

The Three Transportation Revolutions

... and what to do about them

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Transportation System is Broken...Not Sustainable

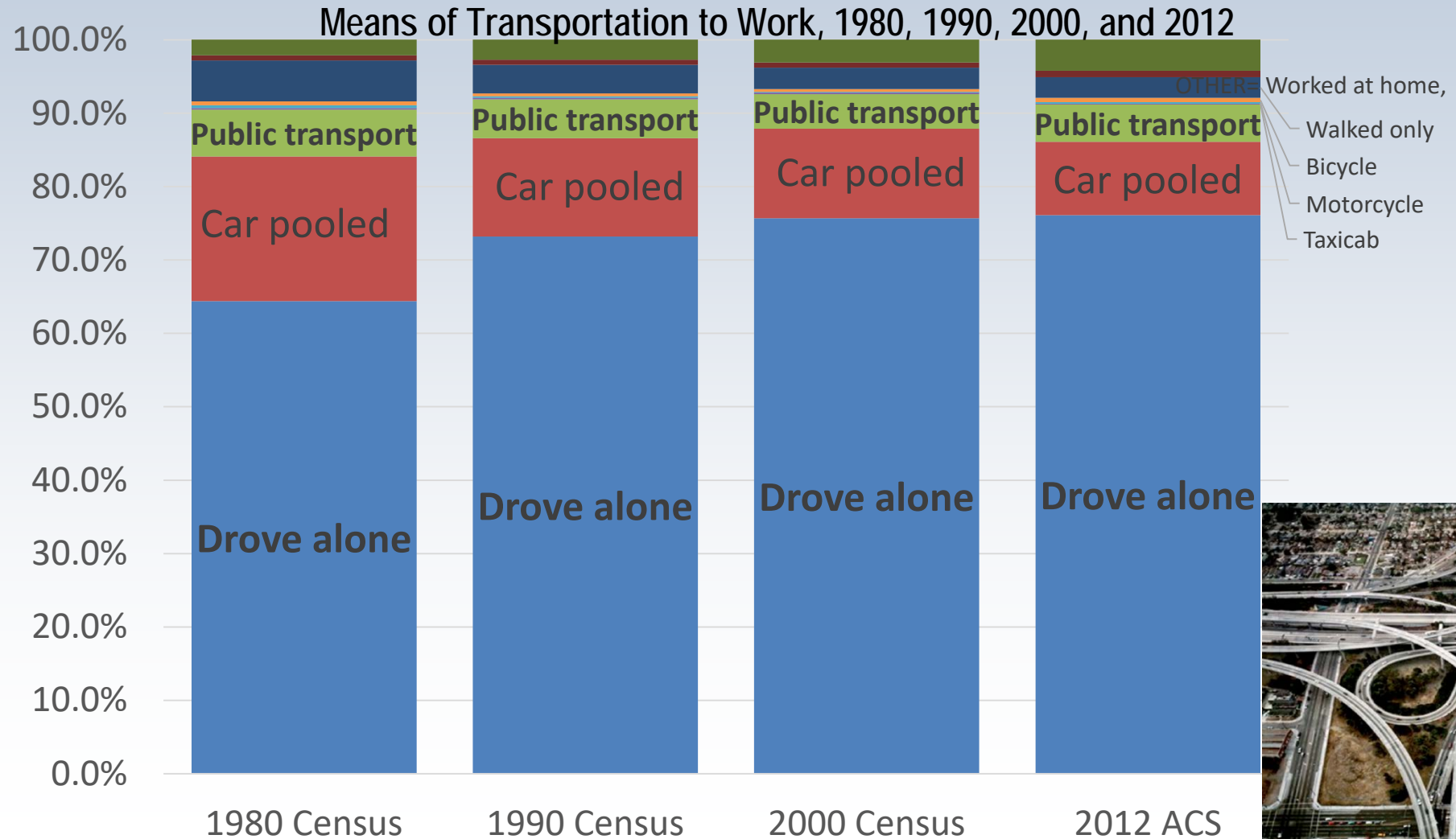
Cities and Lifestyles are Too Car-Centric

Car-Centric LA
I-105 & I-110 with HOV Flyover



Outcome: Transport Monoculture in US

- ✓ Solo driving highest in history
- ✓ Carpooling lowest in history (despite huge investment in HOV lanes)
- ✓ Public transport = 1% of PMT (~5% of work trips)



Car-Centric Monoculture is Extraordinarily Expensive and Resource-Intensive

- Road Infrastructure Cost
 - Over \$100 billion/yr (US)
 - Plus other infrastructure costs to support sprawl
- Personal Cost
 - \$5000-\$9000/year to own and operate a car (US)
 - Car sits idle 95% of time
 - Total = \$1+ trillion/yr (US)
- Oil
 - 70% of oil consumption (USA)
 - \$300-\$500 billion/yr
- Climate Change
 - 1/3 of GHGs (US)
- Air Pollution
 - Half of urban air pollution



Rest of World is Following

Car-Centric Brasilia



Source: Kennedy, MIT

...and Minimal “Systems” Innovation for 5+ Decades
Previous Transport “Revolutions”

Movement of People

1. Streetcars (~1890)
2. Automobiles (Oil) (~1910)
3. Airplanes (~1930)
4. Limited access highways (~1930s...1950s)

Movement of Goods

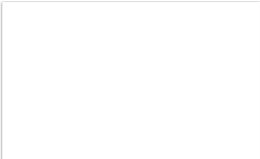
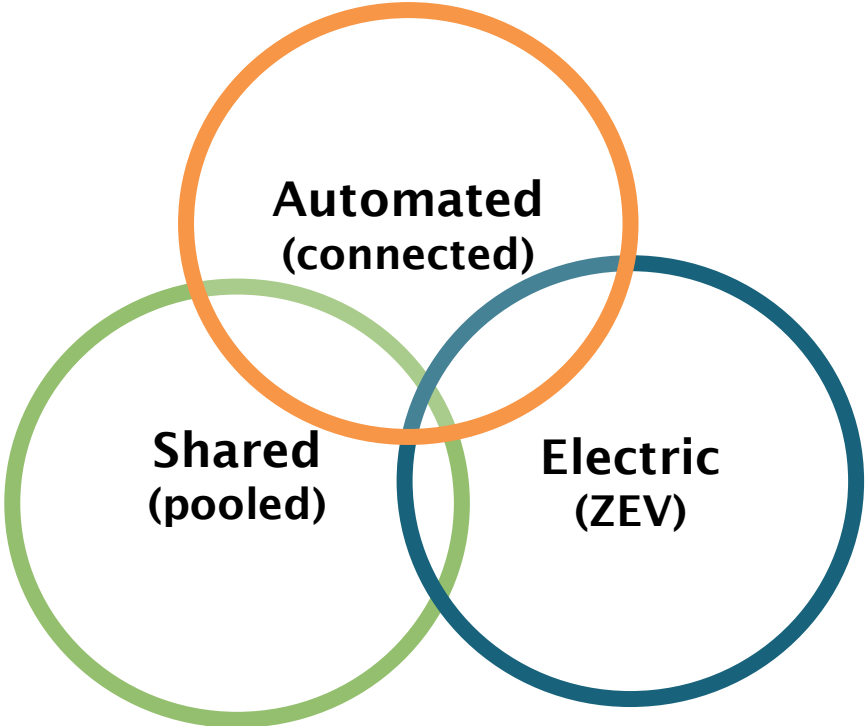
1. Canals (~1800)
2. Railroads (~1830)
3. Trucks (Oil) (~1910)
4. Airplanes (~1930)
5. Containers (~1950)

How to Create Cheaper, Better, More Sustainable Transport?

My LA epiphany



Electrification + Automation + Pooling = ?!



EV Revolution Underway..... Question of When, Not If

Recent Announcements by Automakers and Politicians (2017-18)

Automakers

- Toyota: goal of 1+ million electric vehicles by 2030;
- Volvo aims to beat Toyota by doing the same by 2025;
- VW: 25% of vehicle sales will be electric by 2025;
- BMW: 15% to 25% PEVs by 2025;
- Ford: \$11B by 2022 for PEVs and introduce 40 electrified vehicles (16 BEVs and 24 HEVs and PHEVs)
- Mercedes-Benz: allocated \$11 billion for EVs
- VW: ~\$40 billion allocated for EVs
- PSA (Peugeot/Citroen) to offer 40 PEV (and hybrid) models by 2025

Automakers (globally) have committed \$90 billion to spending on electric vehicles (Reuters)

Countries

- Norway: all new car sales to be electric by 2025;
- France and United Kingdom leaders posit all new car sales to be electric by 2025 (pronouncements)
- California all electric by 2040 (pronouncements)
- China: goal of 20% PEVs by 2025.

On Cusp of AV Revolution

Sales Promised by 2019-2021 (as of 2016)

Old guard:

- GM
- Ford
- Toyota
- Nissan
- Volvo
- BMW
- Mercedes
- Audi
- Volkswagen

New companies:

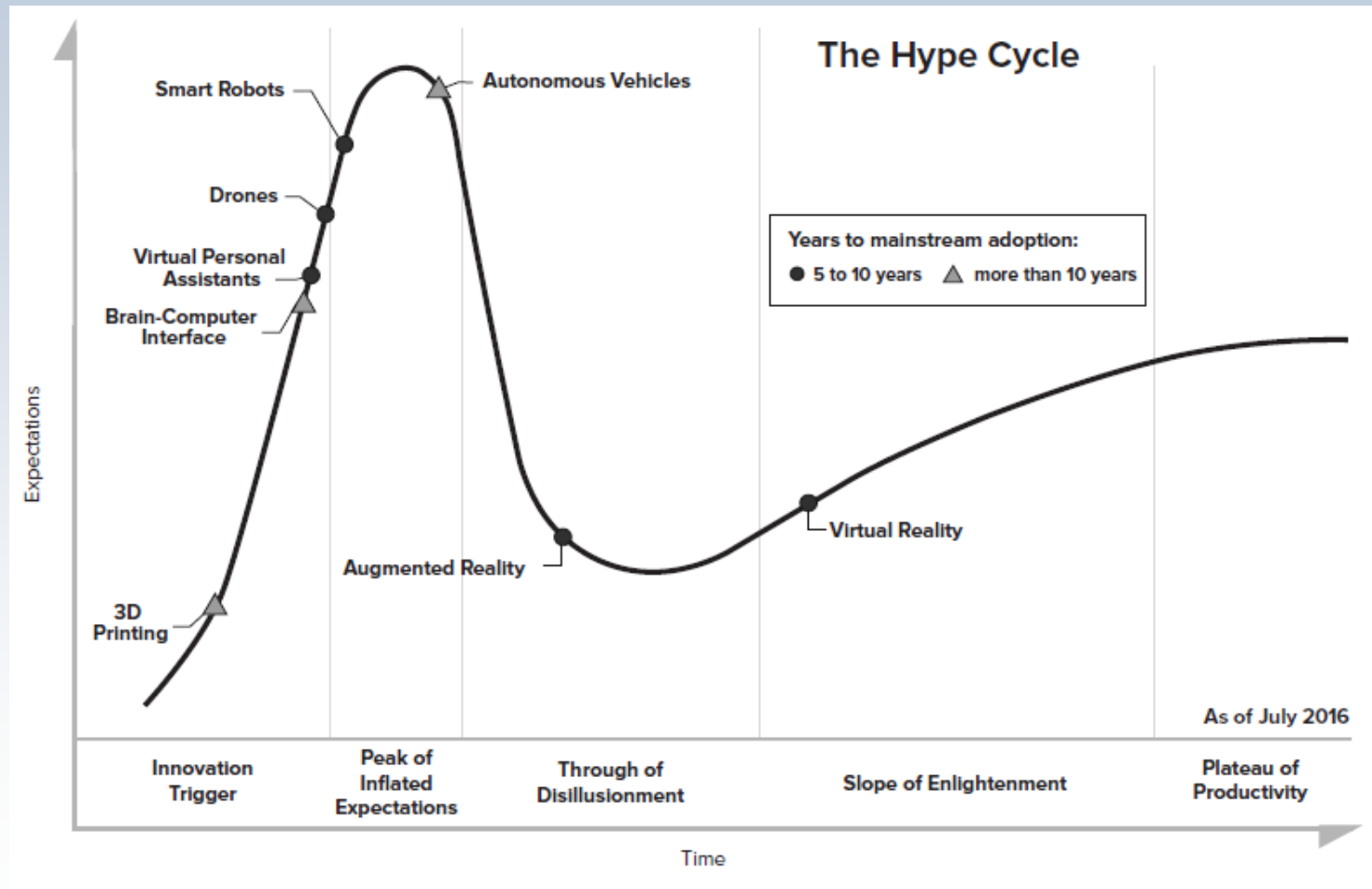
- Google
- Tesla
- Uber
- Apple
- Many startups

Driverless Car Market Predictions

Prediction	Year in the Market (Year Announced)
Google's founder Sergey Brin	2018 (2012)
Volkswagen head of Digitalization Strategy, Johan Jungwirth (not necessarily Volkswagen brand)	2019 (2016)
General Motors head of foresight, Richard Holman	2020 (2016)
Ford's head of production development, Raj Nair	2020 (2016)
Toyota	2020 (2015)
Andy Palmer, the Executive Vice President of California-based Nissan Motors Ltd	2020 (2013)
Ford CEO, Mark Fields	2021 (2016)
BMW CEO, Harald Krueger	2021 (2016)
Baidu's Chief Scientist	2021 (2016)
Tesla's Founder, Elon Musk	2021 (2015)
Justin Rattner, CTO of Intel	2022 (2012)
Jaguar and Land Rover's Director of Research and Technology	2024 (2014)
U.S. Department of Transportation	2025 (2015)
Dieter Zetsche, Chairman of Daimler	2025 (2014)
Automotive Supplier Continental	2025 (2012)
Robert Hartwig, President of the Insurance Information Institute	2028 (2013)
Institute of Electrical and Electronics Engineers (IEEE)	2040 (2012)



Hype by Automakers, Silicon Valley, Media, and Politicians



Sperling et al, 2018, adapted from Gartner, 2016

AUTOMATION LEVELS OF AUTONOMOUS CARS

LEVEL 0



There are no autonomous features.

LEVEL 1



These cars can handle one task at a time, like automatic braking.

LEVEL 2



These cars would have at least two automated functions.

LEVEL 3



These cars handle “dynamic driving tasks” but might still need intervention.

LEVEL 4



These cars are officially driverless in certain environments.

LEVEL 5



These cars can operate entirely on their own without any driver presence.

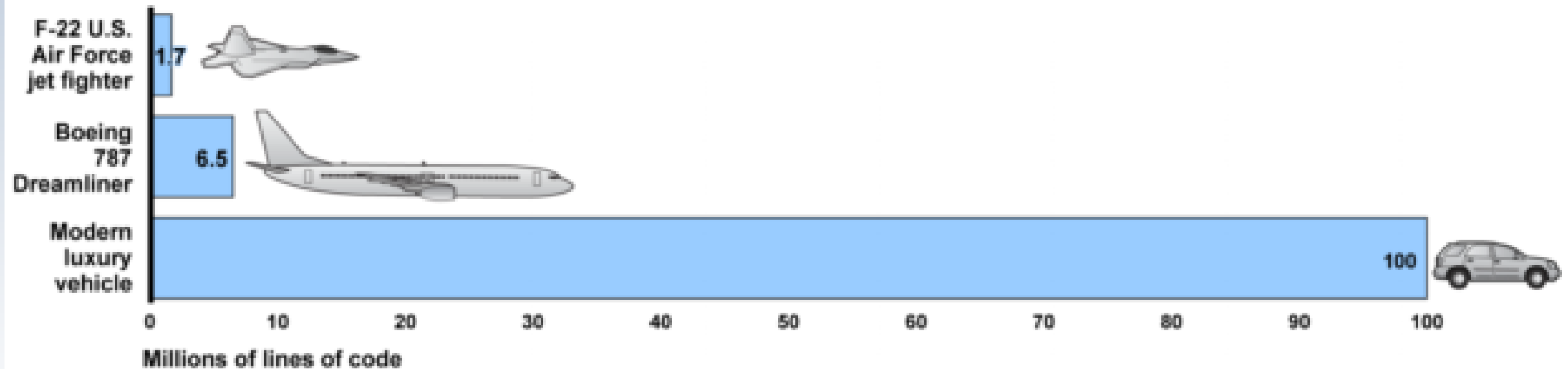
Fully Driverless Vehicles (Level 5) Are Needed to Gain Public Benefit ... But When?!



AVs are Hugely Complex... far greater safety risk than iphones

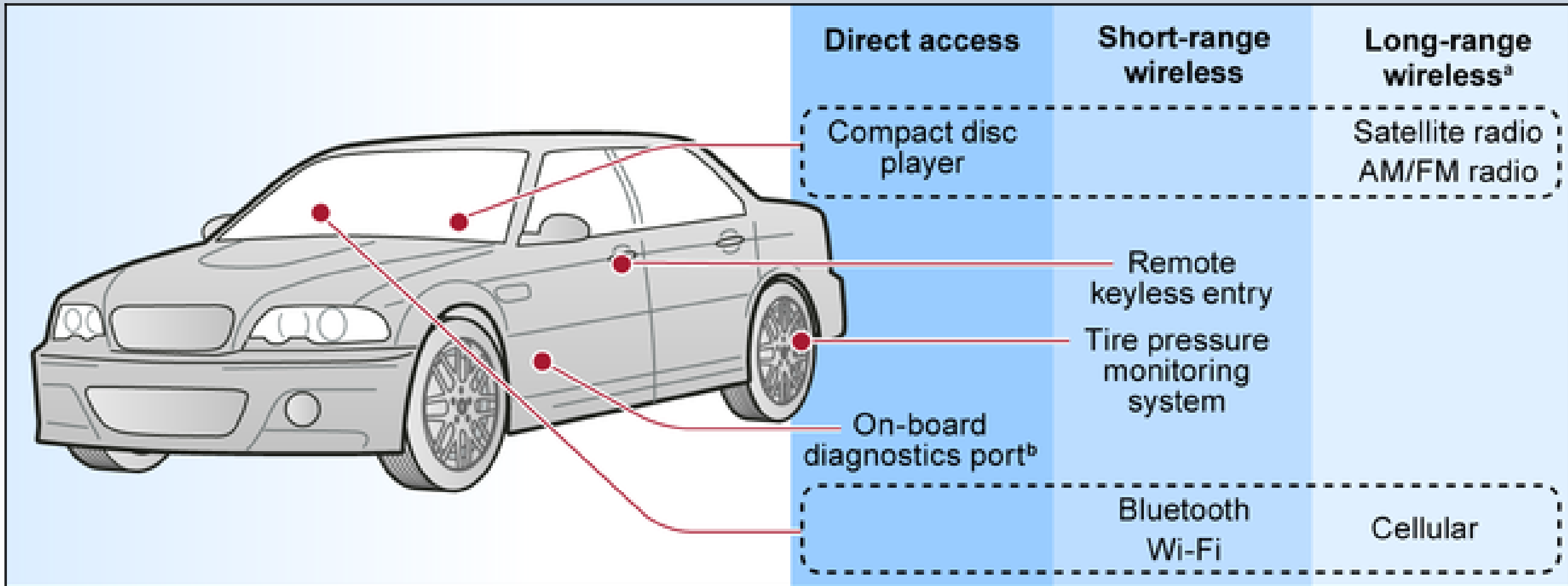
...machine learning, computing, ECUs, hardware (lidar, radar, cameras), software

Figure 2: Average Lines of Software Code in Modern Luxury Vehicle Compared to Types of Aircraft



Source: Battelle. | GAO-16-350

Key Vehicle Interfaces That Could Be Exploited in a Vehicle Cyberattack



Driverless Cars Also Inevitable (for different reasons) ...But Conservative Forces Will Slow Transition

- Conservative safety regulators (NHTSA et al) and safety “policy”
 - Validating artificial intelligence/machine learning
 - How safe is enough? Handling 90% of driving situations is easy and close at hand. 99% is exponentially more difficult. 99.9% effectiveness is currently out of reach. (Lidar technology?)
 - When and where should driverless cars be allowed to operate?
 - How many accidents and deaths caused by driverless cars will the public tolerate?
- Cybersecurity and hacking concerns
- Insurance companies need usage data??

Which “Cost” Factor Will Dominate ... resulting in “hell” or “heaven”?

- Huge time “savings” ... leading to individual ownership of AVs and large increases in VMT (“hell”)

or

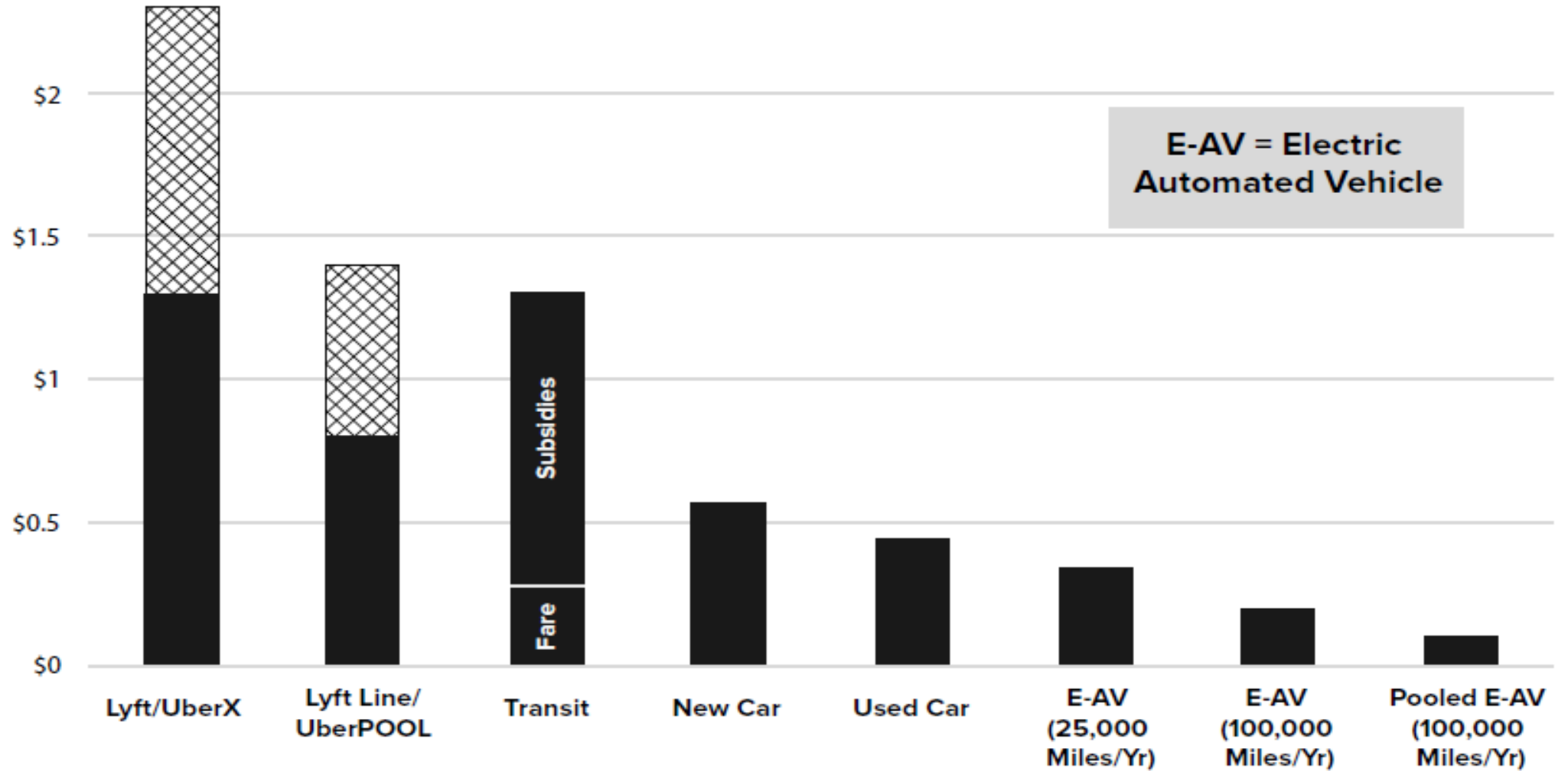


- Huge cost reductions for MaaS ... leading to vast reduction in car ownership and VMT, plus large equity, infrastructure, jobs benefits (“heaven”)

Pooling + Electric + Automated = Very Cheap Mobility

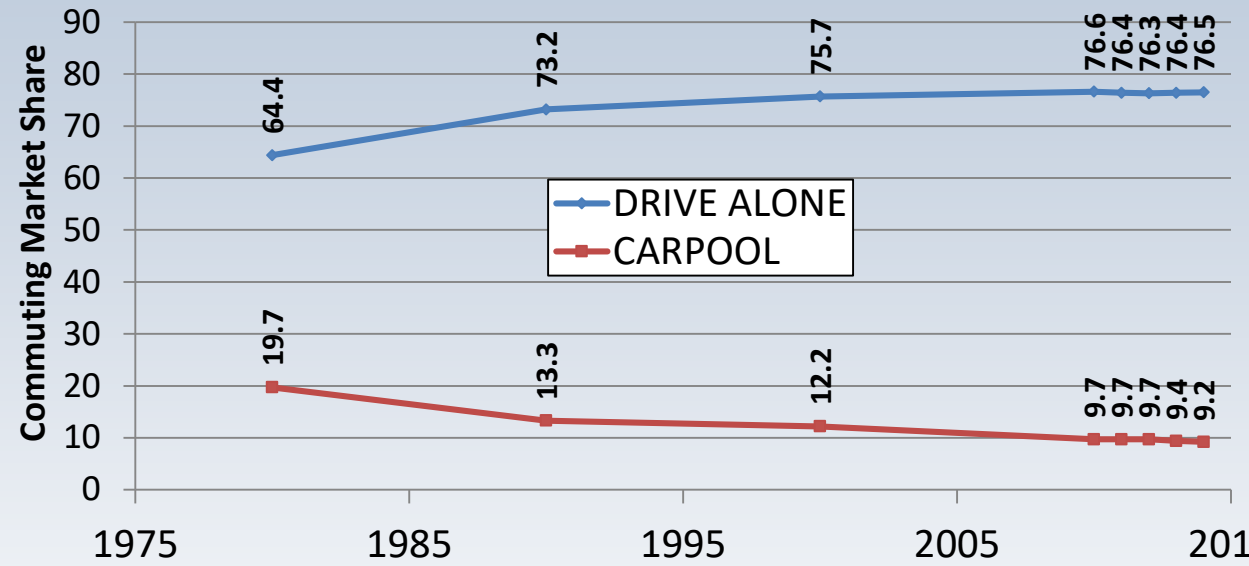
Enough to induce pooling?

Cost Per
Passenger-mile



But Will Travelers Embrace “Pooling”?

- Large in-car time savings (\$3000-\$10,000/year) ($\$10\text{-}30/\text{hr} \times 300 \text{ hours}$)
 - So why bother sharing?
- Concerns about:
 - Personal security (no “adult” in car)
 - Longer and uncertain trip times
- Functional needs
 - Families, sports gear, dogs, business/equipment
- Non-functional “needs”
 - Status and image, entertainment, investment



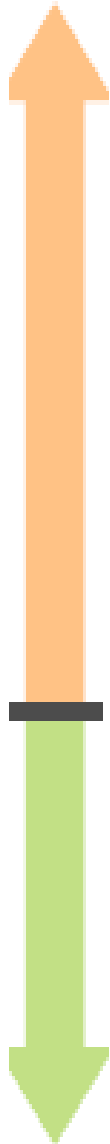
Possible responses:

- Redesign car for privacy (passenger-centric)
- Monitor riders (cameras)
- High “tax” on single-occupant vehicles
 - Usage, reg fees, incentives for pooling (curbspace, HOV lanes...)

If Pooling is **Not** Embraced...

Automation Could Greatly Increase Energy Use and GHG Emissions

+ 200 %



Factors that could increase energy consumption and associated emissions:

+ Reduced In-Vehicle Time Cost → **+ Increased Vehicle Miles Traveled (VMT)**

+ Zero-Occupancy Vehicle operation

+ Access for New User Groups

+ Faster Driving Speeds (vs congested speeds)

+ Shipment of Goods

Factors that could decrease energy consumption and associated emissions:

– Pooling of rides (MaaS)

--Platooning or Drafting

– Eco-Driving

– Congestion Mitigation (smoother driving)

– De-emphasized Performance

– Improved Crash Avoidance

– Electrified Vehicles (PEVs and FCVs)

– Less Hunting for Parking

– Vehicle Right Sizing

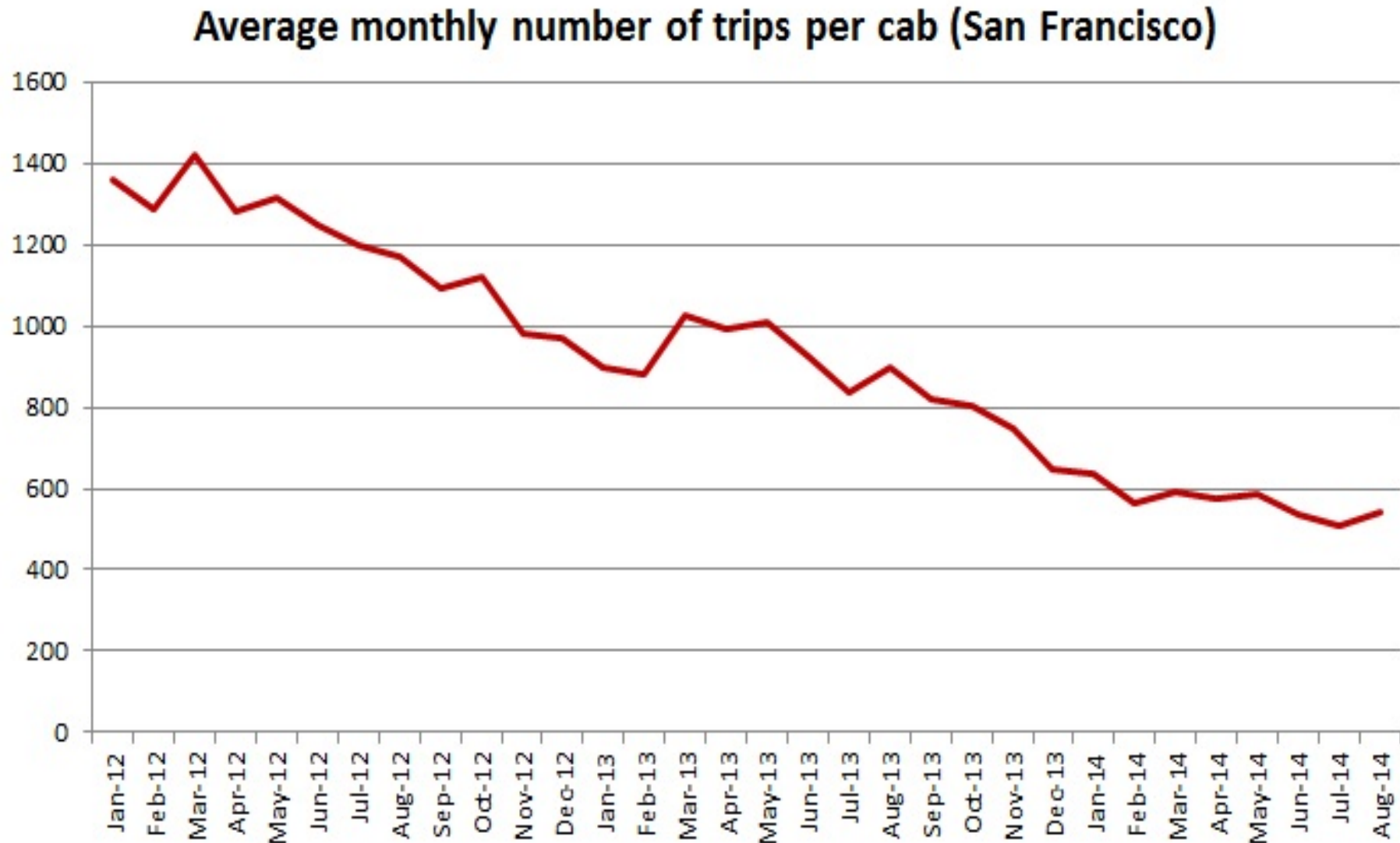
- 60 %

The 3 Revolutions Will Be Broadly Disruptive ... NOW is time to address (and steer) them

- Taxis
- Transit
- Automotive industry (especially with MaaS)
- Oil companies

.... plus rental cars, insurance, parking, vehicle service and repair, aftermarket vehicle parts suppliers, etc.

Taxis Are Disruption #1

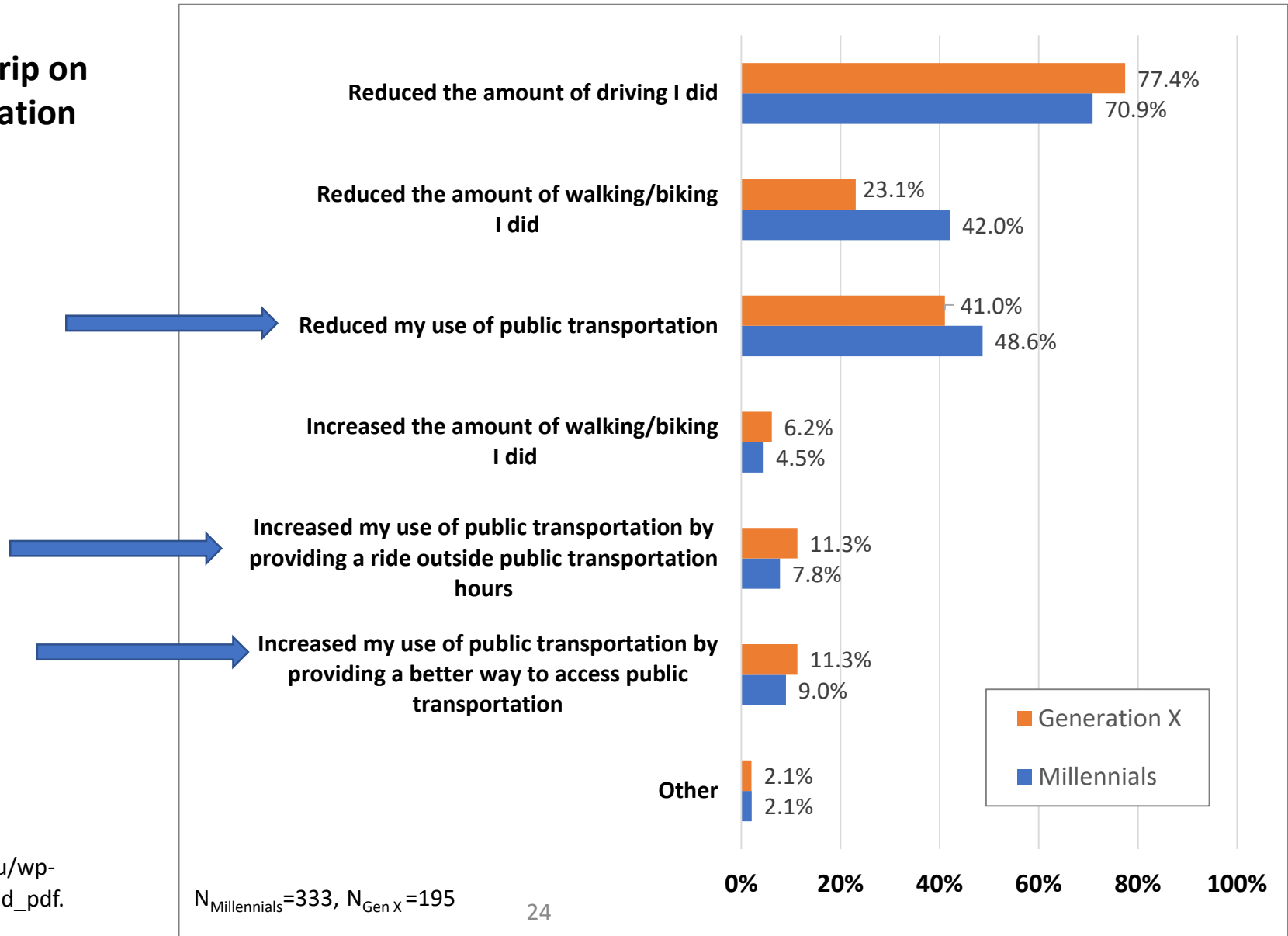


Transit Could Be #2

“We’re losing ridership, we have no money, and we have no idea what to do.” CEO of medium-sized transit operator (fall 2017)

Uber/Lyft Could Be Enemy or Friend

Impact of last Lyft/Uber trip on other means of transportation



What to Do With Legacy Transit? (Fixed Route/Schedule)

Much to Gain ... and Lose

- Essential public service
- Efficient for dense cities and dense routes
- But ...
 - atrophied capabilities
 - 1% of passenger miles
 - More GHGs per passenger mile than cars
 - Very expensive (especially for additional trips)
- 3Rs strategies and solutions
 - Partner with new mobility providers for first/last mile and low-density areas
 - Experiment with on-demand micro-transit (vans and small buses)
 - Learn from Lyft, Uber and innovative mobility services
 - Withdraw to dense routes

Auto Industry Threatened

- Massive investments needed in electrification and vehicle efficiency
 - Shift away from mechanical engineering culture; loss of core technologies (engines); and increased dependence on electricity/hydrogen suppliers and government incentives
 - Risk exacerbated by low oil prices and conservative customers
- Should business model transition from sales to service (MaaS)?
- How to resist Silicon Valley companies who are targeting high margin software/service business, leaving automakers as low-margin commodity providers (like IBM and Microsoft)

Mary Barra, GM: *“This industry will experience more dramatic change in the next decade than it has in the past 50 years.”*

Bill Ford, Ford: *“Ford Motor Co.’s future and that of other automakers is going to involve fewer cars, and the industry needs to become one with that.”*

Sergio Marchionne, FCA: *“Today's automotive industry - as it's structured - is unsustainable.”*

Oil Industry Business Model Under Attack

...from EVs and VMT Reduction

- Royal Dutch Shell is industry leader in “exploring” new business models
 - Shifting investment portfolio to natural gas (and electricity)
 - Purchased major British electricity provider (First Utility)
 - Investing in renewable electricity
 - offshore wind farm in the North Sea
 - solar farms in Oman and California
 - Purchased large electric-car-charging company (NewMotion)
- *But non-fossil investments are 10% of total (so far)*



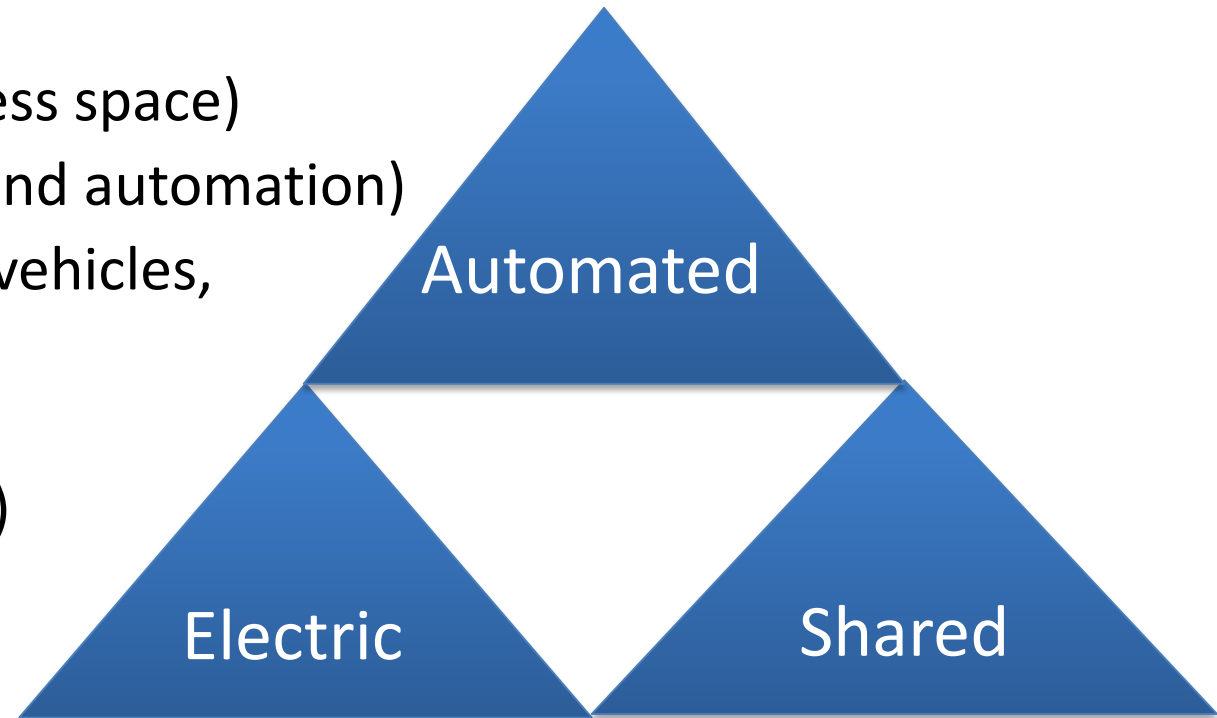
Shell CEO Ben van Beurden (01/18): “...***the era of electric transport is also coming in... The world is changing, and if our customers' needs are changing, we have to change with them.***”

Transportation Heaven

... when the 3 revolutions are integrated so that vehicles are pooled, electric, and automated!

Better for economics, environment, and equity

- Safer (automated)
- Access for mobility disadvantaged (young, elderly, poor, physically disabled)
- Less personal cost
- Less infrastructure cost (pooled AVs need less space)
- Less congestion/VMT (because of pooling and automation)
- Less GHGs and energy use (smaller/lighter vehicles, less VMT, electrified)
- Less local pollution
- More urban space (less parking, roadspace)
- **More jobs**



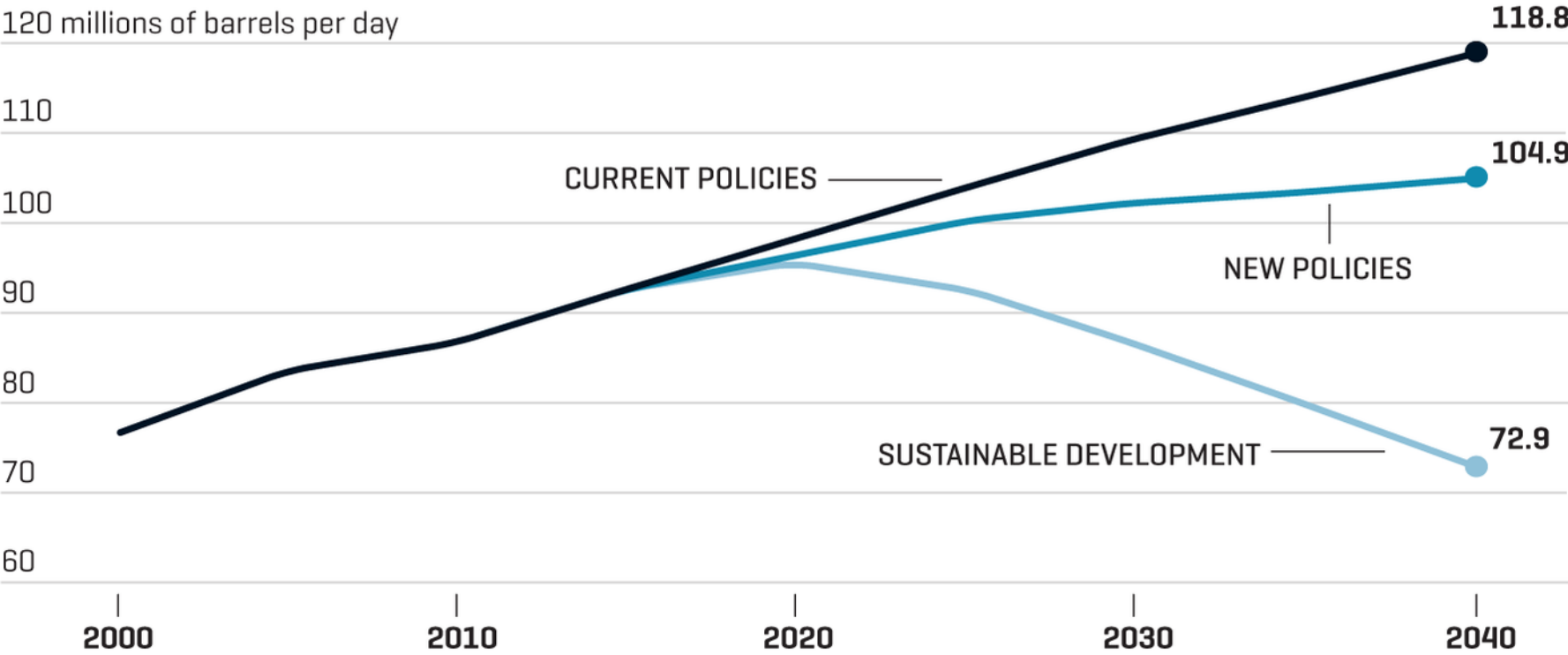
Policy Plays Central Role (for all 3 Revolutions)

RADICAL UNCERTAINTY

Depending on how quickly the world adopts new technologies, oil demand could peak within a decade or in the 2040s. The wide range of possible outcomes is a planning challenge for Shell and other oil giants.

WORLD OIL DEMAND UNDER THREE SCENARIOS

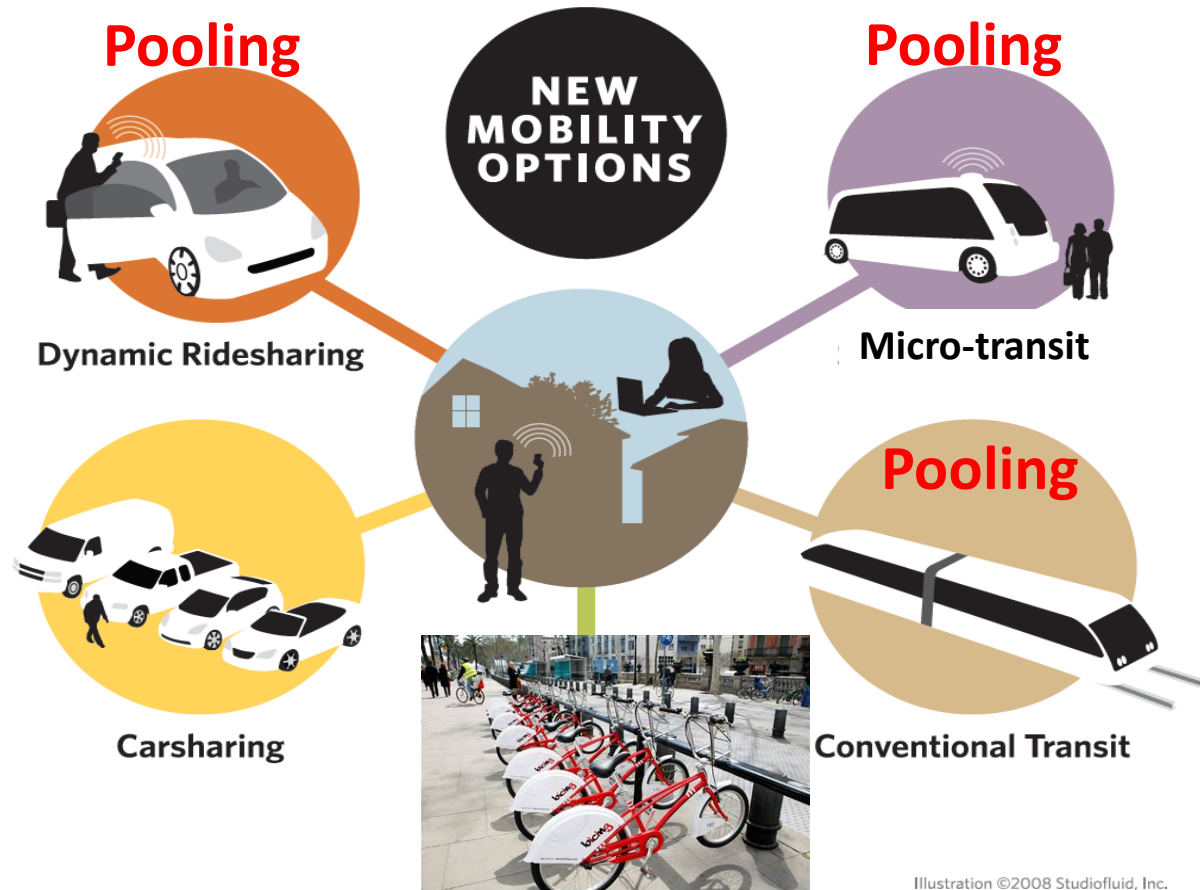
120 millions of barrels per day



SOURCE: IEA

Key Strategy Going Forward

Pooling is Key (including micro-transit)--It Expands Traveler Choice and Thus (Politically) Facilitates **Pricing**... Setting Stage for Automation



NEAR-TERM STRATEGIES

1. Incentivize “pooling”
2. Improve first/last mile access (transit partnerships)
3. Introduce new options to poorly served areas (including micro-transit)

- *Reducing individual ownership*
- *Converting fixed costs into variable costs (for travelers)*

Thanks to co-authors...

1. Will the Transportation Revolutions Improve Our Lives—or Make Them Worse?

Daniel Sperling, Susan Pike, and Robin Chase

2. Electric Vehicles: Approaching the Tipping Point

Daniel Sperling

3. Shared Mobility: The Potential of Ride Hailing and Pooling

Susan Shaheen

4. Vehicle Automation: Our Best Shot at a Transportation Do-Over?

Daniel Sperling, Ellen van der Meer, and Susan Pike

5. Upgrading Transit for the Twenty-First Century

Steven E. Polzin and Daniel Sperling

6. Bridging the Gap between Mobility Haves and Have-Nots

Anne Brown and Brian D. Taylor

7. Remaking the Auto Industry

Levi Tillemann

8. The Dark Horse: Will China Win the Electric, Automated, Shared Mobility Race?

Michael J. Dunne

Epilogue: Pooling Is the Answer

Thank You

