

Will self-driving cars help or hurt efforts to cut emissions?

Don MacKenzie

Civil & Environmental Engineering

When is automation coming?

Partial automation is already mainstream

Lane keeping

Traffic jam assist / low speed follow



<http://www.chrysler.com/en/200/#&asset=2>

Adaptive Cruise Control

Automated Emergency Braking



<http://www.autoblog.com/2015/10/19/2016-honda-civic-first-drive-review->



<http://www.ford.com/cars/fusion/gallery/photos/>

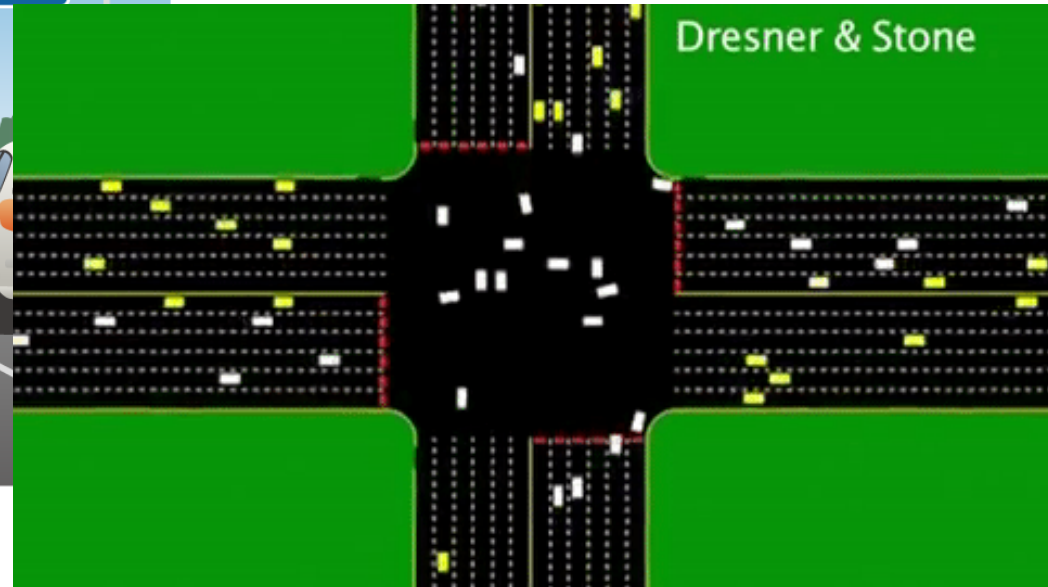
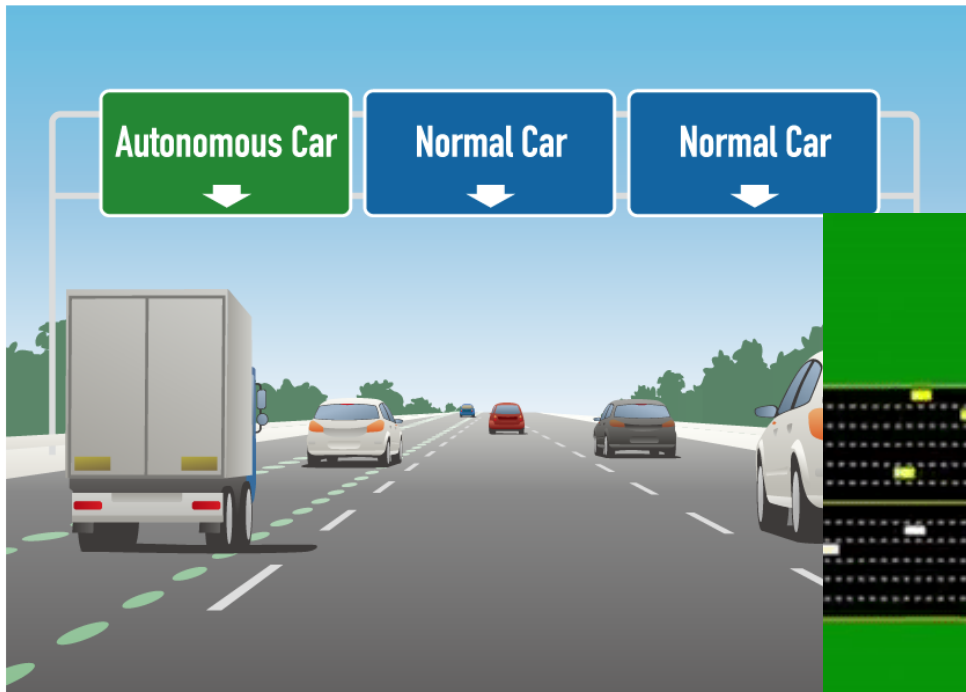


<http://www.subaru.com/vehicles/forester/photos-videos.html>

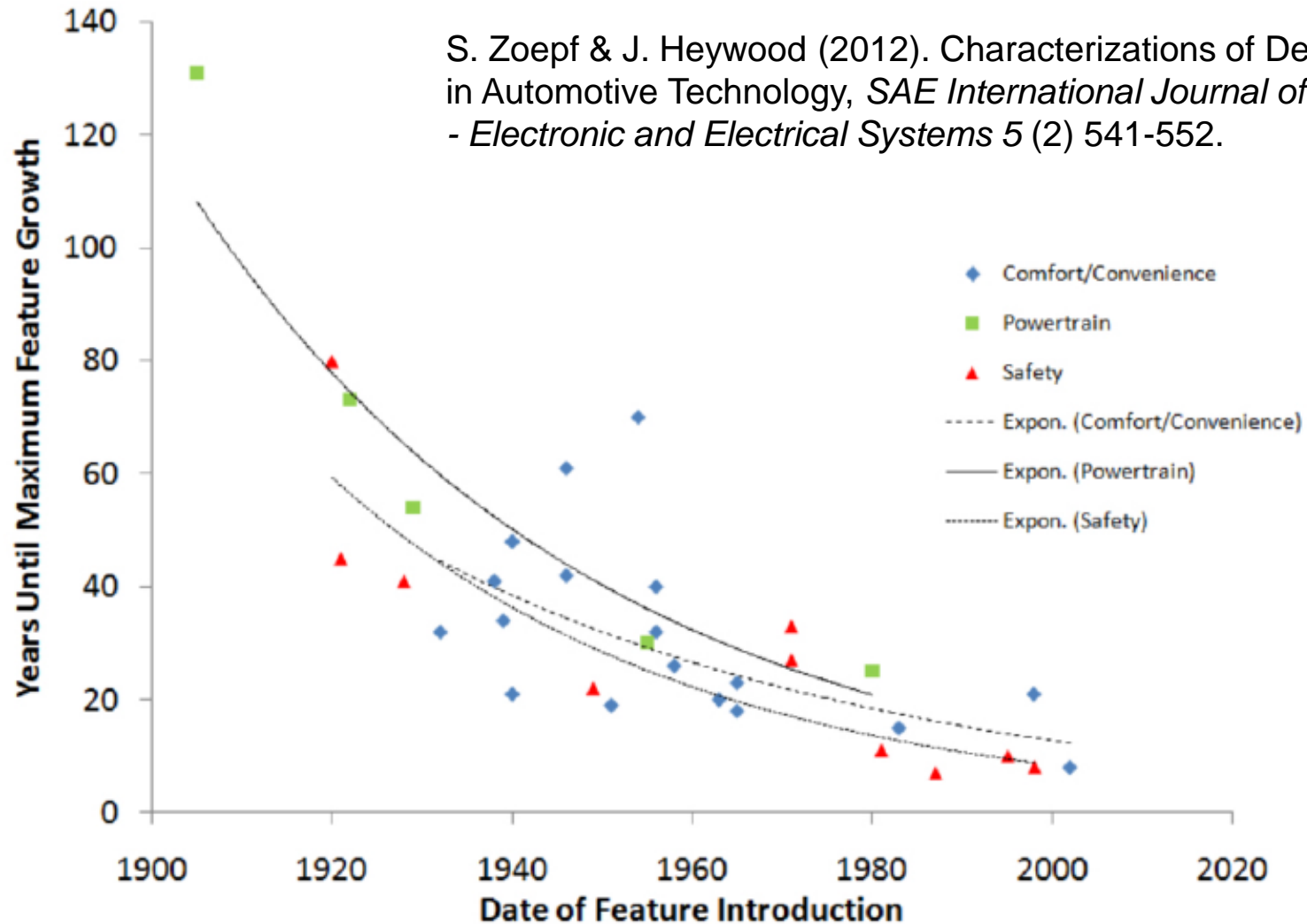
Applications requiring (near) universal automation are decades away

Autonomous Vehicle Plan for the I-5 Seattle/Vancouver B.C. Corridor

By Tom Alberg, Managing Director, Madrona Venture Group, Craig Mundie, former Chief Research and Strategy Officer, Microsoft Corporation, Daniel Li, Associate, Madrona Venture Group, Connor Raikes, Consultant

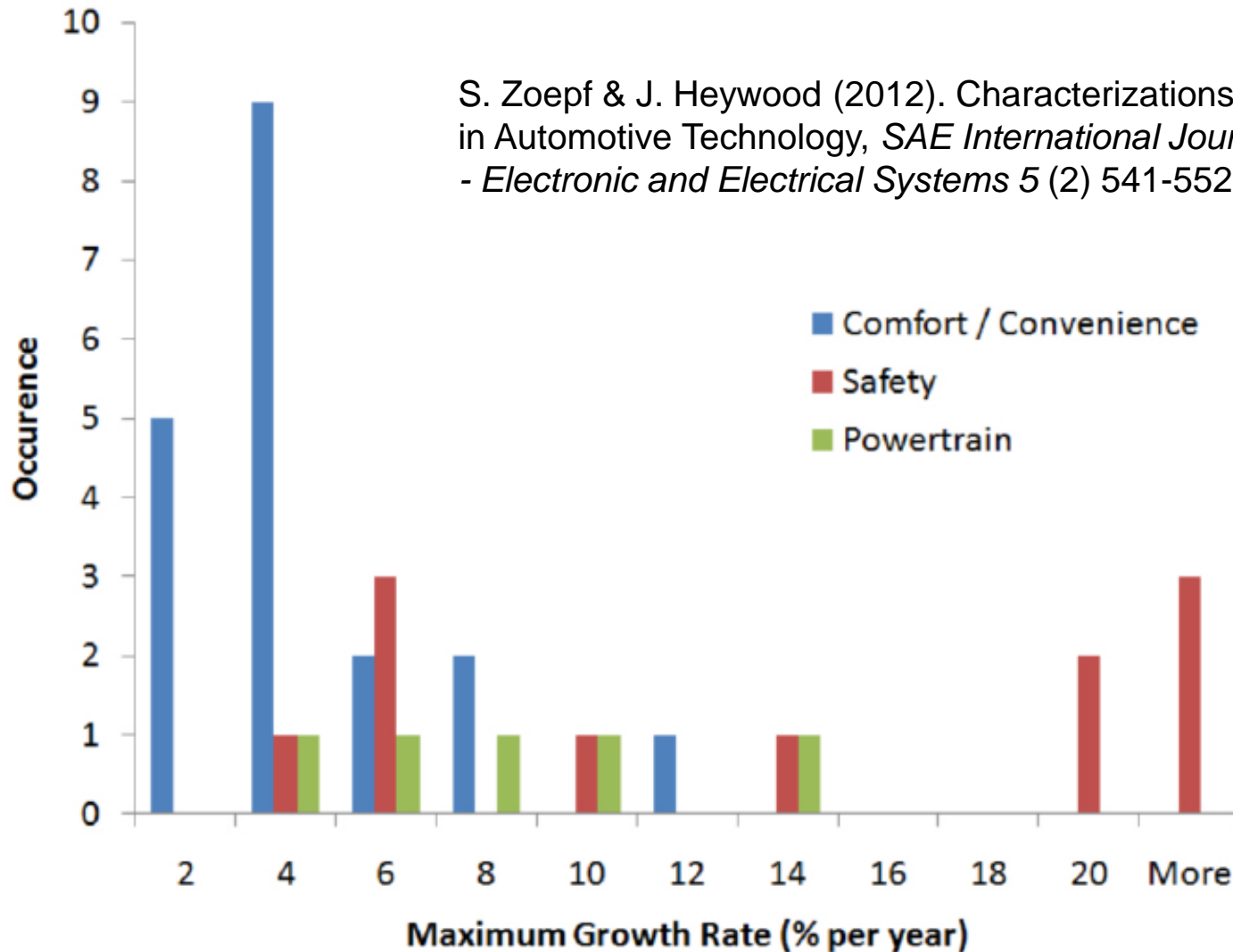


Market intro. to peak growth is ~10 years, could be ~5 years by 2030



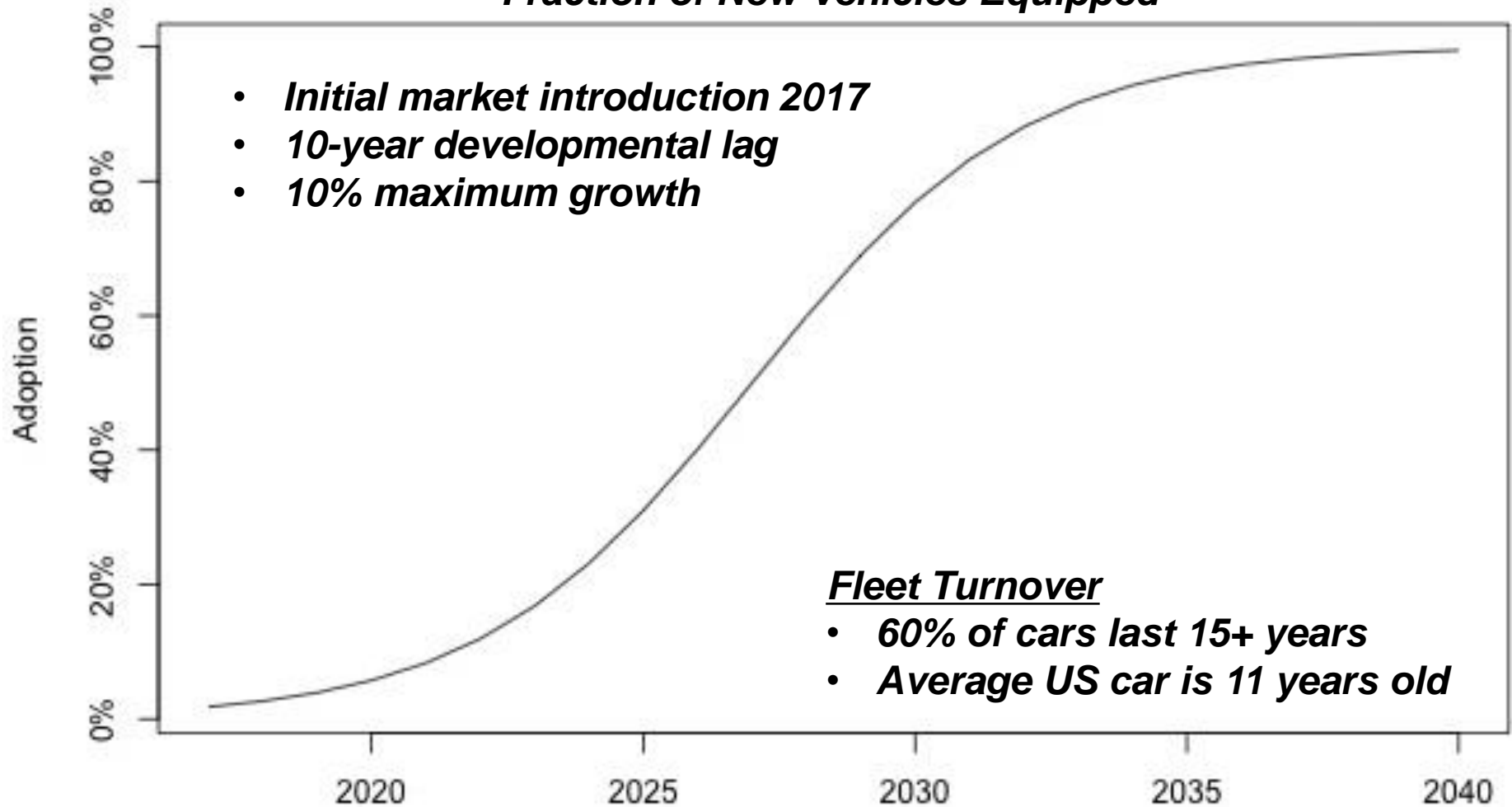
New automotive features rarely grow by more than 10% per year

S. Zoepf & J. Heywood (2012). Characterizations of Deployment Rates in Automotive Technology, *SAE International Journal of Passenger Cars - Electronic and Electrical Systems* 5 (2) 541-552.



It will be decades before all vehicles can drive themselves.

Fraction of New Vehicles Equipped



What will automation mean for energy demand and emissions?

Energy and environment are **not** driving the conversation on automation, but...

Capacity



<http://www.tech-faq.com/vehicle-platooning.html>

Safety



<http://www.carscoops.com/2013/09/iihs-tests-frontal-crash-mitigation-and.html>

Access



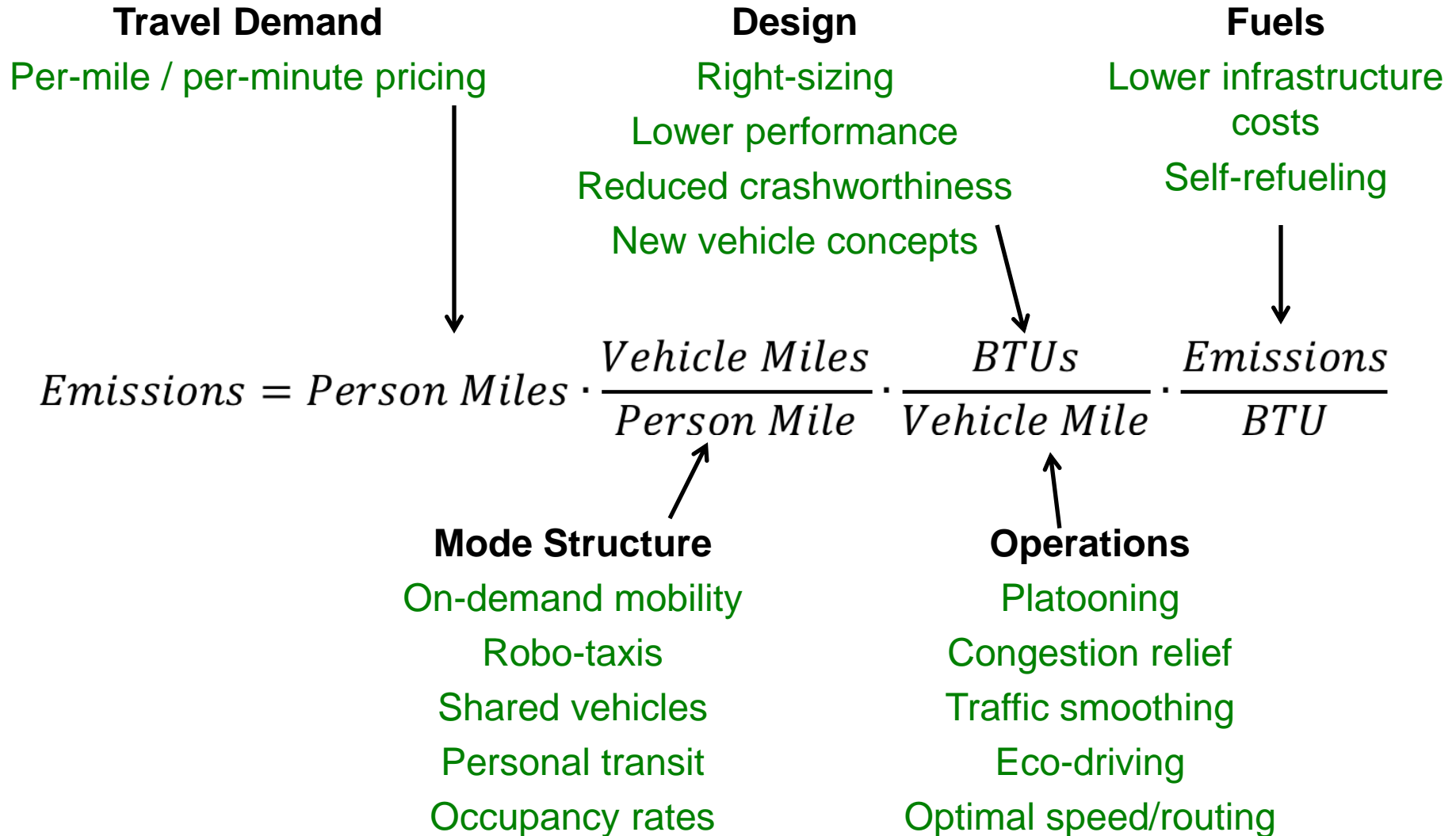
<https://www.pinterest.com/pin/33003009739432031/>

Comfort / Time Use

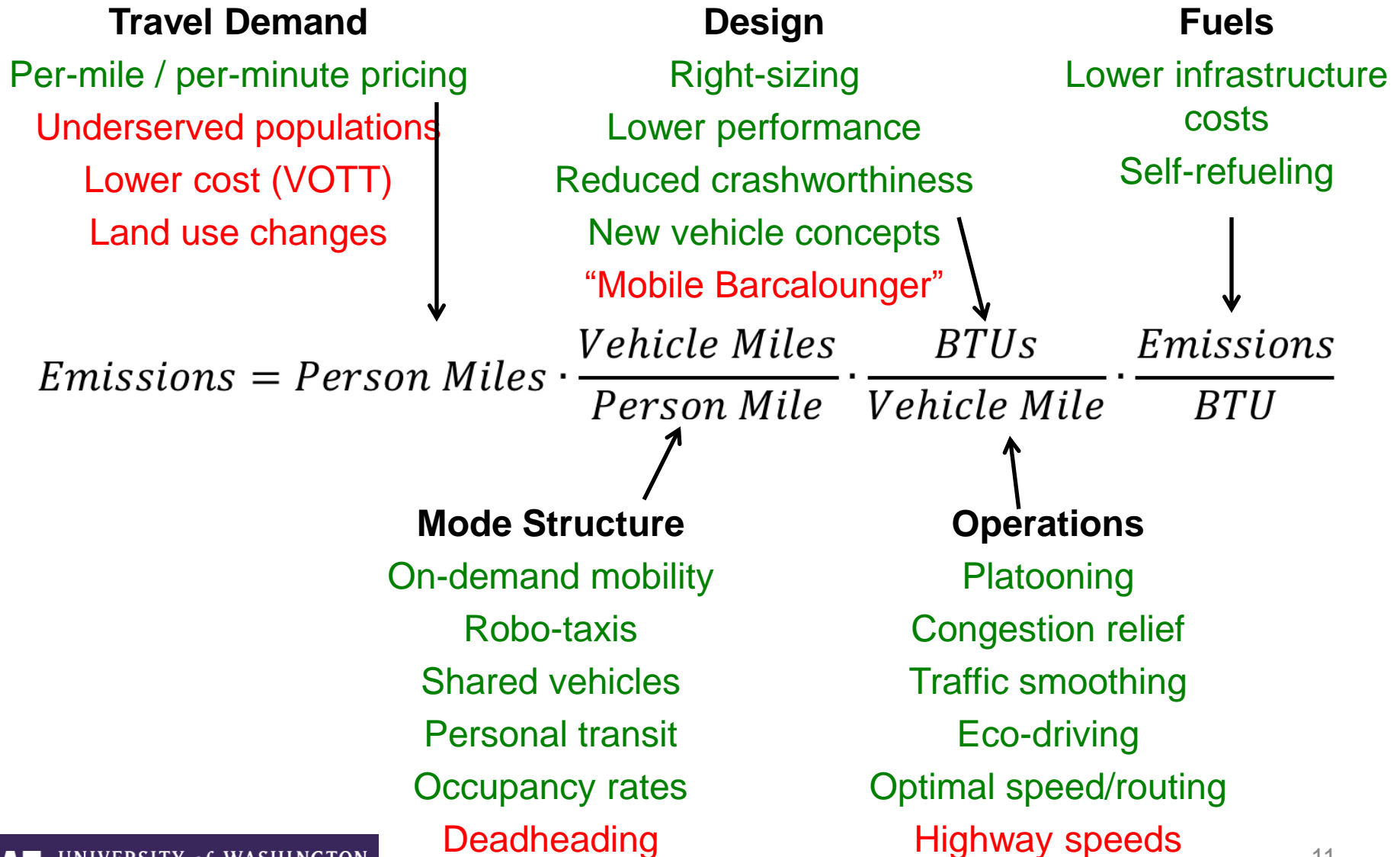


<http://www.autoguide.com/auto-news/2015/10/volvo-previews-self-driving-cars-with-intellisafe-auto-pilot-interface.html>

Automation offers substantial energy & environmental benefits...



Automation offers substantial energy & environmental benefits... and risks



Our goal was to place some bounds on these impacts and explore net effects

Transportation Research Part A 86 (2016) 1–18



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journal homepage: www.elsevier.com/locate/tra



Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles



Zia Wadud^{a,*}, Don MacKenzie^{b,1}, Paul Leiby^{c,2}

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^b Department of Civil & Environmental Engineering, University of Washington, P.O. Box 352700, Seattle, WA 98195-2700, United States

^c Oak Ridge National Laboratory, P.O. Box 2008, MS 6036, Oak Ridge, TN 37831, United States

Automation making vehicle travel cheaper, safer, more convenient, will increase demand

"It was the same distance, but the commute felt like it took half the time"

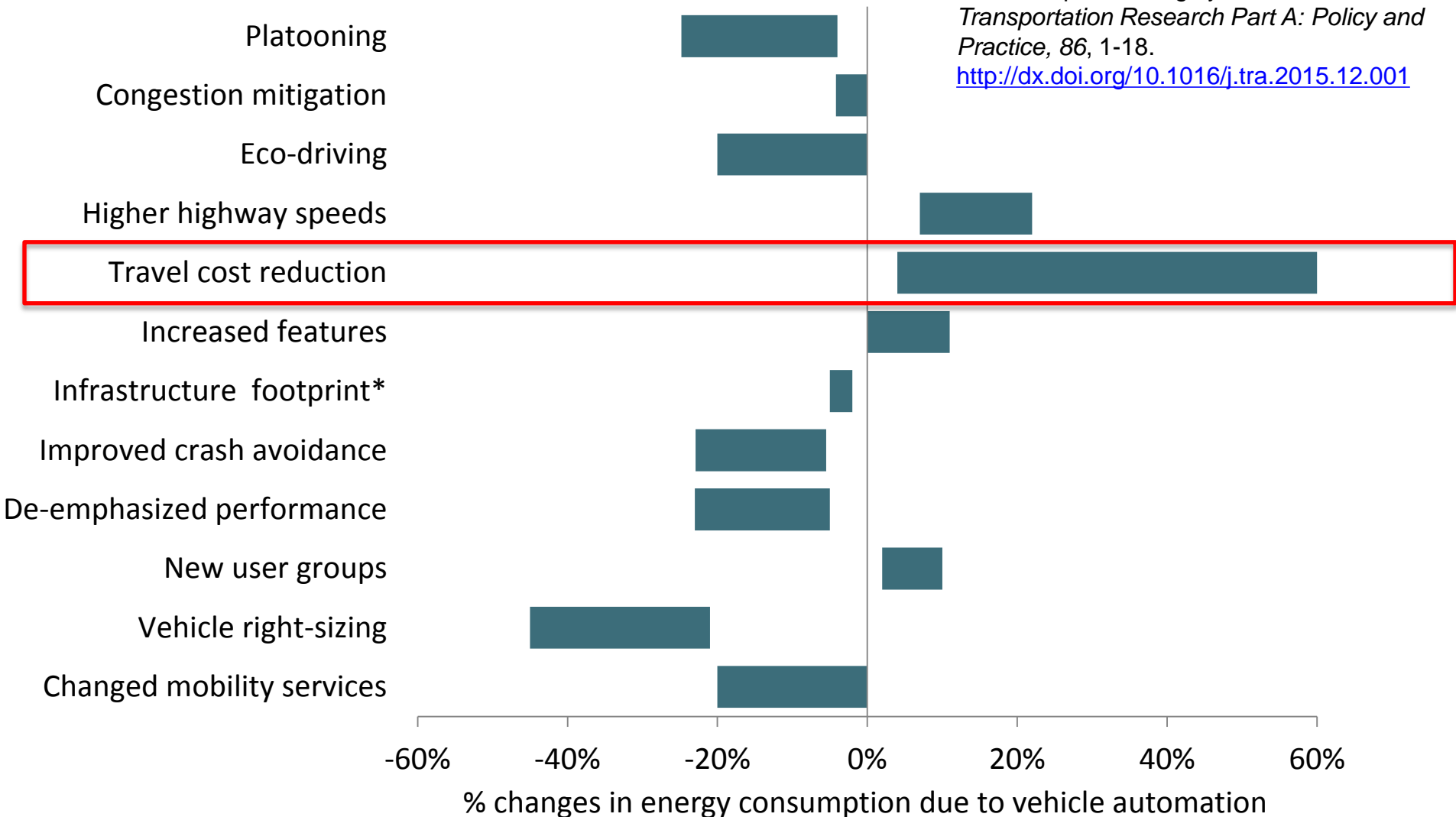


<https://www.teslamotors.com/customer-stories/how-autopilot-added-years-my-life>

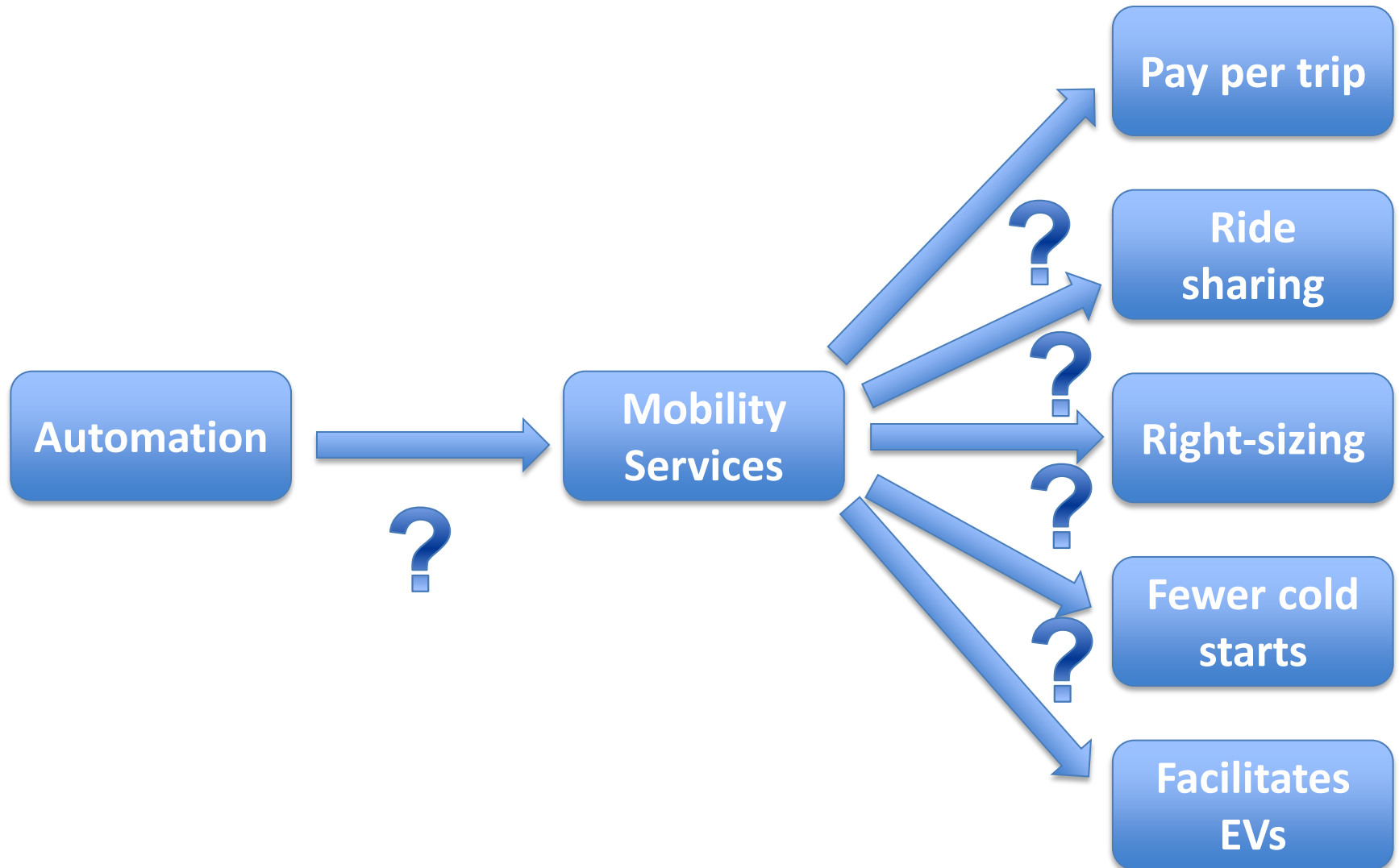
The biggest risk* from automation comes from induced demand

Wadud, Z., MacKenzie, D., & Leiby, P. (2016). Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transportation Research Part A: Policy and Practice*, 86, 1-18.

<http://dx.doi.org/10.1016/j.tra.2015.12.001>

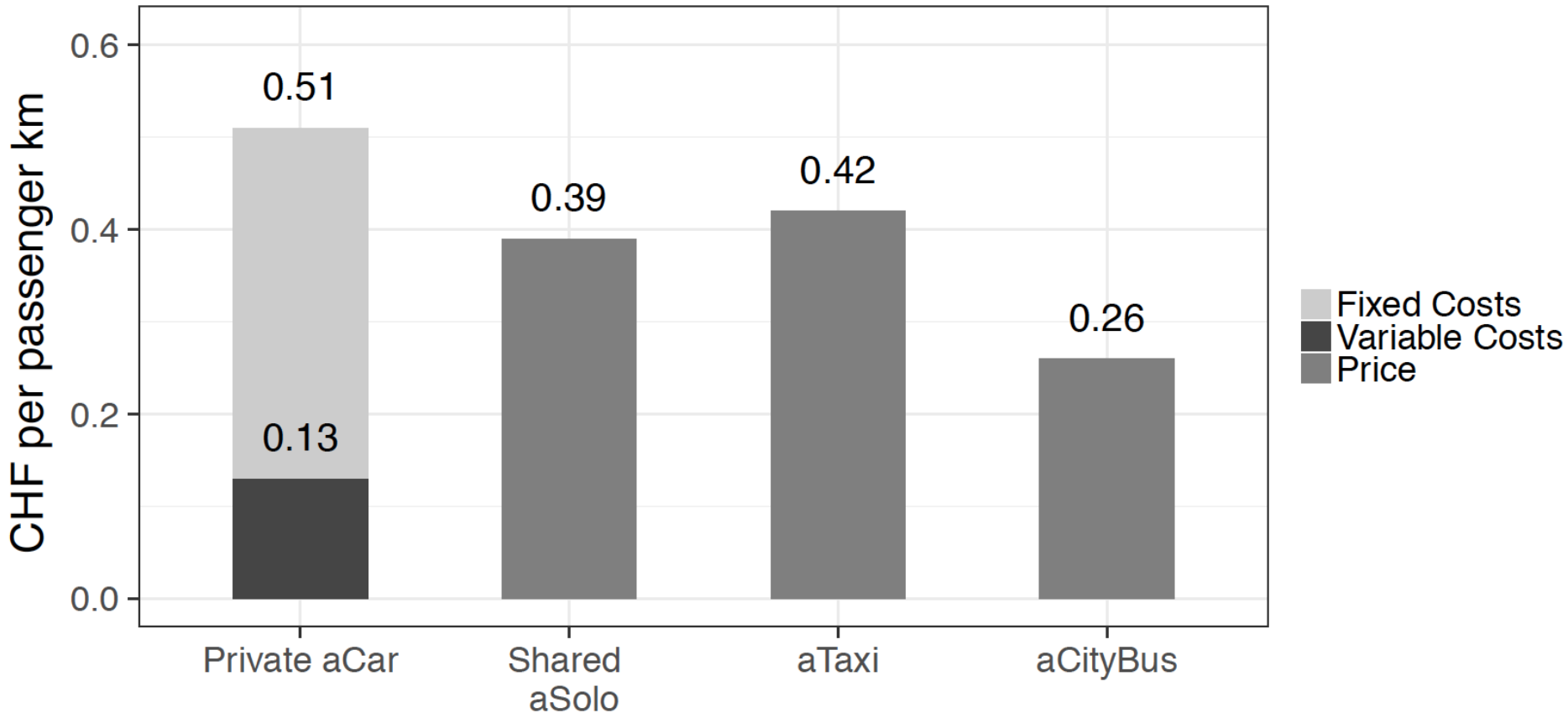


Emerging consensus that mobility services are key to unlocking many benefits of automation.



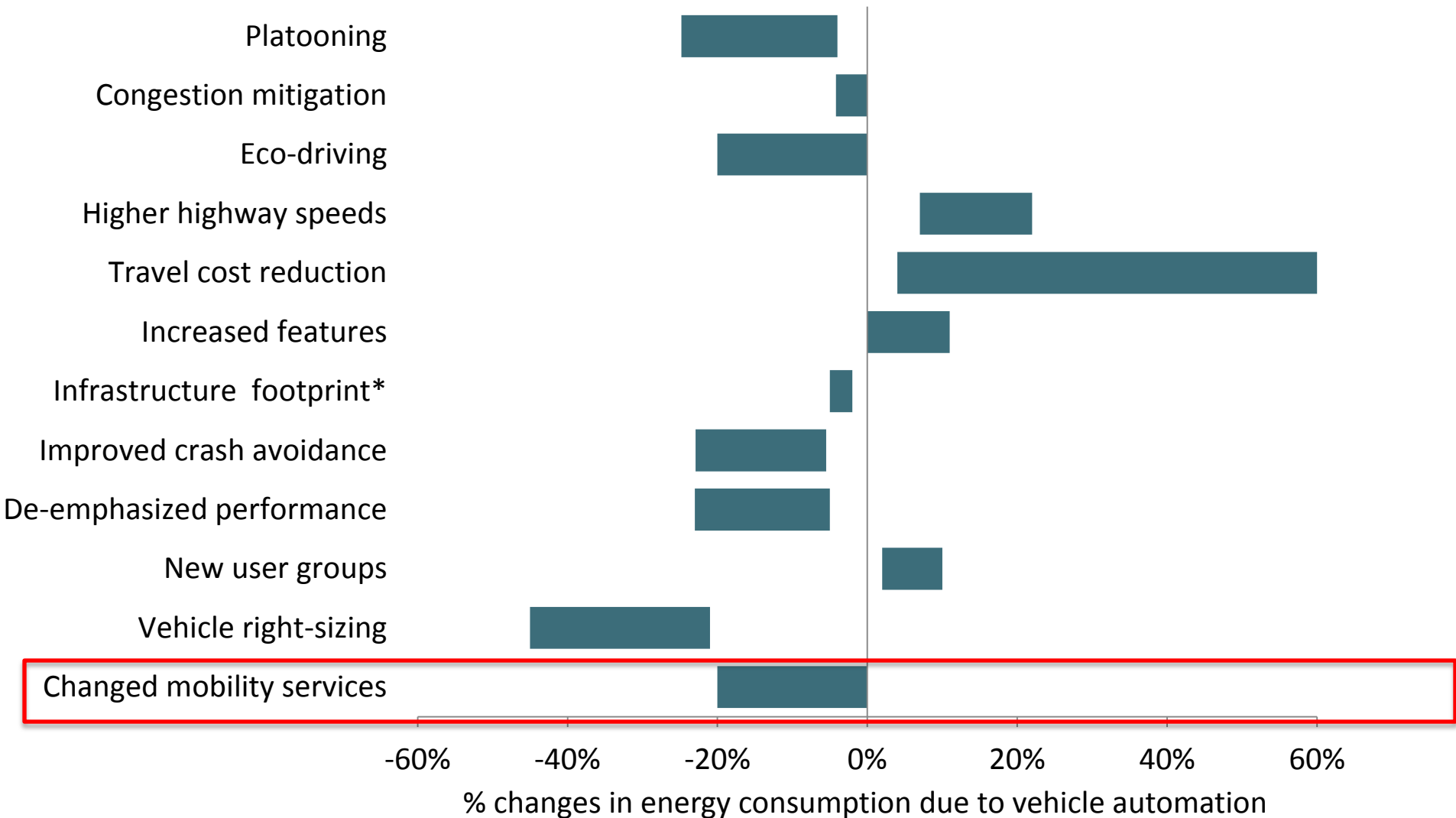
Paying by the trip is expected to reduce travel demand

(a) Future competitive situation - Urban setting.



Bösch, P.M., Becker, F., Becker, H., & Axhausen, K.W. (2017). Cost-based Analysis of Autonomous Mobility Services. Working paper 1225, Institute for Transport Planning and Systems, ETH Zurich. January, 2017.

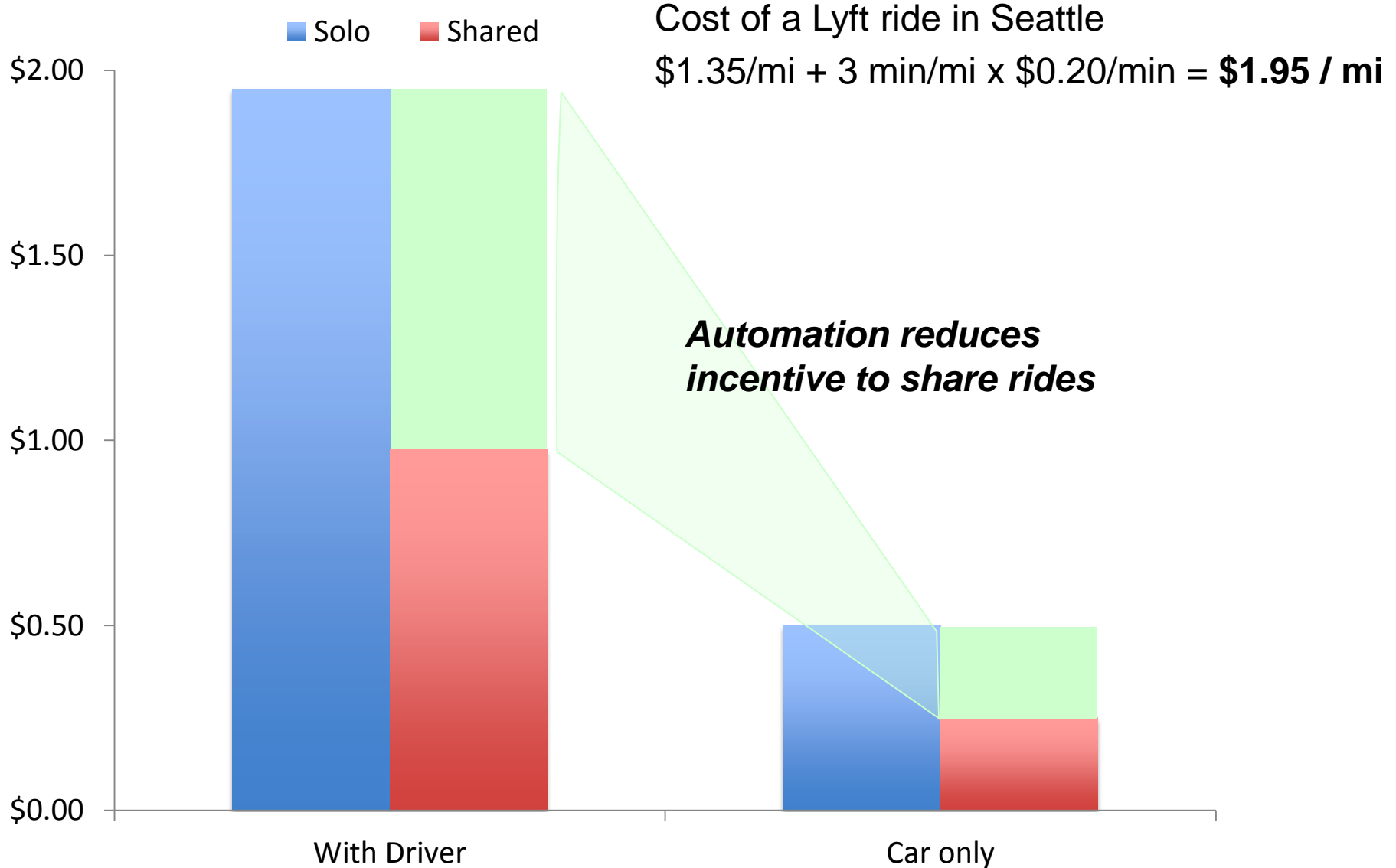
(Full) Automation makes mobility services more feasible, and more essential



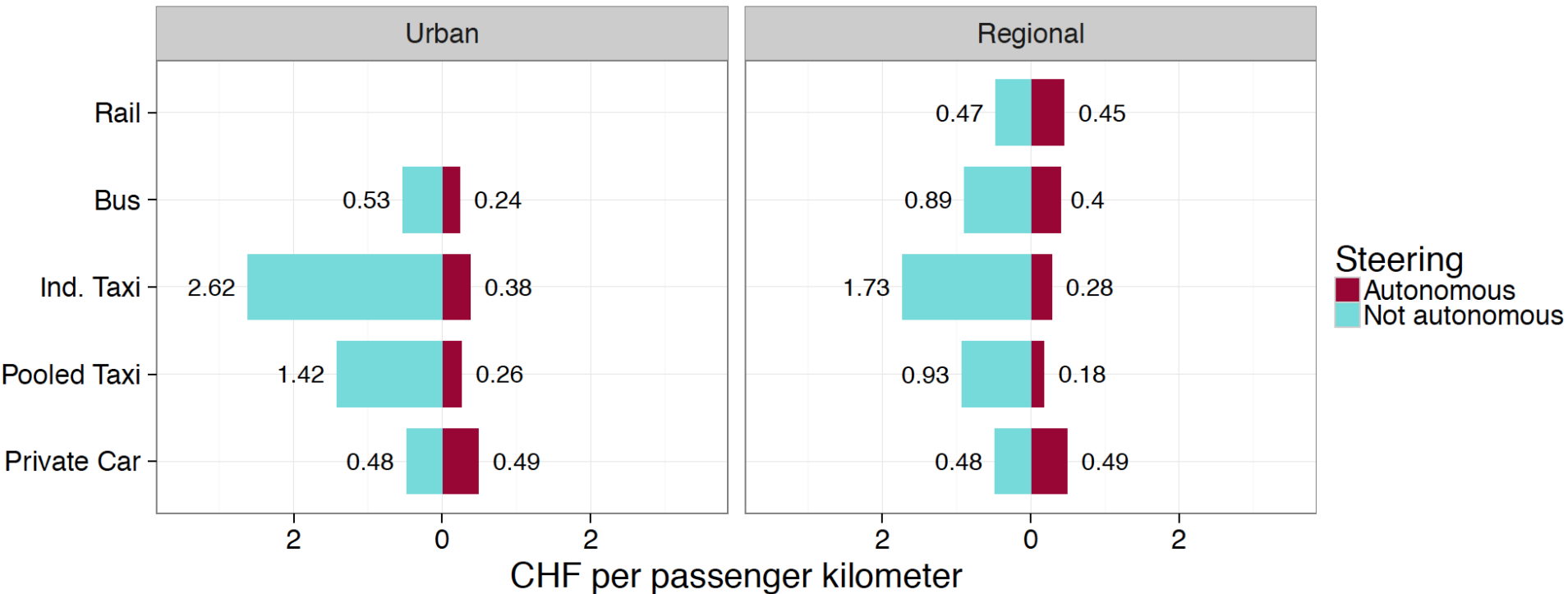
Questions for you

- How many of you have used Uber, Lyft, or a similar service?
- How many of you have used UberPool, Lyft Line, or a similar service?
- Why?

Shared cars are not the same as shared rides

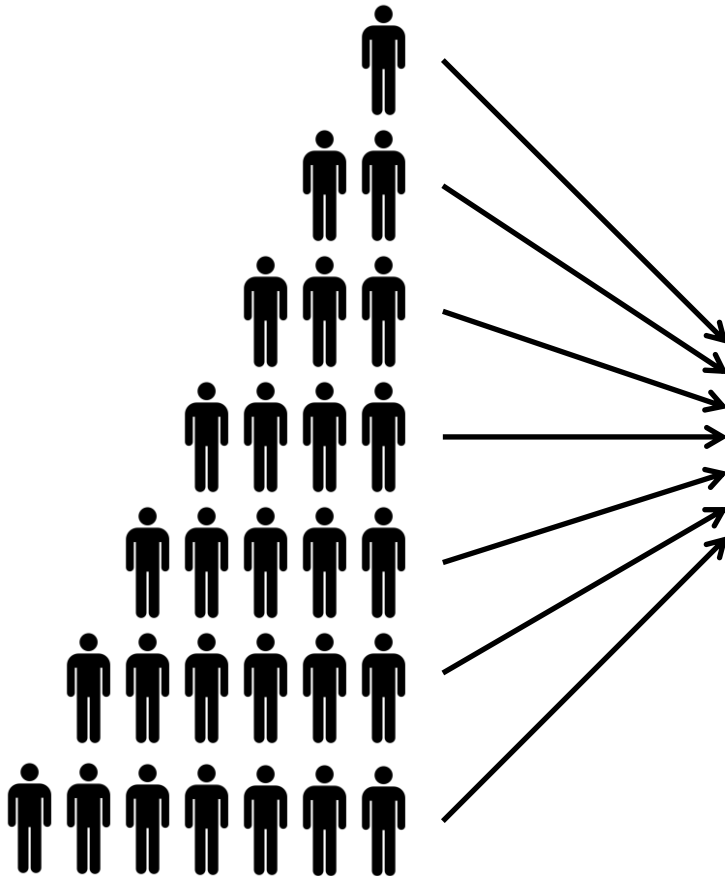


By reducing total cost of mobility services, automation reduces incentive to share rides



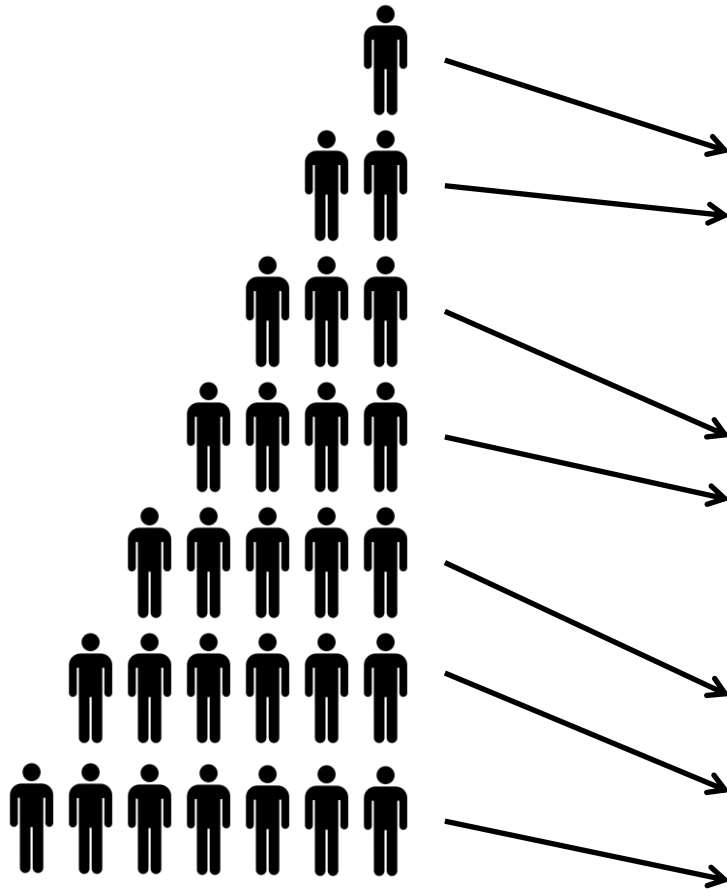
Bösch, P.M., Becker, F., Becker, H., & Axhausen, K.W. (2017). Cost-based Analysis of Autonomous Mobility Services. Working paper 1225, Institute for Transport Planning and Systems, ETH Zurich. January, 2017.

With safe, on-demand mobility, we could "right-size" vehicle for specific trips' needs



<https://www.enterprise.com/en/car-rental/vehicles/us/suvs/standard.html>

With safe, on-demand mobility, we could "right-size" vehicle for specific trips' needs



<http://www.kbb.com/new-cars/5-year-cost-to-own-awards/best-to-compact-car/>

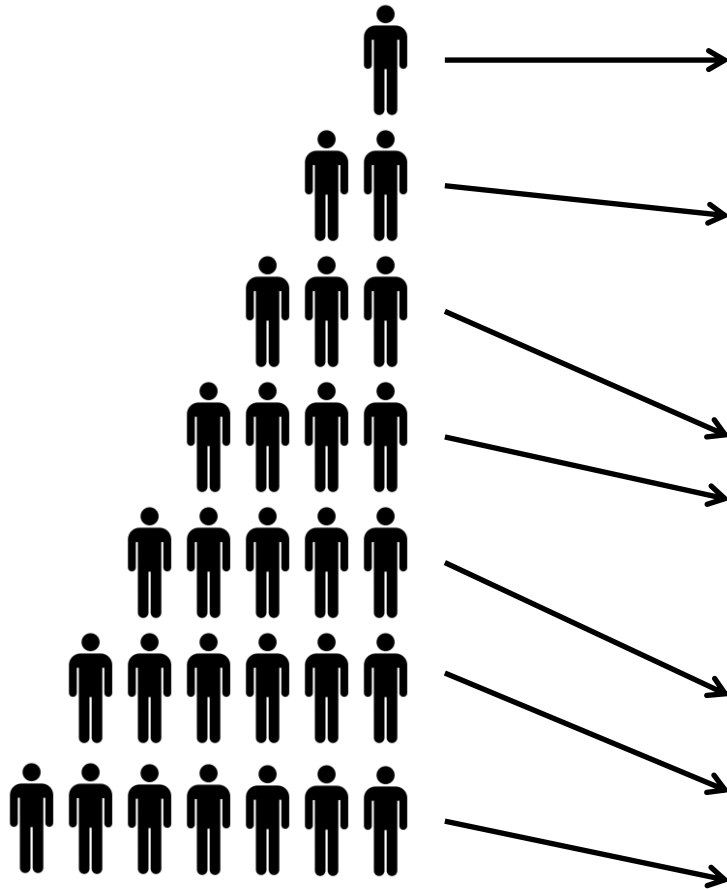


<http://bp3.ford.com/2016-Ford-Fusion?branding=1&lang=en>



https://www.alamo.com/en_US/car-rental/cars/vans.html

How much right-sizing will consumers embrace?



http://www.iappfusion.com/carros/toyota_iroad.png



<http://www.kbb.com/new-cars/5-year-cost-to-own-awards/best-to-compact-car/>



<http://bp3.ford.com/2016-Ford-Fusion?branding=1&lang=en>



https://www.alamo.com/en_US/car-rental/cars/vans.html

Mobility services providers are already starting to right-size



<http://uberestimate.com/what-is-uberx/>



<http://uberestimate.com/what-is-uberxl/>

**CAR
2GO**

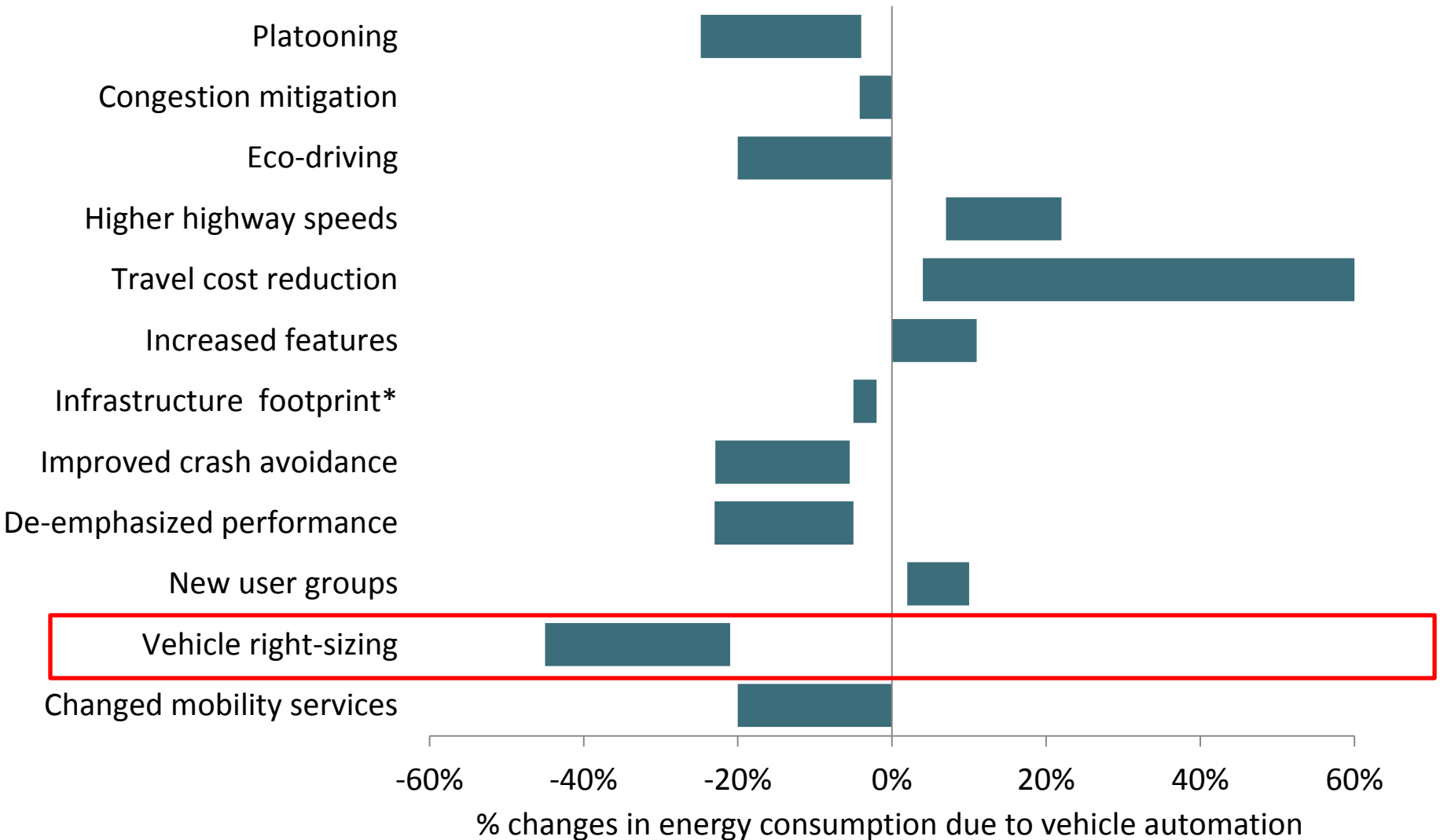


By Wakasui - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=>



<http://www.techtimes.com/articles/148876/20160409/bmw-reachnow-vs-daimler-car2go-how-these-car-sharing-services-work-and-price-comparison.htm>

Right-sizing is largest opportunity



Shared mobility fleets should have fewer emission-intensive cold starts

- Rule of thumb:
 - “80% in first 30 seconds, 90 % in first 5 minutes”

TABLE 5 Comparison of Emissions from Initial Engine Start and Restart

	Tier 2-Bin 5 (15)^a	Initial Engine Start	Engine Restart
THC (mg)	878	191	44
NO_x (mg)	552	228	6
CO (mg)	31290	2970	1253

^a Tier 2-Bin 5 g/mi converted to FTP-75 mg

L. Gaines, E. Rask, and G. Keller. Which Is Greener: Idle, or Stop and Restart? Comparing Fuel Use and Emissions for Short Passenger-Car Stops. TRB Paper No. 13-4606.

Will car ownership end in major cities?

≡ FORTUNE | Tech



Fortune Brainstorm TECH 2016 MONDAY JULY 11TH, 2016: ASPEN, CO 2:05 PM CONNECTING THE CAR: THE ROAD AHEAD Dan Ammann, President, General Motors John Zimmer, Co-founder and President, Lyft Moderator: Adam Lashinsky, Assistant Managing Editor and Editorial Director, Brainstorm TECH, Fortune PHOTOGRAPH BY STUART ISETT/Fortune Brainstorm TECH Photograph by Stuart Isett — Fortune Brainstorm TECH

SELF-DRIVING CARS

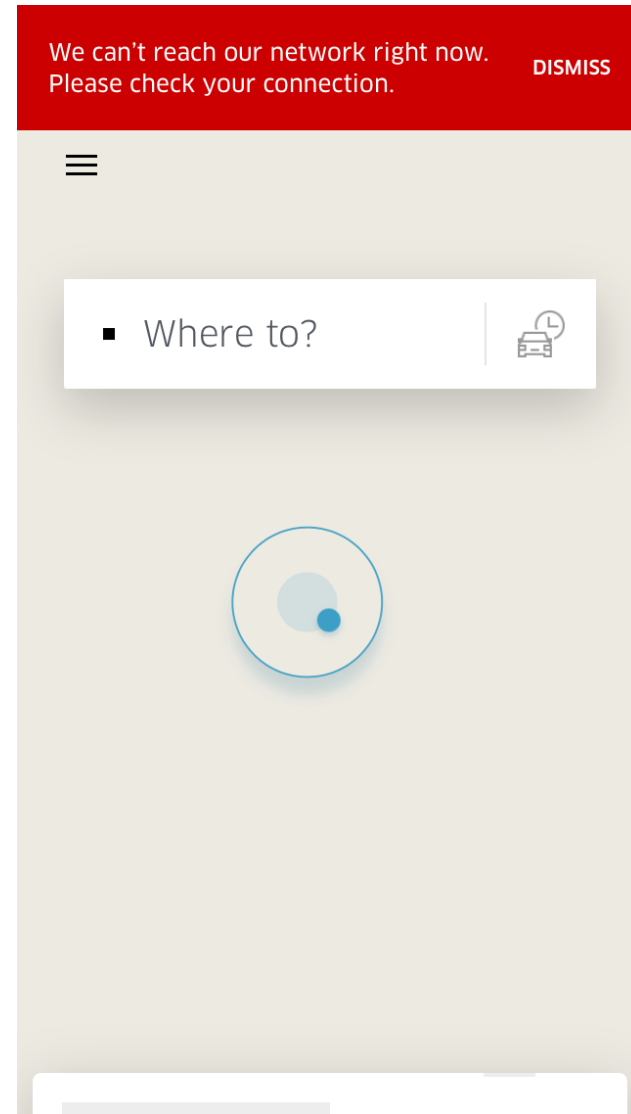
Lyft's President Says Car Ownership Will 'All But End' in U.S. Cities by 2025

Kia Kokalitcheva
Sep 18, 2016



Ride-hailing company Lyft has a bold prediction: Private car ownership will "all but end" in major U.S. cities by 2025—just nine years from now.

What happens when you want to go off the beaten track?



A suite of services can help



The Vision:
Shared, automated, electric vehicles

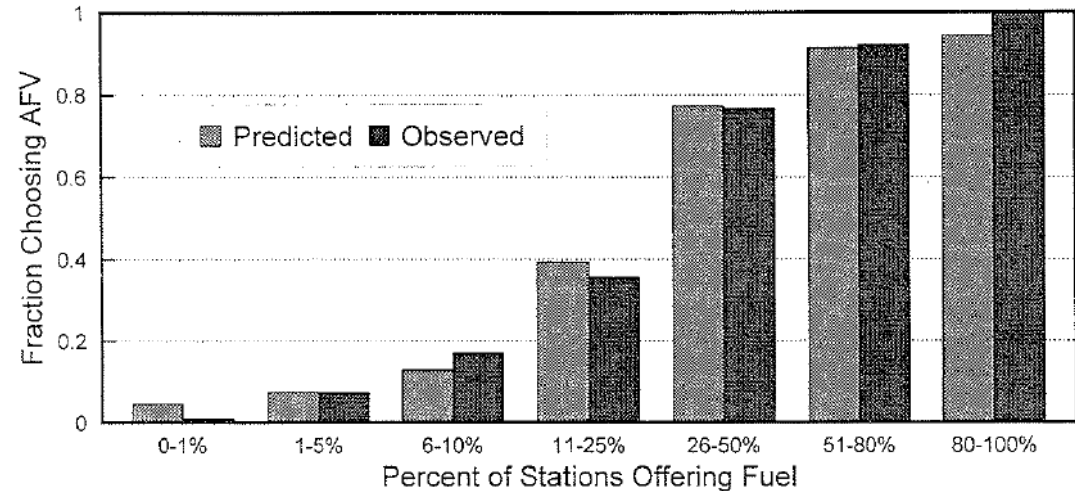
Automation could facilitate alternative fuels adoption

Less range anxiety



<http://www.lawyersforcleanenergy.com/content/can-ev-car-sharing-counter-range-anxiety>

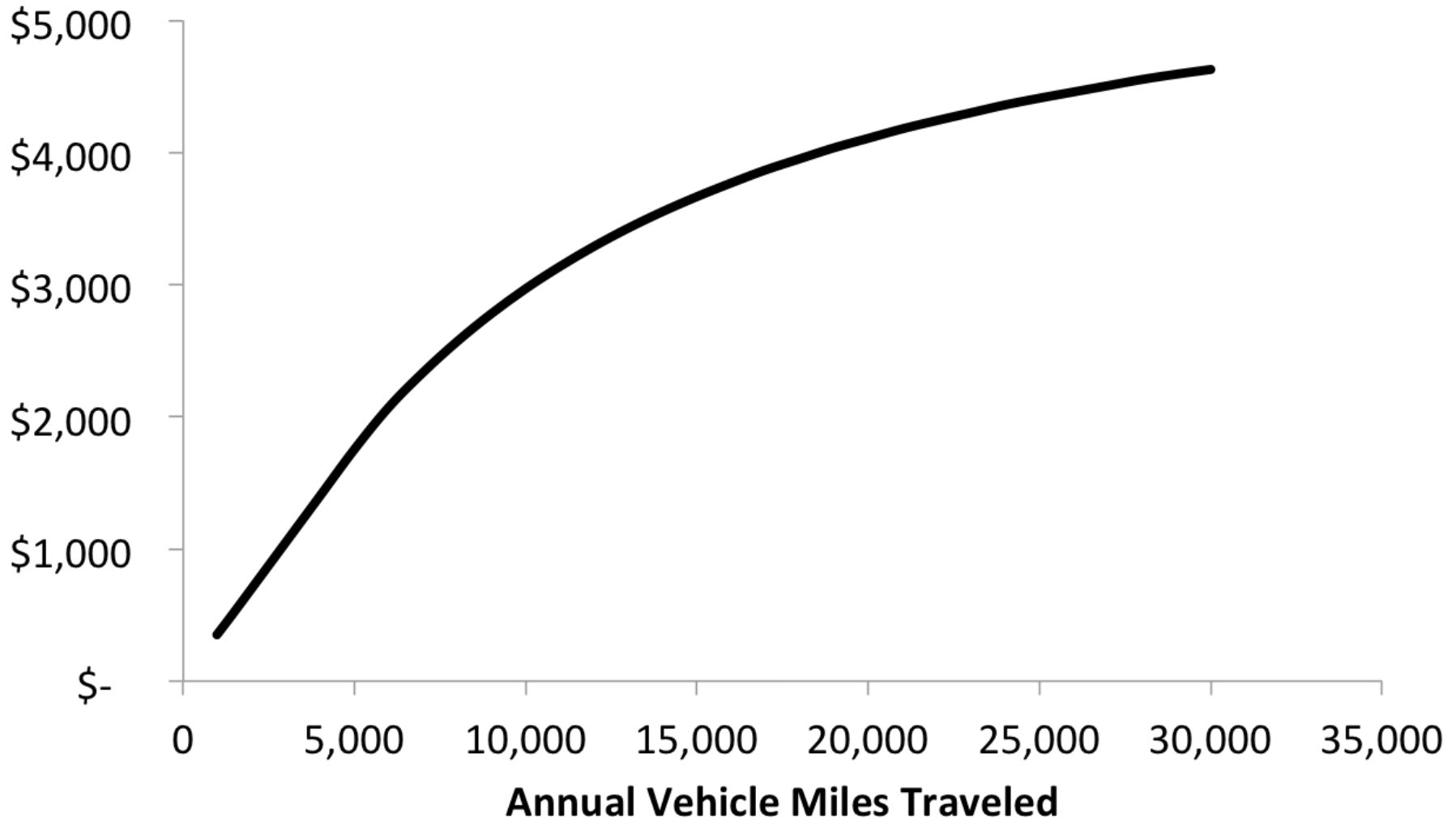
Reduced infrastructure investment



Greene, D.L., 1998. Fuel availability and alternative fuel vehicles. *Energy Stud. Rev.* 8 (3), 215–231.

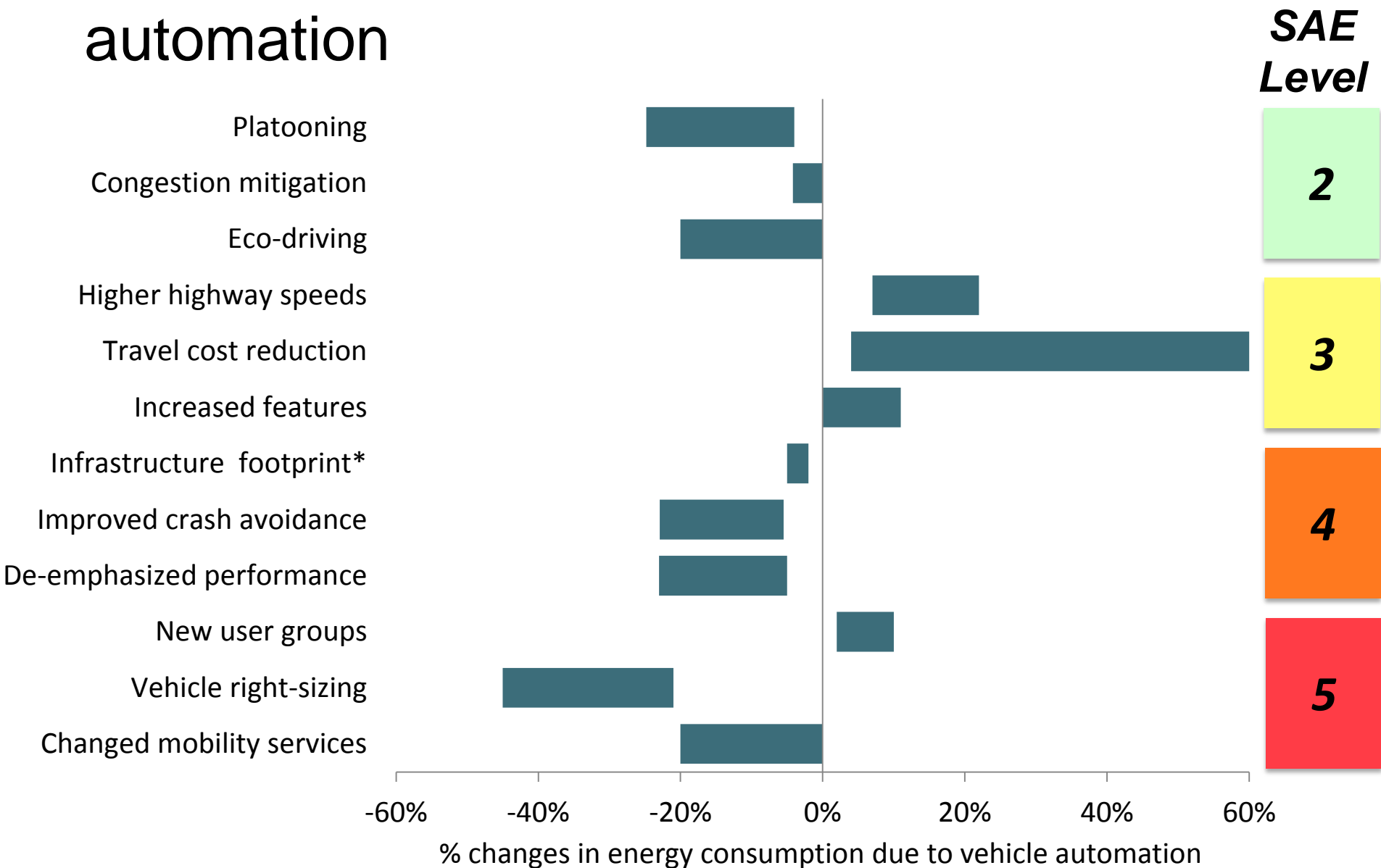
Mobility services fleets can make electric vehicles more cost effective

Present Value of Fuel Savings



How do impacts evolve over time?

Impacts will likely depend on level of automation



Thank you!

Appendix: SAE levels of automation

SAE has emerged as preferred taxonomy for levels of automation

Level	Name	Narrative definition	DDT		DDT fallback	ODD
			Sustained lateral and longitudinal vehicle motion control	OEDR		
<i>Driver performs part or all of the DDT</i>						
0	No Driving Automation	The performance by the <i>driver</i> of the entire DDT, even when enhanced by <i>active safety systems</i> .	<i>Driver</i>	<i>Driver</i>	<i>Driver</i>	n/a
1	Driver Assistance	The <i>sustained</i> and <i>ODD-specific</i> execution by a <i>driving automation system</i> of either the <i>lateral</i> or the <i>longitudinal vehicle motion control</i> subtask of the DDT (but not both simultaneously) with the expectation that the <i>driver</i> performs the remainder of the DDT.	<i>Driver and System</i>	<i>Driver</i>	<i>Driver</i>	Limited
2	Partial Driving Automation	The <i>sustained</i> and <i>ODD-specific</i> execution by a <i>driving automation system</i> of both the <i>lateral</i> and <i>longitudinal vehicle motion control</i> subtasks of the DDT with the expectation that the <i>driver</i> completes the OEDR subtask and <i>supervises</i> the <i>driving automation system</i> .	<i>System</i>	<i>Driver</i>	<i>Driver</i>	Limited
<i>ADS ("System") performs the entire DDT (while engaged)</i>						
3	Conditional Driving Automation	The <i>sustained</i> and <i>ODD-specific</i> performance by an <i>ADS</i> of the entire DDT with the expectation that the <i>DDT fallback-ready user</i> is <i>receptive</i> to <i>ADS-issued requests to intervene</i> , as well as to <i>DDT performance-relevant system failures</i> in other <i>vehicle systems</i> , and will respond appropriately.	<i>System</i>	<i>System</i>	<i>Fallback-ready user (becomes the driver during fallback)</i>	Limited
4	High Driving Automation	The <i>sustained</i> and <i>ODD-specific</i> performance by an <i>ADS</i> of the entire DDT and <i>DDT fallback</i> without any expectation that a <i>user</i> will respond to a <i>request to intervene</i> .	<i>System</i>	<i>System</i>	<i>System</i>	Limited
5	Full Driving Automation	The <i>sustained</i> and unconditional (i.e., not <i>ODD-specific</i>) performance by an <i>ADS</i> of the entire DDT and <i>DDT fallback</i> without any expectation that a <i>user</i> will respond to a <i>request to intervene</i> .	<i>System</i>	<i>System</i>	<i>System</i>	Unlimited

SAE emphasizes "who does what, when"

Level	Name	Narrative definition	DDT		DDT fallback	ODD
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1	Driver Assistance	The <i>sustained</i> and <i>ODD</i> -specific execution by a <i>driving automation system</i> of either the <i>lateral</i> or the <i>longitudinal vehicle motion control</i> subtask of the <i>DDT</i> (but not both simultaneously) with the expectation that the <i>driver</i> performs the remainder of the <i>DDT</i> .	<i>Driver and System</i>	<i>Driver</i>	<i>Driver</i>	Limited
2	Partial Driving Automation	The <i>sustained</i> and <i>ODD</i> -specific execution by a <i>driving automation system</i> of both the <i>lateral</i> and <i>longitudinal vehicle motion control</i> subtasks of the <i>DDT</i> with the expectation that the <i>driver</i> completes the <i>OEDR</i> subtask and <i>supervises</i> the <i>driving automation system</i> .	System	<i>Driver</i>	<i>Driver</i>	Limited

SAE emphasizes "who does what, when"

Level	Name	Narrative definition	DDT		DDT fallback	ODD
			<i>Sustained lateral and longitudinal vehicle motion control</i>	OEDR		
ADS ("System") performs the entire DDT (while engaged)						
3	Conditional Driving Automation	<i>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.</i>	<i>System</i>	System	<i>Fallback-ready user (becomes the driver during fallback)</i>	Limited
4	High Driving Automation	<i>The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</i>	<i>System</i>	<i>System</i>	System	Limited
5	Full Driving Automation	<i>The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</i>	<i>System</i>	<i>System</i>	<i>System</i>	Unlimited