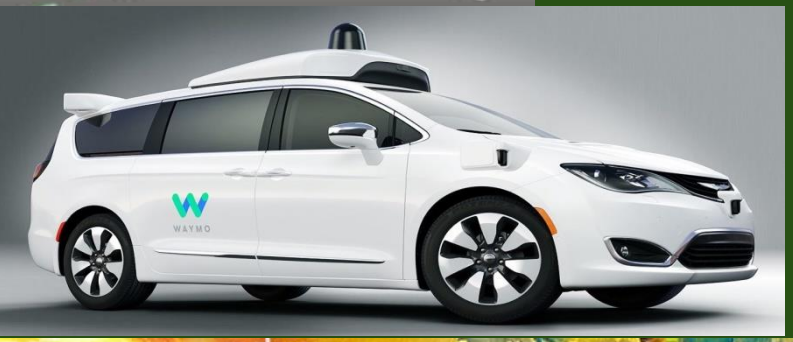

Autonomous Vehicle Implementation Predictions

Implications for Transport Planning

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Presented

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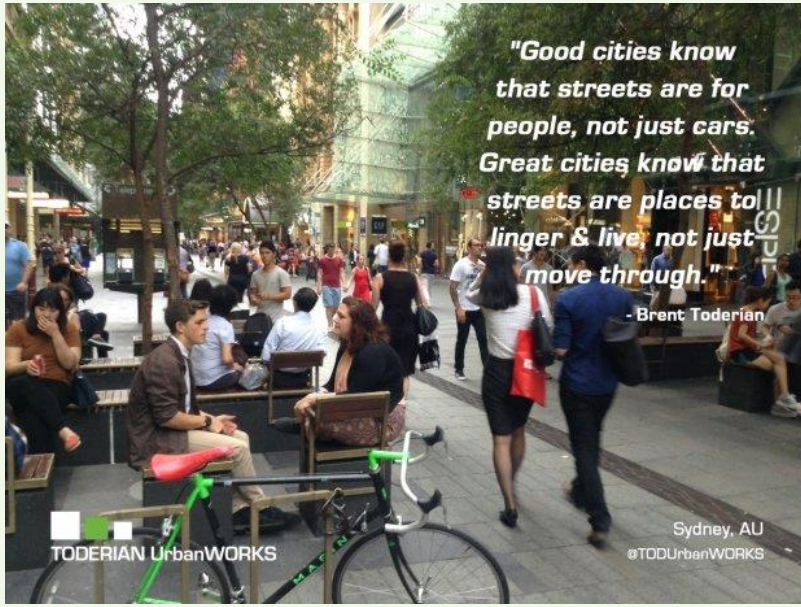
Smart Growth Network

29 May 2020

Why Transportation is Important

- 60-90 daily minutes
- 15-25% of household budgets
- Affects affordability and economic opportunities
- Affects development costs and location
- Streets are the main public realm
- Affects local economic productivity
- Affects health and safety
- External costs (congestion, accident risk and pollution)



Past Visions of Future Transport

1949 ConvAIRCAR Flying Car

Segways

Jet Pack

2001 Moon Service

Supersonic Concord (1976-2003)

Wheeled Luggage

What About Autonomous Vehicles?

How will autonomous vehicles affect individuals and communities?

How should transport, parking and urban planning change?

Levels of Autonomy

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

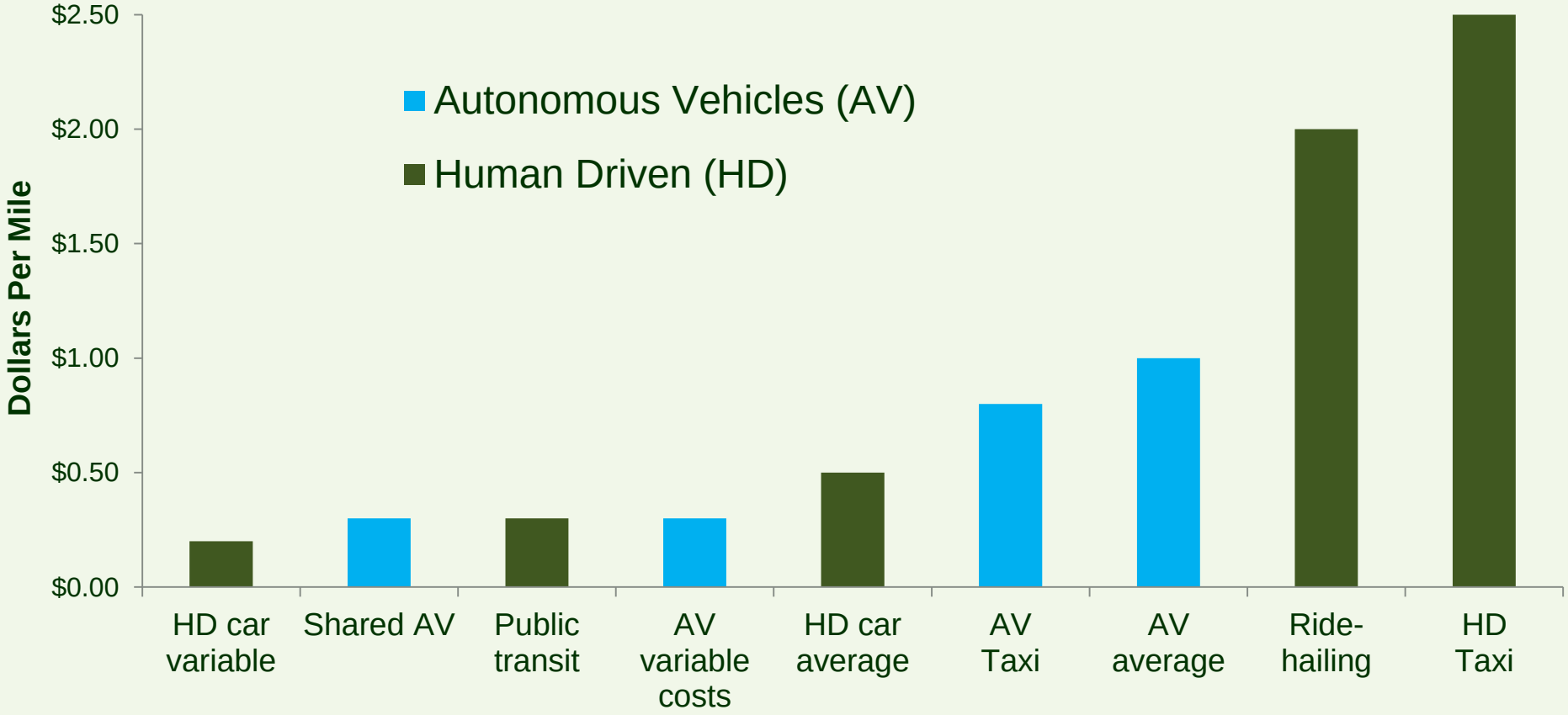
Operational Models

	Advantages	Disadvantages	Appropriate Users
Personal autonomous vehicles - Motorists use their own self-driving vehicles	Maximum convenience and response speed.	High costs. Users cannot choose different vehicles for different types of trips.	People who travel a lot, reside in sprawled areas, want a particular vehicle, or leave items in their vehicles.
Shared autonomous vehicles – Autonomous taxis transport individuals and groups	Moderate convenience. Cheaper than owned vehicles and faster than micro-transit.	Users must wait for vehicles. Limited service (no driver to help passengers and ensure safety) and privacy.	Lower-annual-mileage users.
Shared autonomous mobility - Self-driving micro-transit takes several passengers to or near destinations.	Cheapest option.	Least convenience, comfort and speed, particularly in sprawled areas.	Lower-income urban residents.

Direct User Benefits

- Less stress.
- Cost savings compared with paid human drivers.
- More productivity during travel.
- Independent mobility for non-drivers.

Cost Comparison

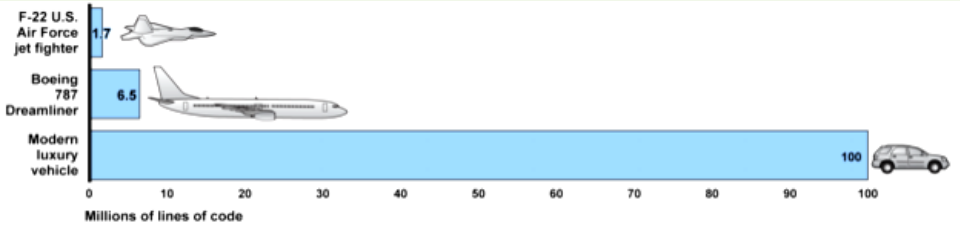


Safety Impacts

Advocates predict that, because human error contributes to 90% of all traffic crashes, autonomous vehicles will reduce crashes by 90%.

This overlooks additional risks these technologies introduce.

Hardware and software failures. Complex electronic systems can fail. Self-driving vehicles will certainly have errors that cause crashes; the question is how frequently.



Malicious hacking. Self-driving technologies can be manipulated for amusement or crime.

Increased risk-taking. When travellers feel safer they tend to take additional risks, for example, reduced seatbelt use and less caution by other road users.

Platooning risks. Many potential benefits, such as reduced congestion and pollution emissions, require platooning. This can introduce new risks.

Increased total vehicle travel. Autonomous driving may increase total vehicle travel and therefore crashes.

Traffic Congestion Impacts

Autonomous driving may increase traffic congestion:

- Increases total vehicle travel.
- It is often cheaper to drive on public roads than pay for urban parking.
- May reduce public transit services.

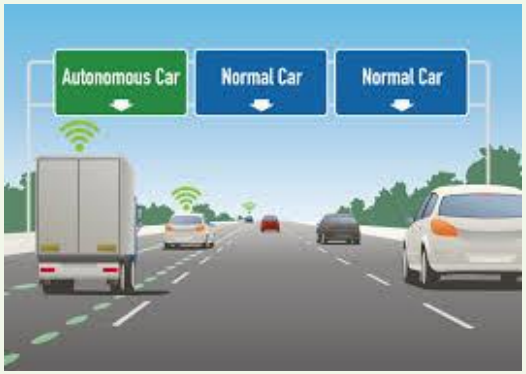
Bus

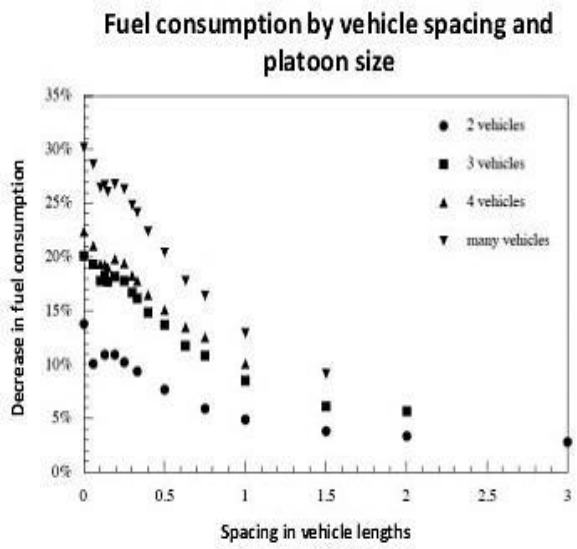
Human-Driven Cars

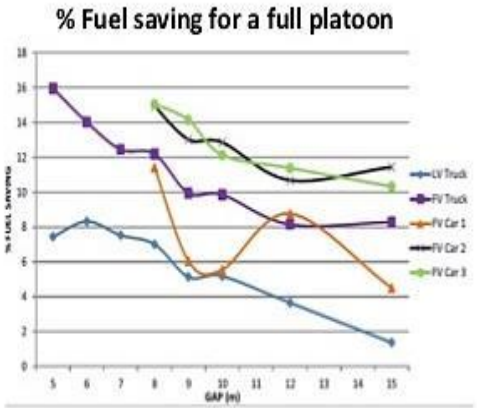
Self-Driving Cars

Benefit Requirements

- Many benefits, such as reducing congestion and pollution, and improved mobility for non-drivers, require that level 4-5 vehicles become common and affordable.
- Reduced congestion, energy consumption and pollution emissions require *platooning*, with vehicles travelling a few meters apart on dedicated highway lanes.







The above graph is based on measurements performed on a demonstrator system consisting of five vehicles: a lead truck (LV), a following truck (FV), and three following cars.

Owned Versus Shared Vehicles

Many projected benefits depend on vehicle sharing, but motorists have reasons to own their cars:

- **Convenience.** Motorists often keep items in their vehicles, such as car seats, tools, and other supplies.
- **Response speed**. In suburban and rural areas, taxi response can be slow and unreliable.
- **Costs.** Vehicle sharing is generally only cost effective for motorists who drive less than about 6,000 annual miles. Most higher annual mileage drivers will own their cars.
- **Cleaning and vandalism.** Autonomous taxis will lack privacy and comfort features.
- **Status.** Many drivers are proud of their skills and vehicles, and so may prefer to own and drive personal cars.

Once the novelty wears off, autonomous taxies will probably seem tedious and inferior, like elevator or economy air travel.

Equipment Costs

- Requires high-quality and redundant sensors, computers, controls, plus subscriptions to high-quality maps and specialized maintenance.

- This will add several thousand dollars to vehicle purchase prices, plus a hundreds of dollars in annual maintenance and service costs, probably increasing annual costs by $1,000 to $3,000.

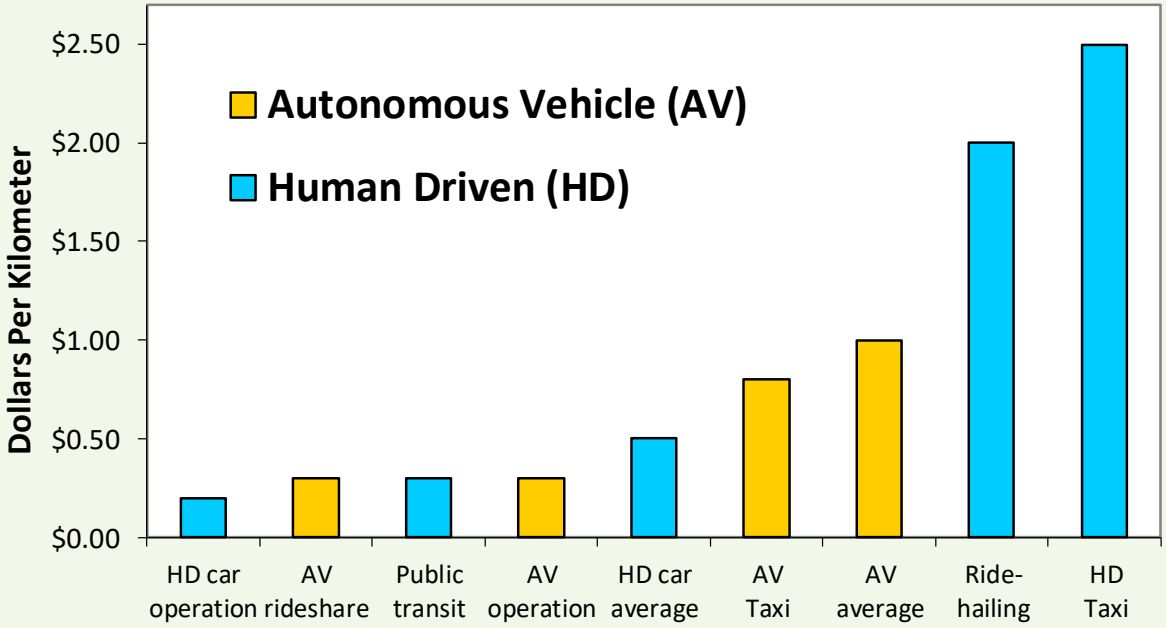
- These incremental costs may be partly offset by fuel and insurance savings.

Typical Operating Costs

Some advocates predict that autonomous taxi fares will cost less than 20¢/km, but this ignores:

- Cleaning
- Maintenance
- Empty vehicle-kilometers
- Roadway costs
- Profits

Actual costs will probably be higher.



Autonomous vehicle travel will probably cost somewhat less than current human-operated taxis or ride-hailing services (Uber and Lyft), but more than current automobile travel.

Travel Impacts

Increases Vehicle Travel	Reduces Vehicle Travel
• Provides vehicle travel to non-drivers (people who are disabled, young or impaired). • Increased convenience and productivity increases travel. • Empty vehicle travel when dropping off or picking up passengers • Encourage sprawled development. • Reduces traffic congestion and vehicle operating costs.	• Convenient shared vehicle services reduce vehicle ownership and use. • Increases vehicle ownership and operating costs. • Self-driving buses improve transit services. • Reduced traffic risk and parking facilities make urban living more attractive. • Reduces some vehicle travel, such as cruising for parking.

Autonomous driving can increase vehicle travel in some ways and reduce it in others. Total impacts will depend on the public policies implemented in a jurisdiction. This will affect external costs including congestion, roadway subsidies, accident risk and pollution emissions.

Costs Compared

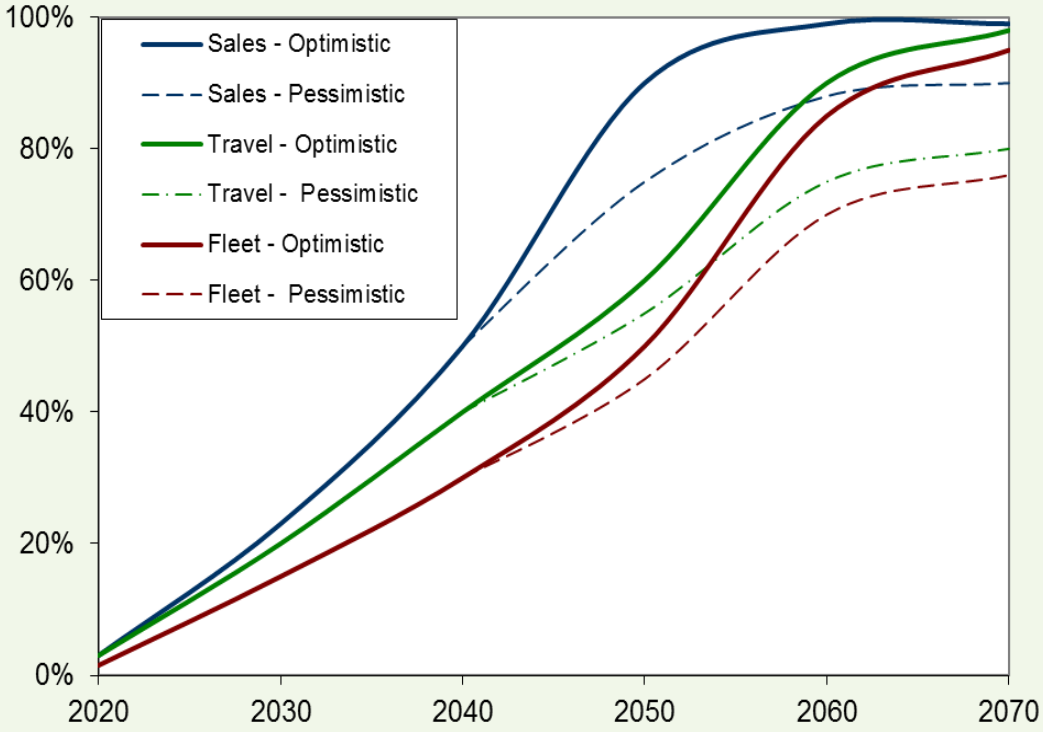
	Private Human-driven Vehicle	Private Autonomous Vehicle	Shared Autonomous Vehicle	Shared Autonomous Ride
Financial costs	Low fixed costs (particularly used cars), moderate variable.	High fixed costs, low variable costs.	Minimal fixed costs, moderate variable costs.	Minimum fixed costs, low variable costs.
Convenience	High. A private vehicle is available any time.	High. A private vehicle is available any time. Provides vehicle travel to non-drivers.	Moderate. Vehicles will often require several minutes to arrive. Provides door-to-door service.	Moderate. Collecting passengers will often take several minutes. Does not provide door-to-door service.
Comfort	Low to moderate, depending on driving conditions.	High. Users have their own vehicles with chosen amenities.	Moderate. Shared, vehicles may be abused.	Lowest. Travelers share vehicles with strangers.
External costs (congestion, facilities, crashes and pollution)	Moderate to high.	High. Likely to increase total vehicle travel which will increase external costs.	Moderate. May increase total vehicle travel in some circumstances and reduce it in others.	Lowest. Can reduce total vehicle travel and associated costs
Most appropriate uses	Moderate- and low-income suburban and rural residents.	Affluent suburban and rural residents	Suburban and urban travelers.	Urban travelers.

	Benefits	Costs/Problems
Internal (user Impacts)	*Reduced drivers' stress and increased productivity.* Reduces stress and allows motorists to rest, play and work while travelling. *Mobility for non-drivers.* Provides independent mobility for non-drivers which can reduce motorists' chauffeuring burdens and public transit subsidy needs. *Reduced driver costs.* Reduces costs of paid drivers for taxis and commercial transport.	*Increased vehicle costs.* Requires additional vehicle equipment, services and fees. *Additional user risks.* Additional crashes may be caused by system failures, platooning, higher travel speeds, additional risk-taking (offsetting behavior) and increases in total vehicle travel. *Reduced security and privacy.* May be vulnerable to information abuse (hacking), and features such as location tracking and data sharing may reduce privacy.
External (Impacts on others)	*Increased safety.* May reduce crash risks and insurance costs. May reduce high-risk driving. *Increased road capacity and reduced costs.* More efficient vehicle traffic may reduce congestion and roadway costs. *Reduced parking costs.* Reduces demand for parking at destinations. *Increase fuel efficiency and reduce pollution.* May increase fuel efficiency and reduce pollution emissions. *Supports vehicle sharing.* Could facilitate carsharing and ridesharing, helping to reduce total vehicle ownership and travel, and associated costs.	*Additional risk to others.* Additional crash risk may harm other road users. *Increased traffic problems.* By inducing additional vehicle travel, traffic congestion, pollution and sprawl-related costs may increase. *Reduced security.* May be used for criminal and terrorist activities (e.g. bomb delivery and crashes). *Social equity concerns.* May have unfair impacts, for example, by reducing convenience and safety of non-auto travel. *Reduced employment and business activity.* Jobs for drivers may decline. *Reduced support for other solutions.* Optimistic predictions of autonomous driving may discourage implementation of other transport improvements and management strategies.

Autonomous vehicles can provide various user benefits and costs, and external impacts on other people.

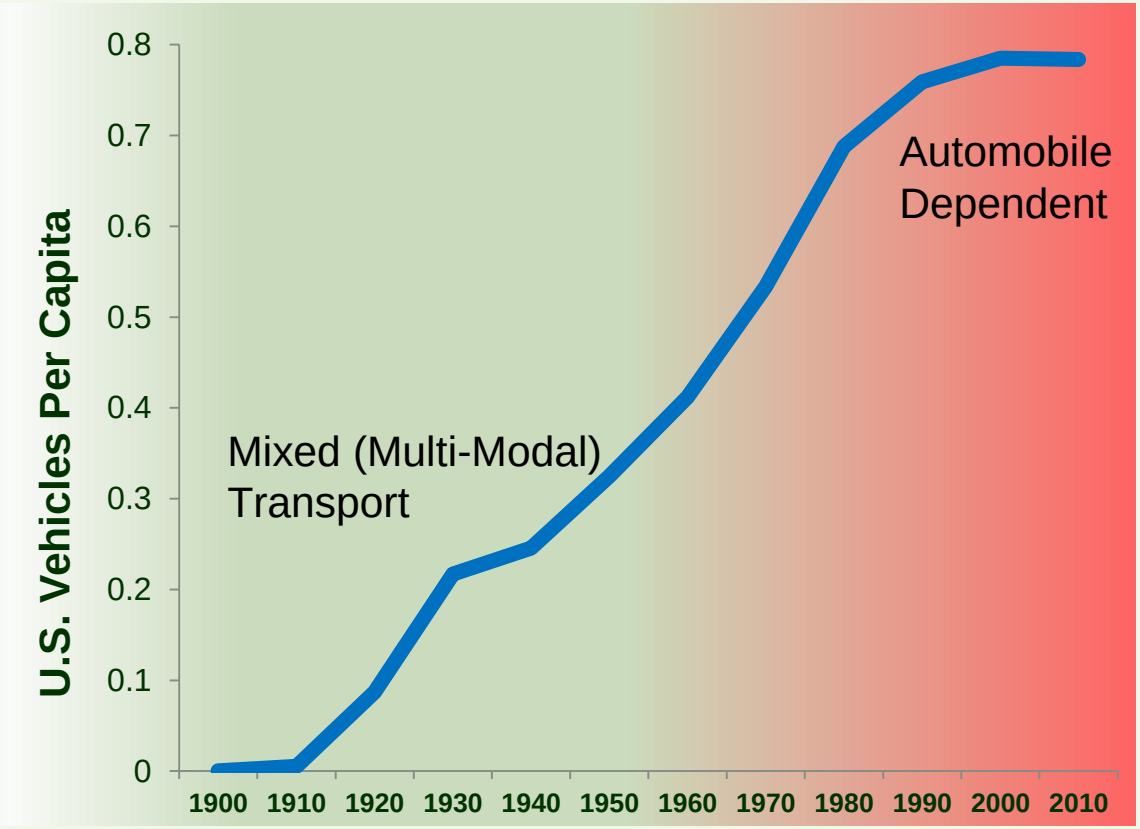
Implementation Projections

If autonomous vehicle implementation follows previous vehicle technology patterns it will take one to three decades to dominate vehicle sales, plus one or two more decades to dominate vehicle travel, and even at market saturation it is possible that a significant portion of vehicle traffic will continue to be self-driven, indicated by the dashed lines.



U.S. Automobile Market Saturation

Although mass automobile production started in 1908, for the next half century the transportation system was mixed. Only after the 1960s did most potential drivers own a personal vehicle, and only after 1980 did ownership approach saturation.



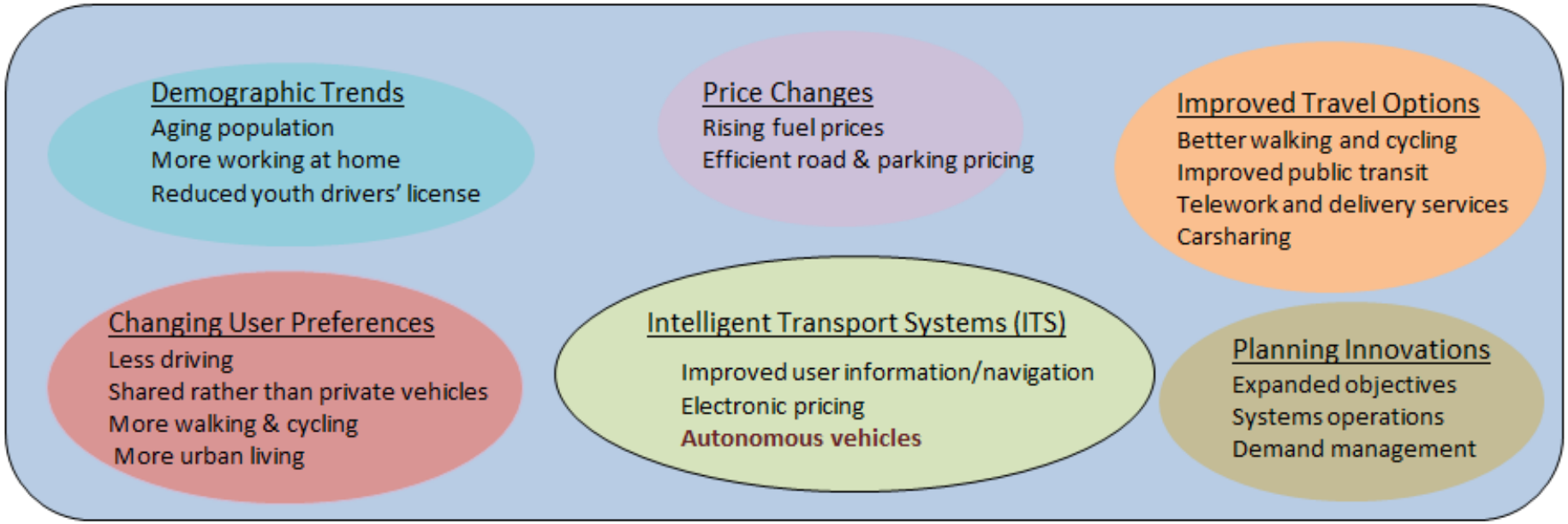
Heaven and Hell (Robin Chase)

Heaven	Hell
• More vehicles are shared so total vehicle ownership declines. • Self-driving cars help create a more diverse and efficient transport system. • Walking, cycling and public transit conditions improve. • Less total vehicle travel. • Total transport costs decline.	• Most autonomous vehicles are privately-owned. • Support for walking, cycling and public transit services decline. Transport systems become more auto-dependent. • Total vehicle travel increases. • Traffic problems (congestion, accidents, pollution, user costs) increase.

Heaven requires policies that create more diverse and efficient transport systems:

- *More efficient road and parking pricing.*
- *Increased walking, cycling and public transit investments.*
- *Reduced parking requirements in zoning codes.*

Many Transport Planning Issues



Types of Benefits

Autonomous Vehicle Types	Mobility for Non-drivers	Reduced Driver Stress	User Savings	Occupant Safety	External Benefits
Level 1-4 private vehicles		✓		?	
Level 5 private vehicles	✓	✓		✓	?
Shared autonomous vehicles	✓		✓		✓
Shared autonomous rides	✓		✓		✓
Dedicated AV lanes			✓		?

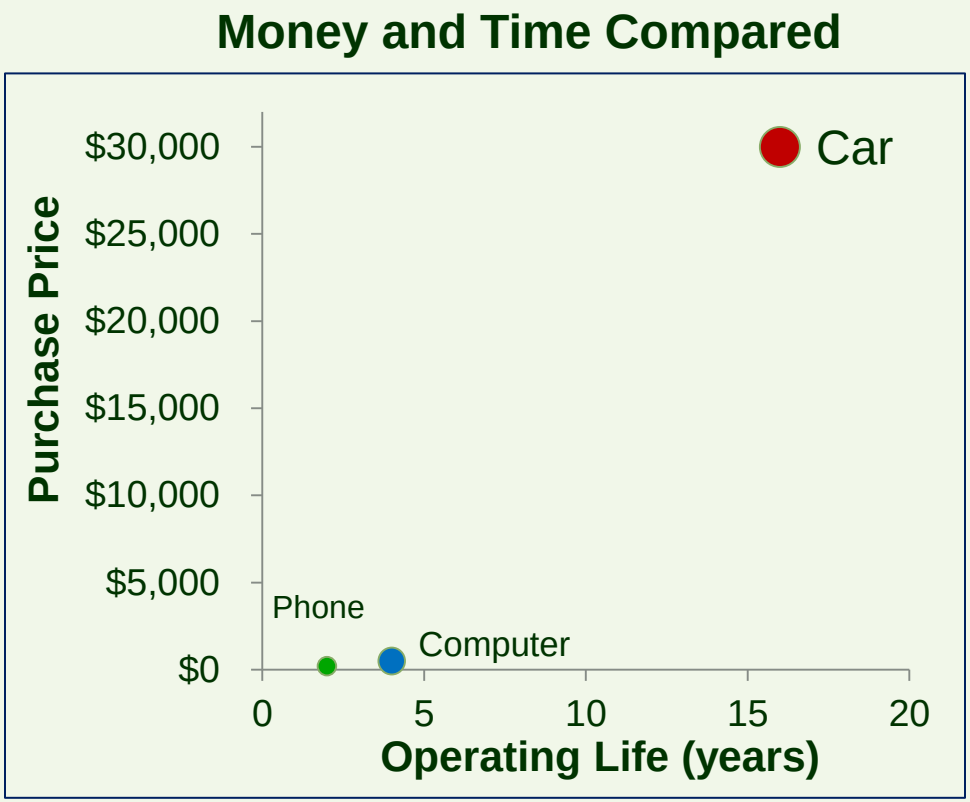
Shared Mobility Principles

(www.sharedmobilityprinciples.org)

1. Plan our cities and their mobility together.
2. Prioritize people over vehicles.
3. Support shared and efficient use of vehicles, lanes, curbs, and land.
4. Engage with stakeholders.
5. Promote equity.
6. Lead the transition towards a zero-emission future and renewable energy.
7. Support fair user fees across all modes.
8. Aim for public benefits via open data.
9. Work towards integration and seamless connectivity.
10. In urban areas autonomous vehicles should only operate in shared fleets.

Conclusions – Deployment

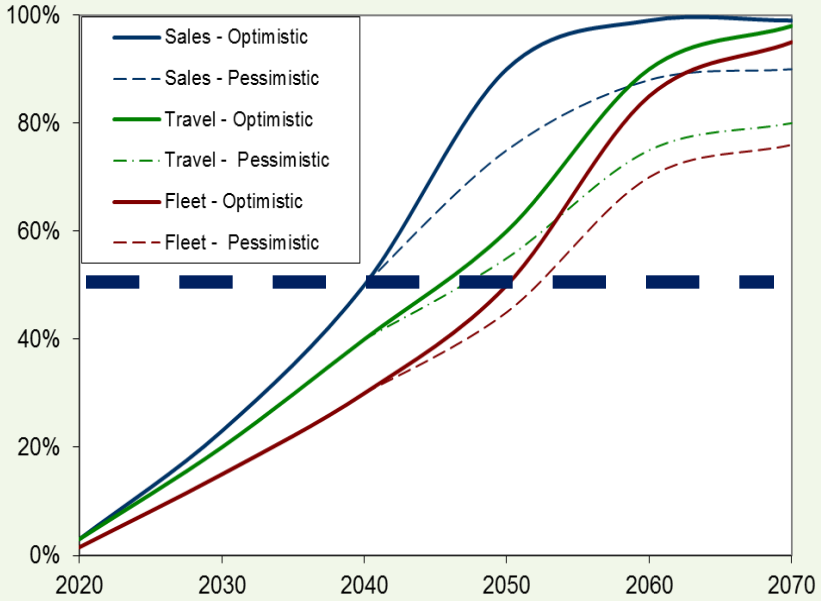
- Autonomous vehicles will initially be costly and imperfect.
- Vehicle innovations are implemented more slowly than for other technological change due to high costs, strict safety requirements, and slow fleet turnover.



Automobiles cost fifty times as much and last ten times as long as personal computers and mobile phones, so consumers seldom purchase new vehicles simply to obtain a new technology.

Conclusions - Development

- During the 2020-30s they are likely to be expensive novelties with limited abilities. It will probably be the 2040s before most middle-income families can purchase reliable and affordable autonomous vehicles, and longer before lower-income households can own them.
- Some people may prefer driving. Saturation levels are uncertain and depend on public policies.
- It is unlikely that most vehicles to be autonomous before 2050 unless many functional vehicles are scrapped to accelerate deployment.



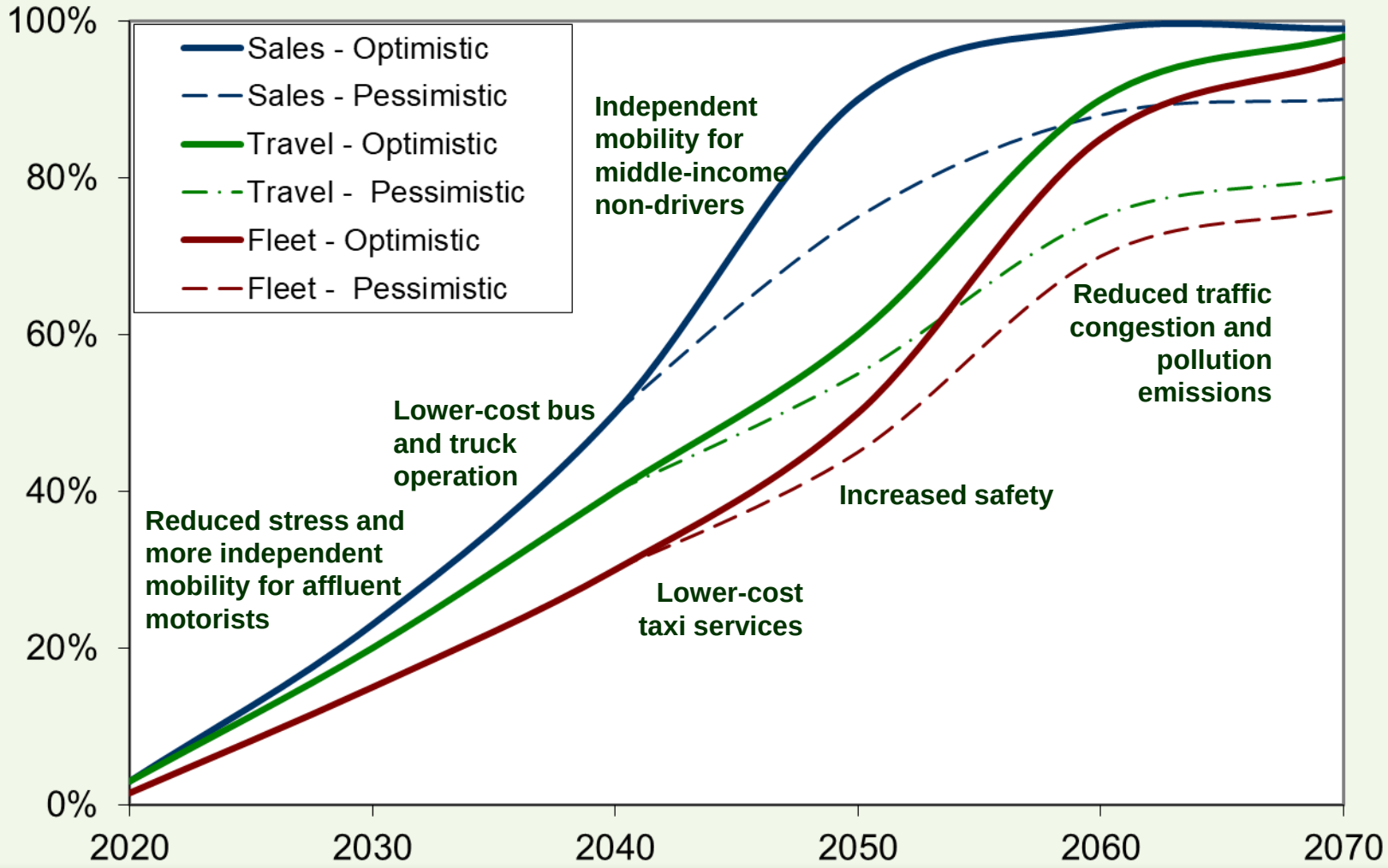
Conclusions – Deployment

- Vehicle innovations tend to be implemented more slowly than for other technological change due to high costs, strict safety requirements, and slow fleet turnover.
- Automobiles cost fifty times as much and last ten times as long as personal computers and phones. Consumers seldom purchase new vehicles simply to obtain new technologies.
- Many people may probably prefer human-operated vehicles.
- It is unlikely that most vehicles to be autonomous before 2050 unless large numbers of functional vehicles are scraped to accelerate deployment.

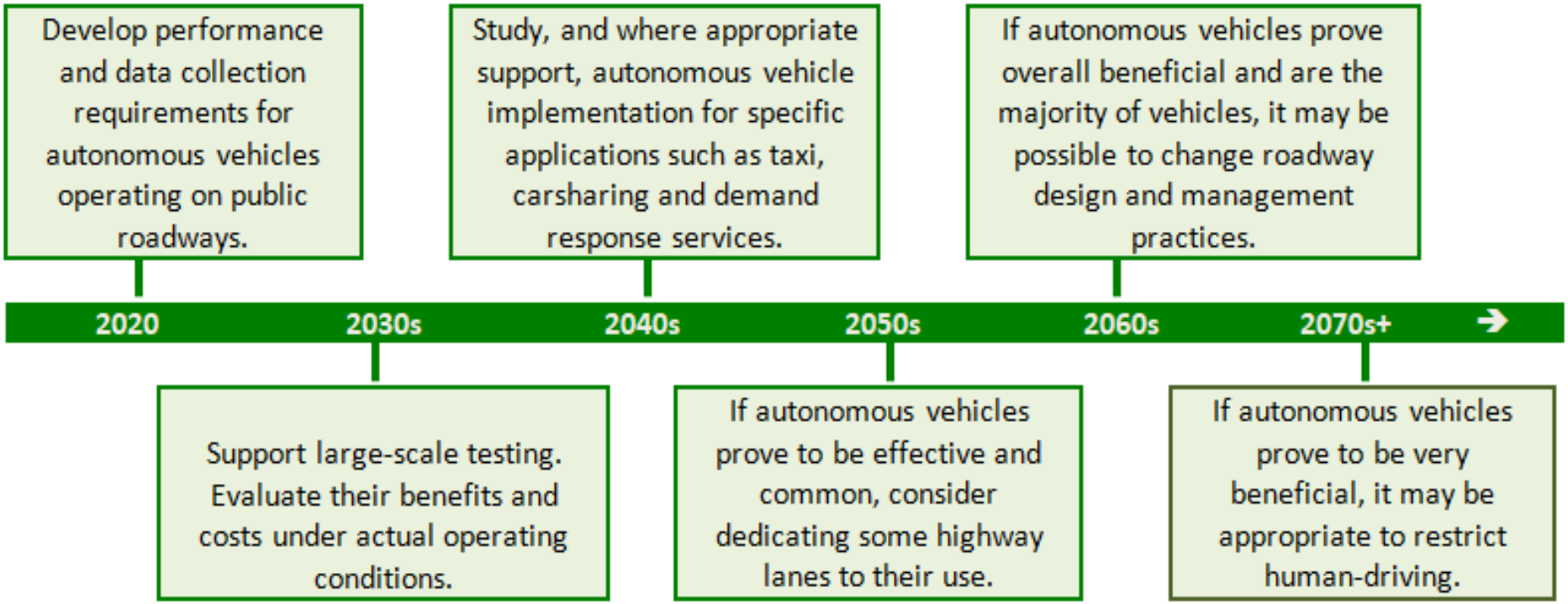
Conclusions – Benefits and Costs

- There is considerable uncertainty concerning autonomous vehicle benefits, costs and travel impacts.
- Recent predictions that autonomous vehicles will soon be cheap and ubiquitous, and by 2030 will displace most private vehicle travel, are mostly by people with financial interests in the industry based on experiences with disruptive telecommunications technologies
- Advocates often exaggerate net benefits by ignoring new costs and risks, rebound effects, and harms to people who do not to use the technology.

Benefit Projections



Planning Issues Time-Line



This timeline summarizes how autonomous vehicles are likely to impact transport planning.

Benefits Are Contingent

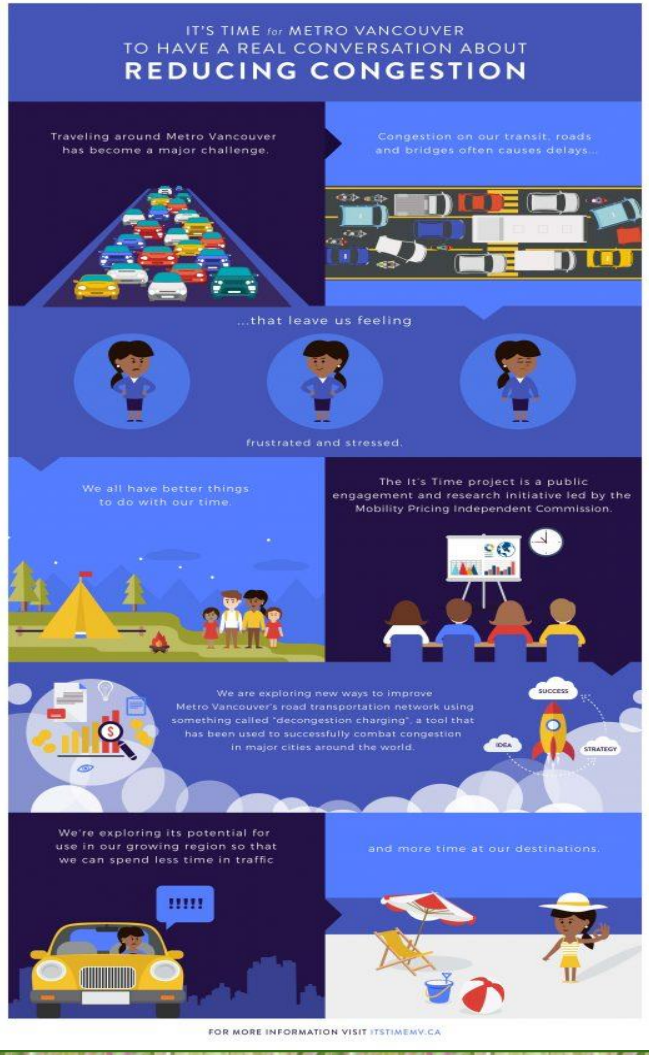
Many expected benefits (reduced congestion, parking costs and pollution emissions) require **dedicated autonomous vehicle lanes**, plus **shifts from owned to shared vehicles**. There are costs and constraints to both of these, and they will depend on public policies and consumer preferences.

Conclusions – Planning Issues

- **Congestion and pollution.** If they stimulate more vehicle travel, self-driving vehicles can increase congestion and pollution, except where they have dedicated lanes.
- **Roads and parking.** Shifts from owned to shared vehicles can reduce parking and roadway demands, and vehicles can park further from destinations.
- **Crashes.** They reduce some risks but increase others. Net safety benefits will depend on policies.
- **Mobility for non-drivers.** They can improve mobility for affluent non-drivers, but many non-drivers may be worst off if they increase urban traffic or cause public transit disinvestment.
- **Road and curb rights.** Cities should manage road space and curb rights for efficiency and fairness.

Policy Recommendations

- Test and regulate new technologies for safety and efficiency.
- Require autonomous vehicles to be programed based on ethical and community goals.
- Efficiently regulate and price roads and curb space to favor shared vehicle use.
- Support high capacity public transit on major travel corridors.
- Reduce parking requirements to take advantage of shared vehicles.
- Plan and price to prevent inefficient sprawl.



“Toward More Comprehensive and Multimodal Evaluation”

“Autonomous Vehicle Implementation Projections”

“Transportation Cost and Benefit Analysis”

“New Transportation Planning Paradigm”

“The Future Isn’t What It Used To Be”

“A New Traffic Safety Paradigm”

“Online TDM Encyclopedia”

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