TRAVEL BEHAVIOR IMPLICATIONS AND MODELING OF AUTOMATED VEHICLES

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May 10, 2018

Transportation Research Institute

Read more at https://www.thestar.com.my/tech/tech-news/2018/04/04/waymo-starts-to-eclipse-uber-in-race-to-self-driving-taxis/#AJYcCDefMc5Xkigv.99

Background

- Automated driving technology is starting to enter the market....
- This will have far-reaching implications on travel behavior, activity participation and land use.
- Waymo Signed a deal to build 20,000 self-driving SUV with Jaguar on top of its plan for thousands of Chrysler hybrid minivans. Within 2 years it plan to have thousands of fully automated taxis, and it predicts to give 1 million robot-taxi rides a day by 2020
- Only 2 of the 25 largest MPO in the US mention automated vehicles in official long-range regional transportation plans (Guerra, 2015

THE Star ONLINE

Waymo starts to eclipse Uber in race to self-driving taxis

TECH NEWS

Wednesday, 4 Apr 2018 7:00 AM MYT

By Carolyn Said

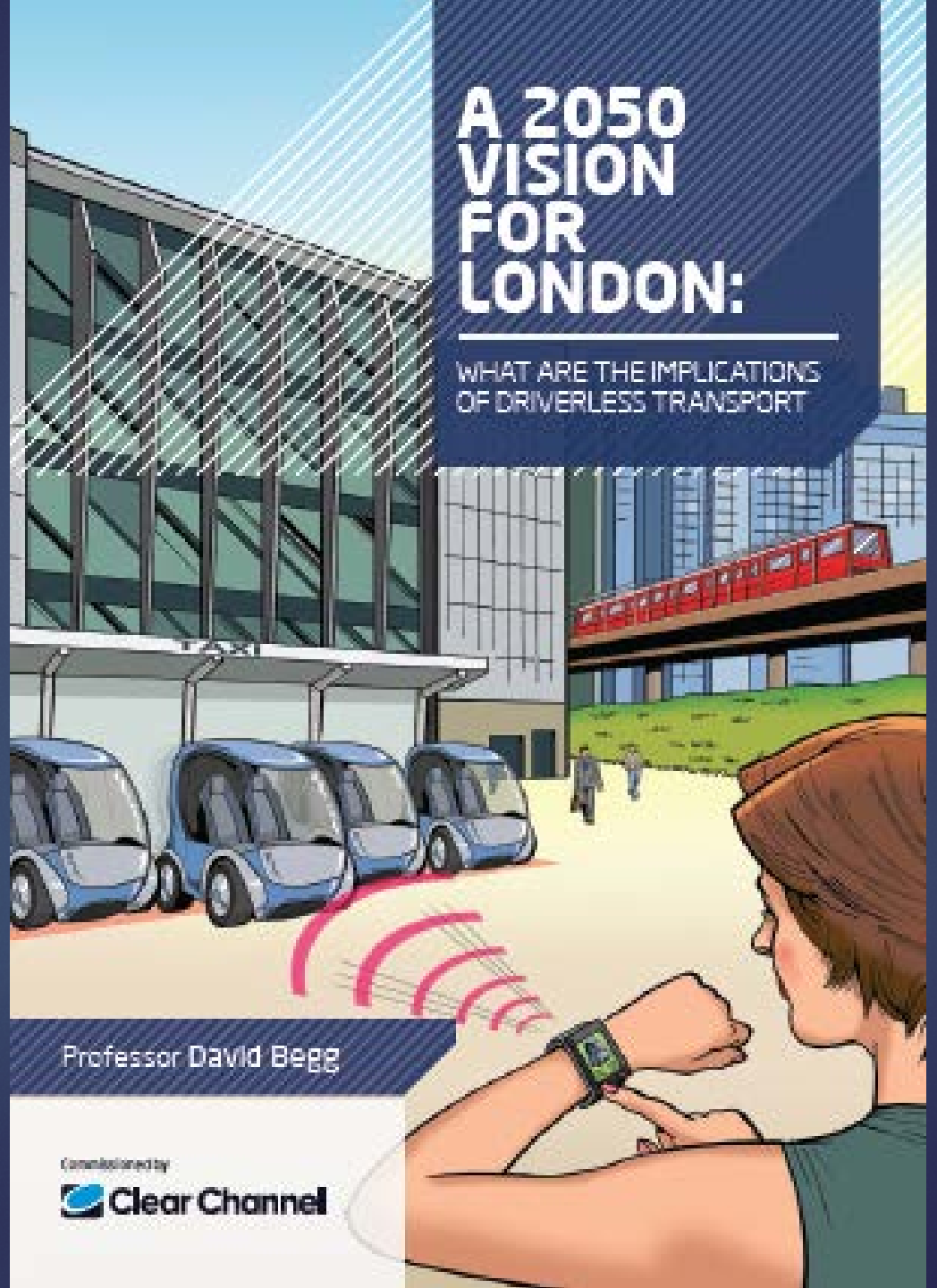
An Independent Study
Commissioned by

Ontario Must Prepare for Vehicle Automation

Automated vehicles can influence urban form, congestion and infrastructure delivery

A 2050 VISION FOR LONDON:

WHAT ARE THE IMPLICATIONS OF DRIVERLESS TRANSPORT



Professor David Begg

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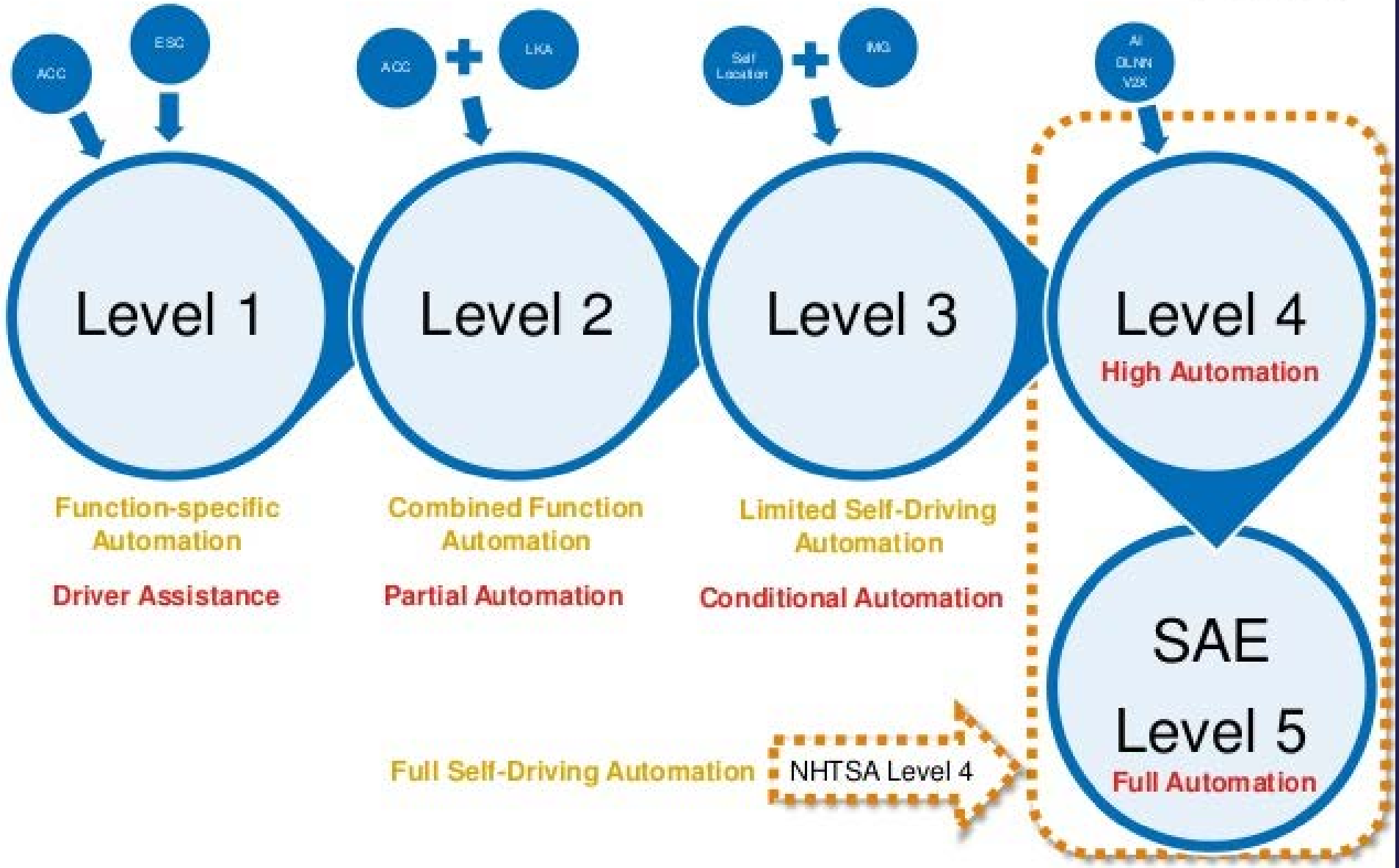
Clear Channel

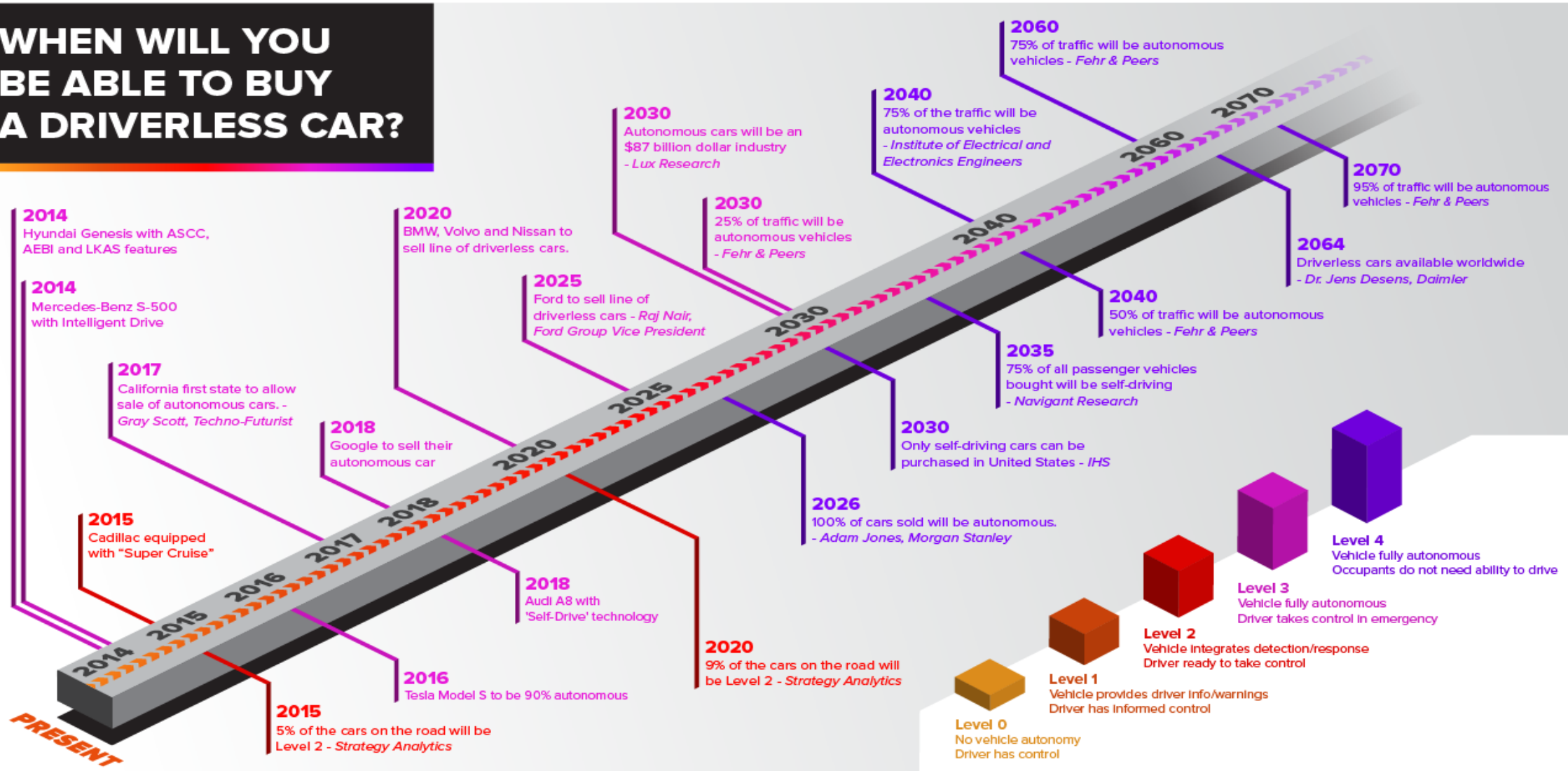
Some Terms

- Automated/autonomous/driverless
- Connected/unconnected automated vehicles

NHTSA and SAE Levels of Automation



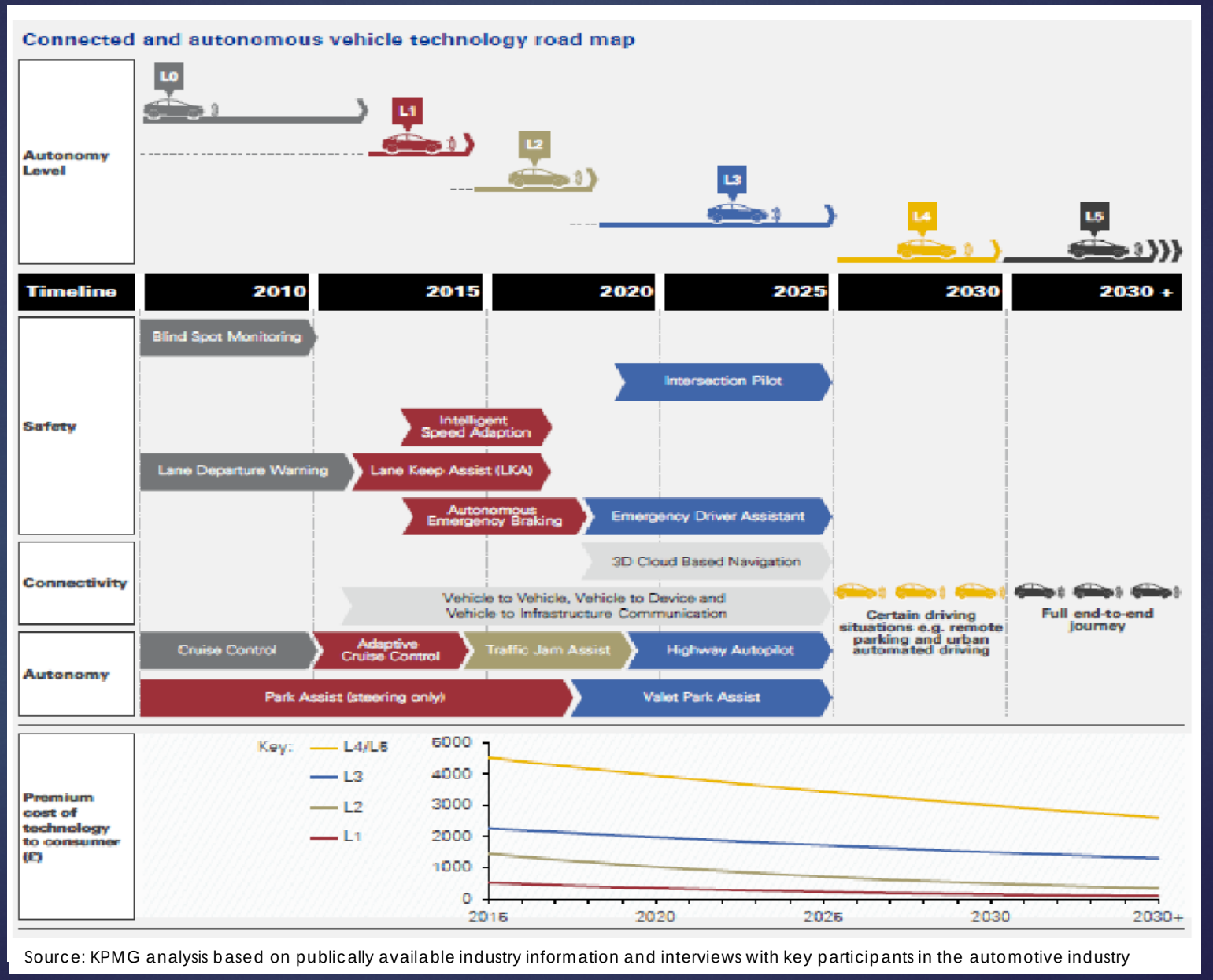
WHEN WILL YOU BE ABLE TO BUY A DRIVERLESS CAR?



Source: Mercedes-Benz, GM News, Strategy Analytics, Automotive News, Nissan News, Navigant Research, Volvo News, Fehr & Peers, Lux Research, IHS

mojomotors

Into the Future: Technology Roadmap



Source: KPMG analysis based on publically available industry information and interviews with key participants in the automotive industry

Literature Review

- Past research has focused on the supply side of AVs, with little focus on the demand side
- Mostly opinion studies
- Focus groups
- Some SP studies

Willingness to pay for automated features

- Shin et. al. (2014) found that on average, individuals in South Korea are willing to pay the equivalent of US $1500 for wireless connectivity and internet/communications, and about US $500 for voice command and smart real-time applications features.
- Kyriakidis et al. (2014) collected data from 109 countries and found that 22% did not want to pay any additional price for a fully automated driving system, whereas 5% indicated they would pay more than $30,000.

Stated Preference Studies

Willingness to go driverless and preferred degree of automation

Studies reveal a wide range of opinions among users:

- Megens (2014) found that users prefer partial automation over full automation (Van der Waerden, 2015 obtained similar findings).
- Schoettle & Sivak (2014) surveyed travelers in China, India, Japan, U.S., U.K. and Australia and obtained high levels of concern about riding automated vehicles.
- Alessandrini et al. (2014) showed that users did not perceive automation as valuable when there weren't savings in travel time and fare.
- Howard and Dai (2013) showed that people are most attracted to the safety benefits, parking convenience, and en route multitasking.

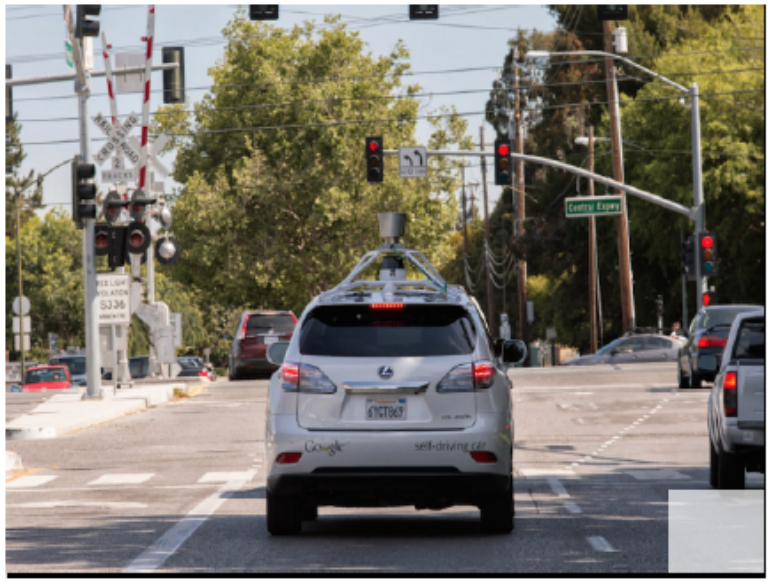
Tendency toward AV

- Megens, 2014; Missel, 2014; Yvkoff, 2012; Kyriakidis et al., 2015; Payre et al., 2014: male, educated, young

Issues in (Modeling) Adoption of Driverless Cars

The Driverless Car Debate: How Safe Are Autonomous Vehicles?

By **Lauren Keating**, Tech Times | July 28, 9:00 AM



As companies like Google and Delphi Automobile continue to test autonomous vehicles on the road, issues concerning the safety in regard to accidents and vulnerability in the software continue to rise. How safe are autonomous cars? (Photo : Google)

When it comes to the future of transportation, the first thing that comes to mind is the possibility of flying cars. It's easy to imagine an urban utopia with vehicles that float through the air, swerving around buildings, reaching toward the heavens.

While *Back to the Future: Part II* wrongly predicted that we would have this technology in 2015, autonomous vehicles—which are currently being tested—may just be the stepping stone to making this a reality. Who would've thought robot cars would be our present?

No matter what side you stand on in the safety debate, even those who have concerns still agree that this innovative technology is the way of the future.

Companies like Google, Delphi Automotive, Bosche, Tesla, Nissan Mercedes-Benz, Uber and Audi have already begun testing self-

The Washington Post

Gridlock

Self-driving Uber vehicle strikes and kills pedestrian

By Faiz Siddiqui and Michael Laris March 19 at 6:19 PM

After one of Uber's driverless cars hit and killed a pedestrian in Arizona Monday, there was broad agreement — among both proponents and detractors of the speedy adoption of self-driving technologies — that this day was coming.

Uber abruptly halted testing across North America on Monday after a 49-year old woman, Elaine Herzberg was struck late Sunday night, leaving the rest of the burgeoning industry wondering what the crash means for their future. There was no immediate indication that the brakes would be put on by government authorities or the companies they regulate.

Skeptics were hardly surprised that one of the cars they warned were not yet ready had been implicated in a deadly tragedy. And evangelists of the technology had long understood, as one executive from a major car maker put Monday, that "just as a matter of data, this point would come."

THE VERGE

TRANSPORTATION | CARS | TESLA

294

Tesla driver killed in crash with Autopilot active, NHTSA investigating

by Jordan Golson | @jlgolson | Jun 30, 2016, 4:42pm EDT

A Tesla Model S with the Autopilot system activated was involved in a fatal crash, the first known fatality in a Tesla where Autopilot was active. The company revealed the crash in a blog post posted today and says it informed the National Highway Transportation Safety Administration (NHTSA) of the incident, which is now investigating.

Effect of Safety/Trust on Driverless Vehicles Acceptance

- People don't feel comfortable using a new technology which's safety hasn't been proven yet. Issues of trust are expected to be a major issue of AV acceptance (Howard & Dai, 2014; Choi & Ji, 2015)
- Automation can cause over trust that will lead to reduced situation awareness and increased reaction time (Endsley, 1996; Parasuraman & Riley, 1997; Young & Stanton, 2007)
- Operator's trust might exceeds the actual capabilities and cause over trust (Cunningham & Regan, 2015)
- Long periods of no manual driving may result in degradation of both the cognitive and psychomotor skills required to execute driving safely (Cunningham & Regan, 2015)
- The vehicle control algorithm affect trust (Price et. al., 2016)

Self-Driving Cars and Insurance

FEBRUARY 2015

THE TOPIC

Each new generation of cars is equipped with more automated features and crash avoidance technology. Indeed, many of today's high-end cars and some mid-priced ones already have options, such as blind-spot monitoring, forward-collision warnings and lane-departure warnings. These will be the components of tomorrow's fully automated vehicles. At least one car manufacturer has promised to have fully automated cars available by the end of the decade.

Except that the number of crashes will be greatly reduced, the insurance aspects of this gradual transformation are at present unclear. However, as crash avoidance technology gradually becomes standard equipment, insurers will be able to better determine the extent to which these various components reduce the frequency and cost of accidents. They will also be able to determine whether the accidents that do occur lead to a higher percentage of product liability claims, as claimants blame the manufacturer or suppliers for what went wrong rather than their own behavior. Liability laws might evolve to ensure autonomous vehicle technology advances are not brought to a halt.

RECENT DEVELOPMENTS

- A study by the Insurance Institute for Highway Safety (IIHS) has found that improvements in design and safety technology have led to a lower fatality rate in accidents involving late model cars. The likelihood of a driver dying in a crash of a late model vehicle fell by more than a third over three years, and nine car models had zero fatalities per million registered vehicles. Part of the reason for the lower fatality rate might also stem from the weak economy, which led to reduced driving, the IIHS said.
- The study, which looked at fatalities involving 2011 model year cars over a year of operation, found that there were an average of 28 driver deaths per million vehicle car years through 2012, down from 48 deaths for 2008 model cars through

Why You Shouldn't Worry About Liability for Self-Driving Car Accidents

By Mark Harris
Posted 12 Oct 2015 | 20:00 GMT

Photo: Volvo

Håkan Samuelsson—President & CEO, Volvo Car Group

Volvo president Håkan Samuelsson caused a stir earlier this week when he said that Volvo would accept full liability whenever its cars are in autonomous mode (https://www.media.volvocars.com/global/en-gb/media/pressreleases/167975/us-urged-to-establish-nationwide-federal-guidelines-for-autonomous-driving). Samuelsson went further, urging lawmakers to solve what he called "controversial outstanding issues" over legal liability in the event that a self-driving car is involved in a crash.

"If we made a mistake in designing the brakes or writing the software, it is not reasonable to put the liability on the customer," says Erik Coelingh, senior technical leader for safety and driver support technologies at Volvo. "We say to the customer, you can spend time on something else, we take responsibility."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Security Nightmare of Driverless Cars

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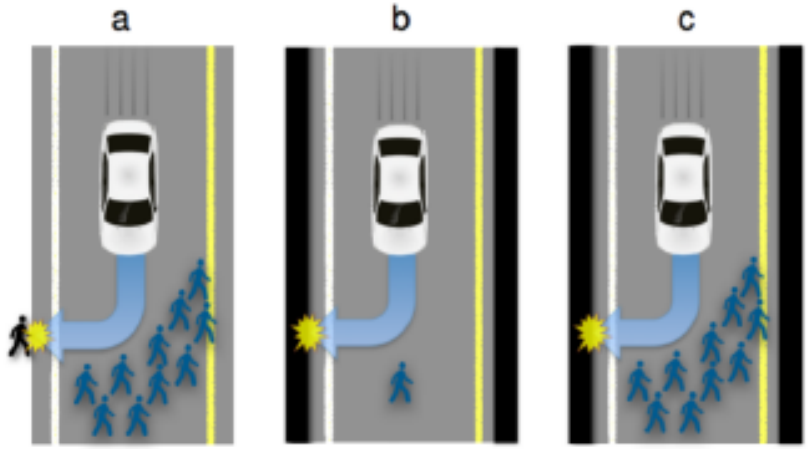
A View from **Emerging Technology from the arXiv**

Why Self-Driving Cars Must Be Programmed to Kill

Self-driving cars are already cruising the streets. But before they can become widespread, carmakers must solve an impossible ethical dilemma of algorithmic morality.

October 22, 2015

When it comes to automotive technology, self-driving cars are all the rage. Standard features on many ordinary cars include intelligent cruise control, parallel parking programs, and even automatic overtaking—features that allow you to sit back, albeit a little uneasily, and let a computer do the driving.



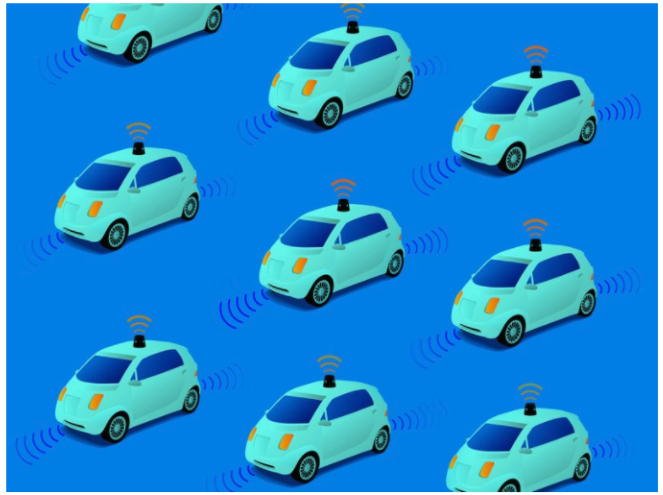
Cost

- High technology cost (but decreasing over time).
- Decreased cost of crashes and insurance policies due to increased safety.
- Decreased operating costs, including parking cost and car-sharing vehicles.
- Decrease time cost
- Savings in parking space where land is scarce.
- Fuel and emission reduction

- Annual economic benefits for the US are estimated at $27 billion for 10% penetration and $450 billion for high penetration (Fagmant and Kockelman, 2015)
- Feldman and Avineri estimated this figure for Israel from 1.1 billion NIS today to 4.5 billion NIS in the future (ITS Israel, 2016)

AARIAN MARSHALL TRANSPORTATION 06.03.17 08:00 AM

ROBOCARS COULD ADD $7 TRILLION TO THE GLOBAL ECONOMY



GETTY IMAGES

MENTION AUTONOMOUS VEHICLES, and people conjure two visions of the future. The rosy picture features a world in which cars zip around by themselves, allowing commuters to while away their time checking email as they benefit from technology expected to save 600,000 lives by 2045. The dystopian view holds that all those vehicles will put some 5

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ANGELA WATERCUTTER

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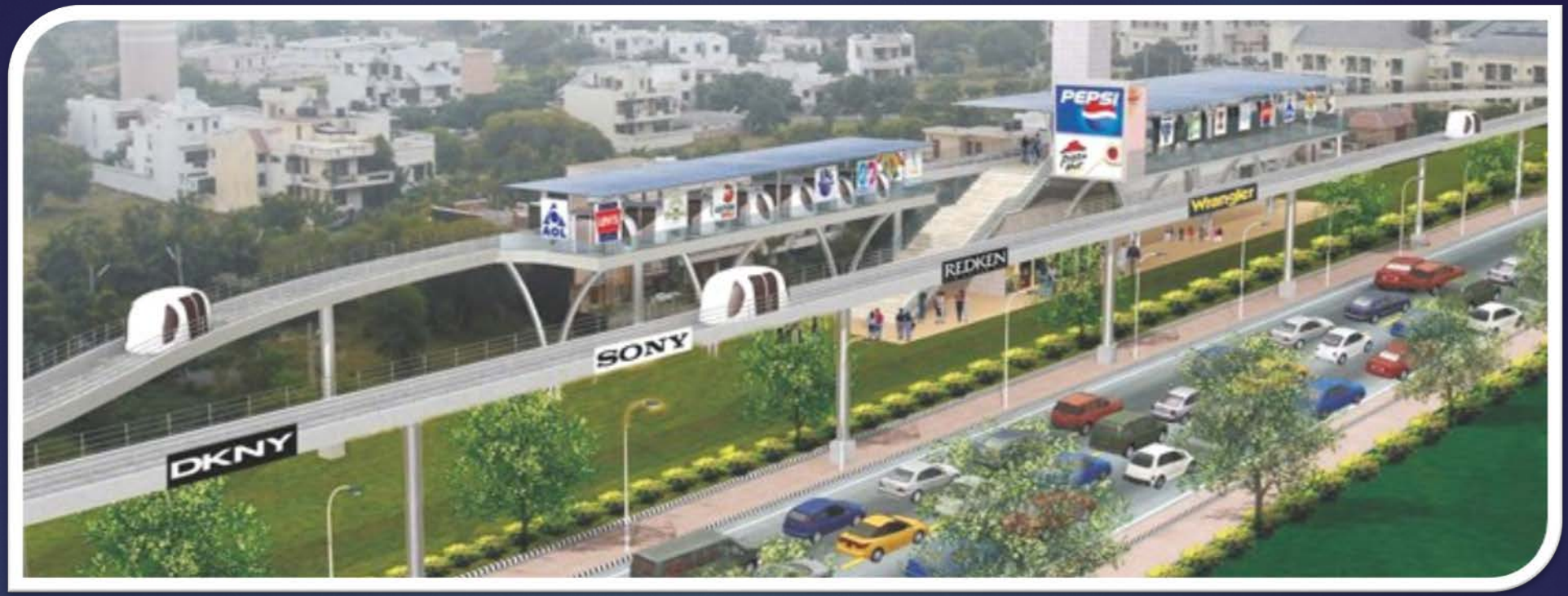
GEEK'S GUIDE TO THE

Emerging Services

- Reducing service operating costs by eliminating the need to pay drivers
- Increase flexibility by positioning vehicles to better respond to demand
- Encouragement of widespread use of vehicle and ride-sharing programs
- Engendering new modes that will be a cross between public and private modes available today


PEPSI
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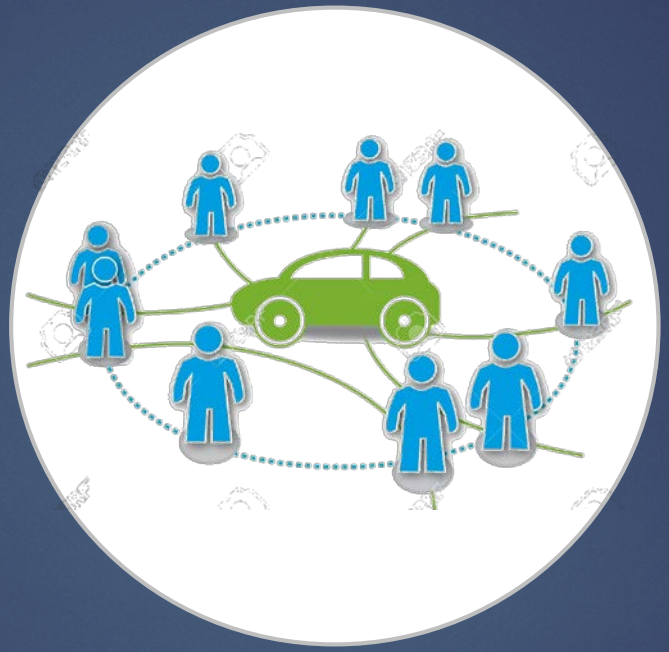
The driver's private "**Capsule**"

The alternate "**Chassis**" that is infrastructure-dependent

Road Chassis

Rail Chassis


Harmonious Mobility Network




Flinkster

Ford will rent out your ride in new car-sharing pilot

Alisa Priddle, Detroit Free Press *11:21 a.m. EDT June 24, 2015*

(Photo: Ford)

SAN FRANCISCO — Instead of fighting public transportation, bicycles and car-sharing services, Ford is looking to join them -- and still make money even if fewer people are buying cars.

Ford is trying to reinvent itself as a mobility company and address the trend in urban areas of cities growing and becoming more congested, CEO Mark Fields said in an interview. "People value access more than ownership. We need to understand customers' concerns and make their lives easier."

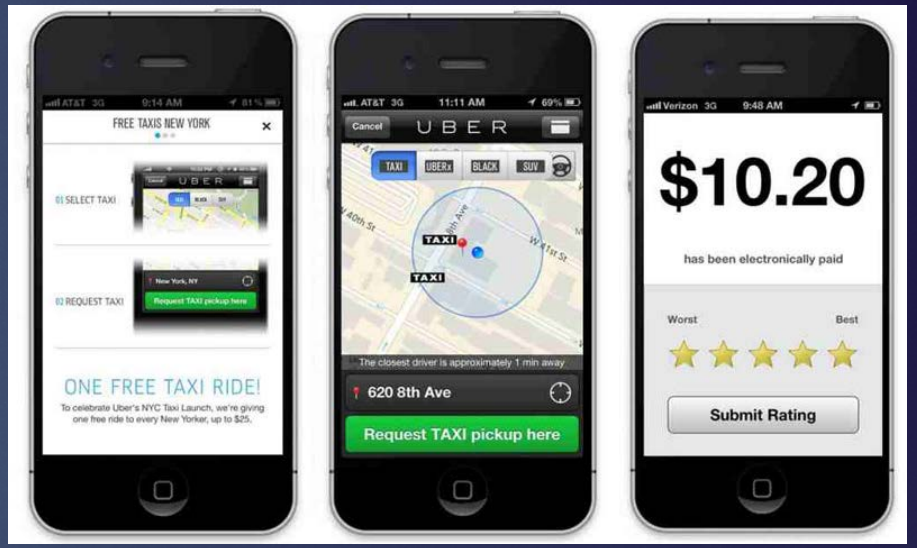
USA TODAY

Ford diving into autonomous-car horse race

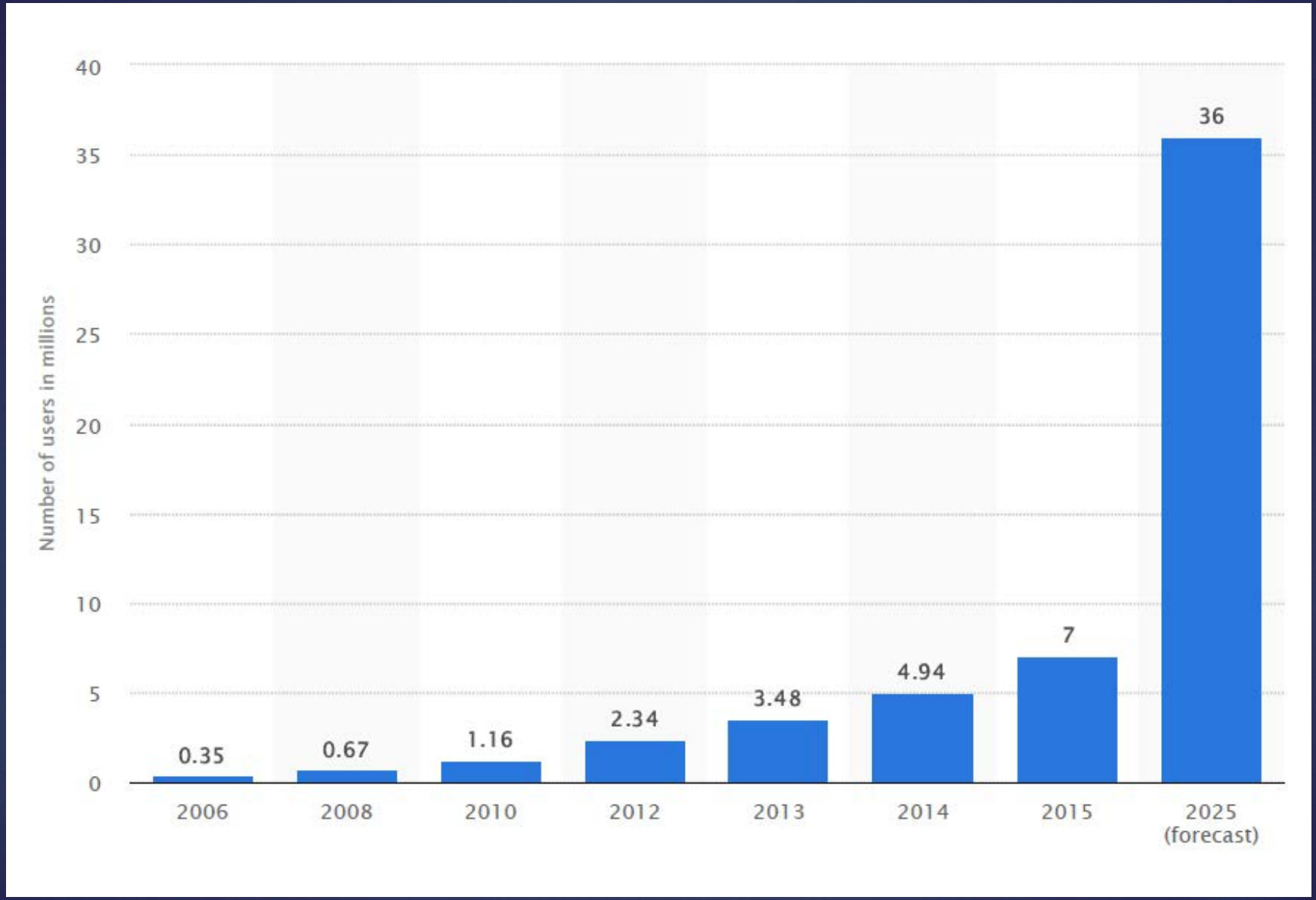
(http://www.usatoday.com/story/tech/2015/06/23/ford-diving-into-autonomous-car-horse-race/29187375/)

Data Collection for Analog Modes

- Behavioral response, modality styles, diffusion, adoption, network effects
- Car sharing services (ownership/membership)
- On-demand services (multitasking/value of time)
- Electric cars (energy efficiency/new technology)
- Chauffeurs



Number of vehicle sharing users worldwide (in millions)



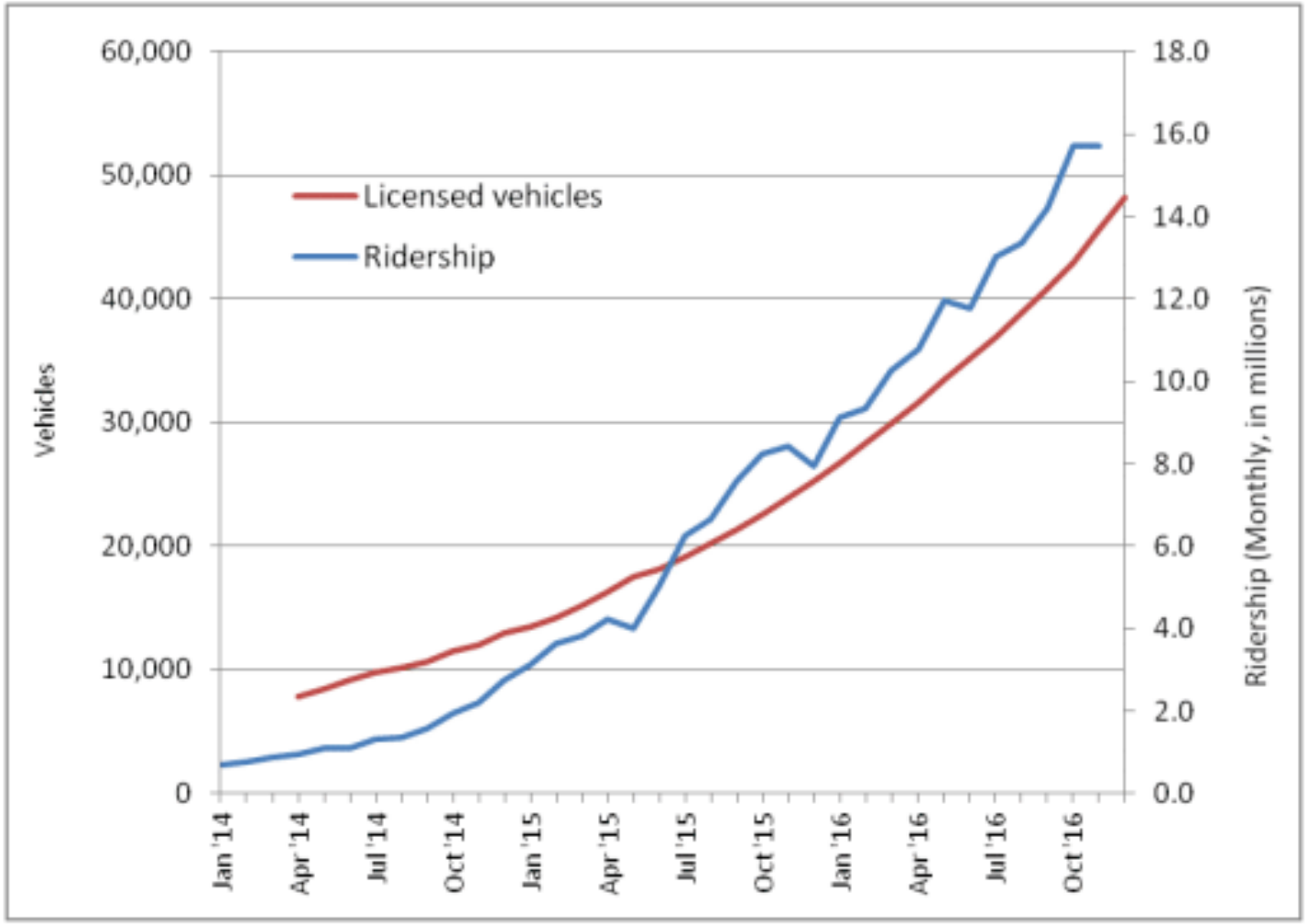
Source: https://www.statista.com/statistics/415636/car-sharing-number-of-users-worldwide/

New York

Travel speeds in Manhattan south of 60th Street have dropped 20% from 2010 speeds—and declined 10% in the past year alone. (Taxi GPS is used as a proxy for travel speeds.)

http://www.nyc.gov/html/dot/downloads/pdf/mobility-report-2016-print.pdf

Figure 2. TNC licensed vehicles and monthly ridership, 2014 to 2016



Sources: Ridership is from TLC trip files and assumes 1.66 passengers per trip. Licensed vehicles is from TLC base and vehicle licensing files for mid-2014, mid-2015, mid-2016 and Dec. 2016, and interpolated for other months.

Schaller Consulting, 2017

Figure 9. Changes in ridership by mode, 2012 to 2013

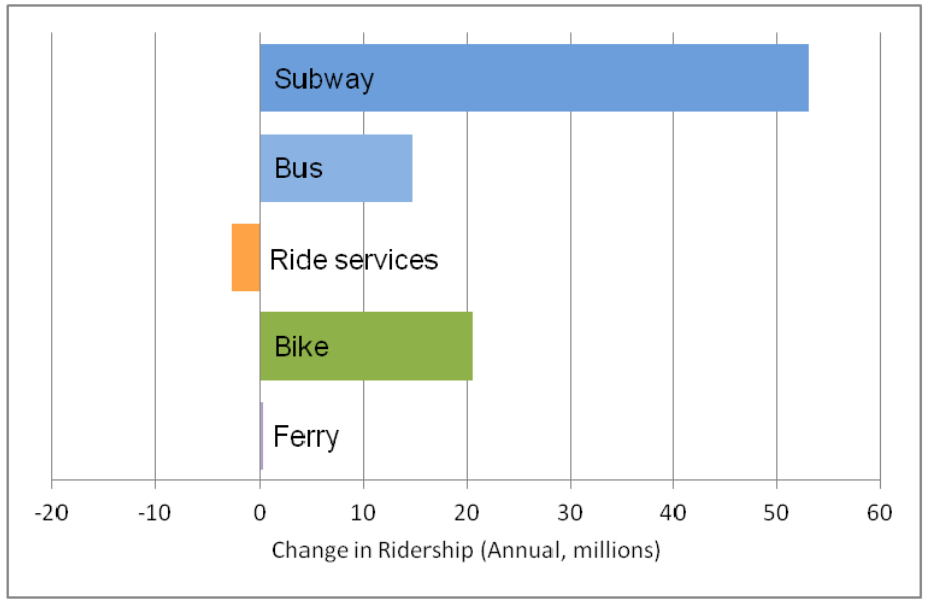


Figure 10. Changes in ridership by mode, 2013 to 2014

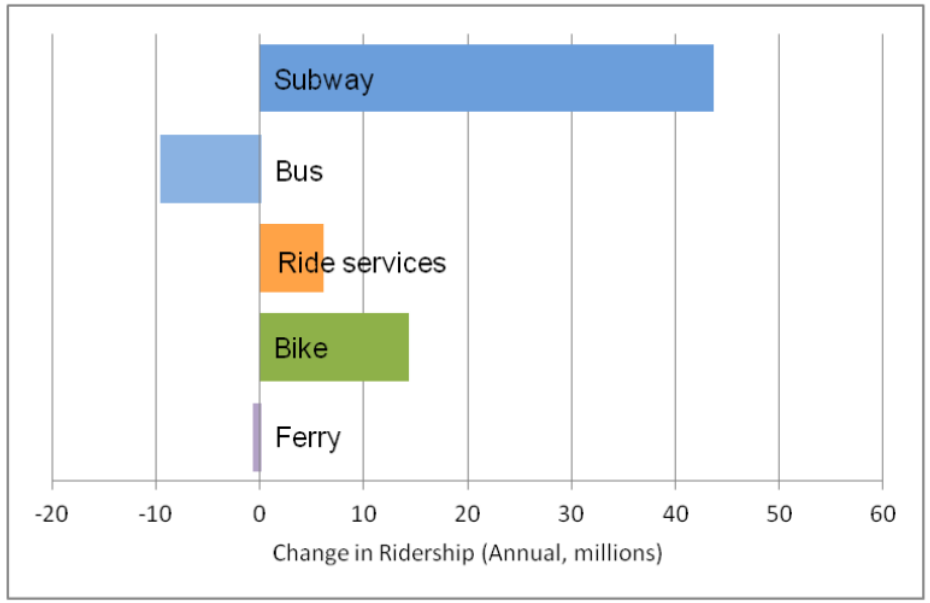


Figure 11. Changes in ridership by mode, 2014 to 2015

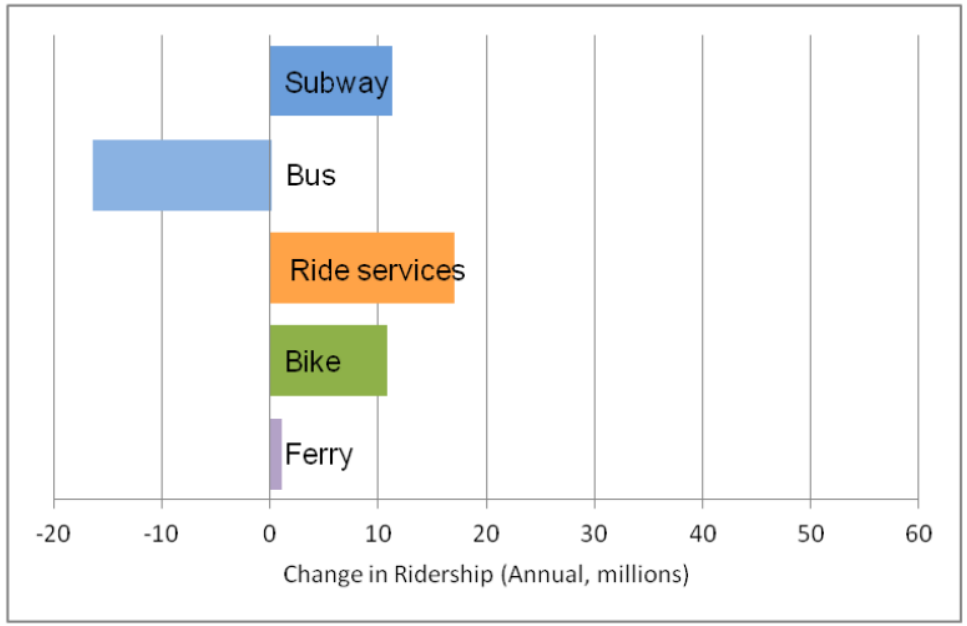


Figure 12. Changes in ridership by mode, 2015 to 2016

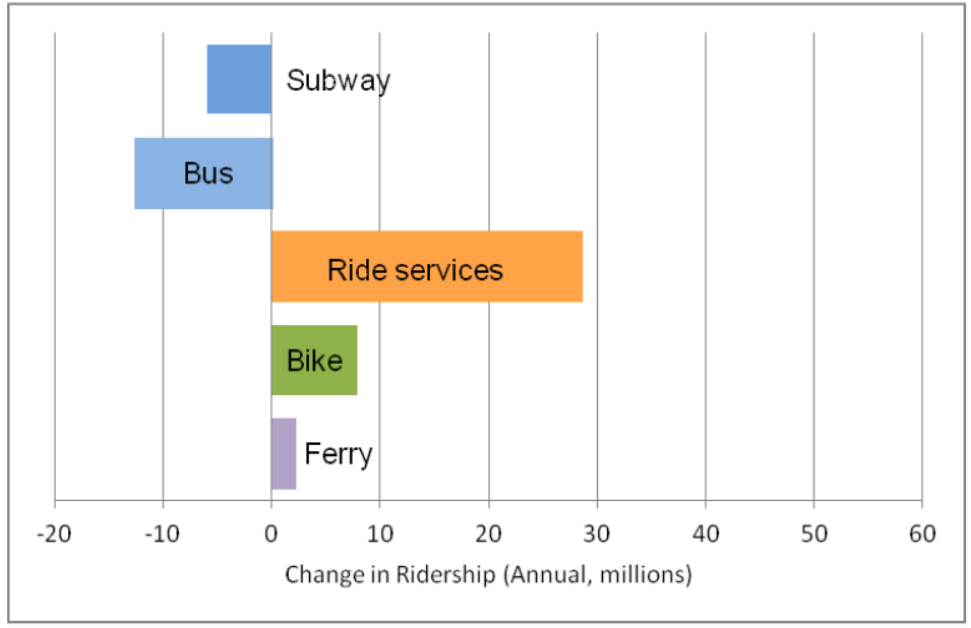
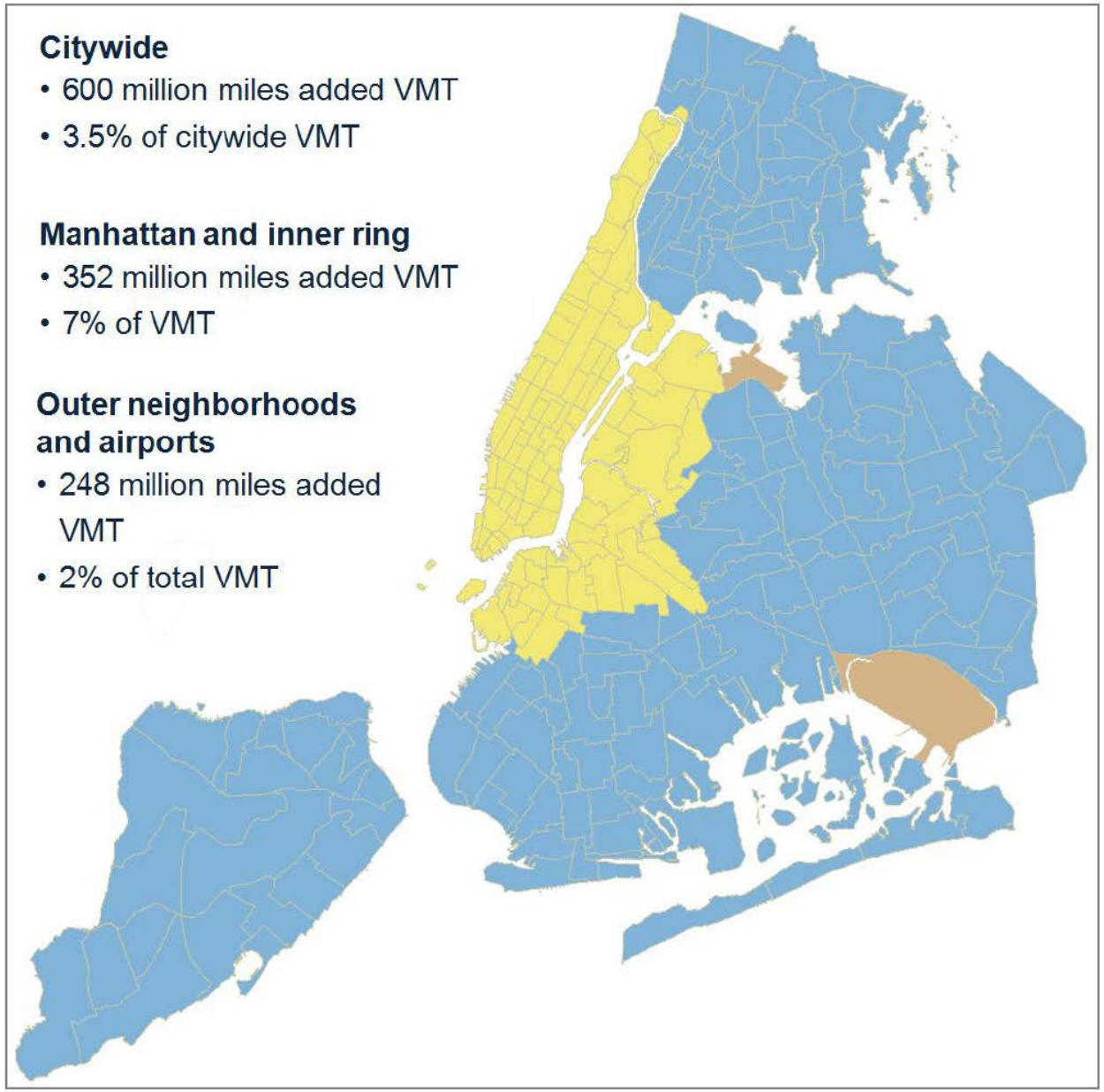


Figure 13. TNC mileage by geographic area, 2016



Source: TLC odometer and trip files.

Initial Evidence From Previous Studies of Emerging Services (Analog Modes)

Shaheen and Cohen, 2013	North American car-sharing members reduced their driver distance by 27% | approximately 25% of members sold a vehicle and another 25% forgone a vehicle purchase.
Martin et al., 2010	Car sharing facilitates a substantial reduction in household vehicle holdings in North America. Car sharing has taken between 90,000 and 130,000 cars off the road.
Firnkorn & Müller, 2015	Having driven an electric-car2go increased car2go-users' willingness to forgo a private car purchase.
Becker et al., 2015	Free-Floating Car Sharing (FFCS) - the car can be returned in any legal parking space.
Kopp et al., 2015	Using GPS tracking smartphone application, higher trip frequency was found for FFCS compared to non-car-sharers. FFCS users are more prone to intermodal and multimodal travel.

Simulation studies/Network based studies

- Given a network and an OD demand matrix, how can it be better served by various new mobility services
- Schoettle & Sivak (2015) analyzed the potential of self-driving vehicles with a “return-to-home” mode. Analysis of the 2009 U.S. National Household Travel Survey revealed a that most families rarely use more than one vehicle simultaneously. Self-driving vehicles could cut ownership rates of up to 43%
- Kockelman & Fagnant (2014) showed that while the advent of automated vehicles may address many current car-sharing barriers, shared automated vehicles can add up to 10% more travel distance than comparable non-SAV trips

Scenario Analysis using existing Activity Based Modeling

	Assumptions	Scenarios	Range of Impacts
Atlanta **Kim et al. (2015)**	• 71% reduction in vehicle operation cost • 50% increase in road capacity • 50% reduction of the IVT coefficient • No parking cost at primary destinations	• 100% market penetration of level 4 in 2014	• Average trip length increases from 10 to 12 miles • Number of daily trips increase from 2.5% • Average delay reduce by 14% • Transit share reduce by 42%
Puget Sound **Childress et al. (2015)**	• 30% increase in road capacity • 35% reduction in VOT (all HH or only high income HH) • $1.65 per mile for SAV	• SAV replaces private care	• 4-20% increase in VMT • 17% increase in VHT • 30% reduction in VMT • 45% reduction in VHT • 140% increase in transit • 50% increase in walking
MTC **Gucwa (2014)**	• 50% reduction in VOT • No parking cost • 50% reduction in parking cost		• 8-24% increase in VMT

- Reduce driver burden (stress, fatigue, productive time
- No need to park

Reduced cost (operators)

Reduced cost (traveler)

- Travel time budget, VOT
- Travel money budget

New services and modes

Increased flexibility

Efficient Use of Travel Time

- How to adequately describe and measure **alternative time use**? (including productivity improvements or even the possibility of performing activities during the trip that are more enjoyable than driving)
- Extended time allocation models: impact on the **value of time**

Value of Travel Time Saving

- There are some early indications for such implications Becker (1965), Becker and DeSerpa (1973), Horowitz (1978)
- Several SP studies show VOTTS is affected by travel multitasking (Ettema and Verschuren 2007; Connolly et al. 2009; and van der Waerden et al. 2010; Bergman and Shiftan, 2017)

- Transit already provides such advantage, what can we learn from this?
- The social factor: time with kids/time alone…

Stated Preference Studies

The Impact of Multi-Tasking

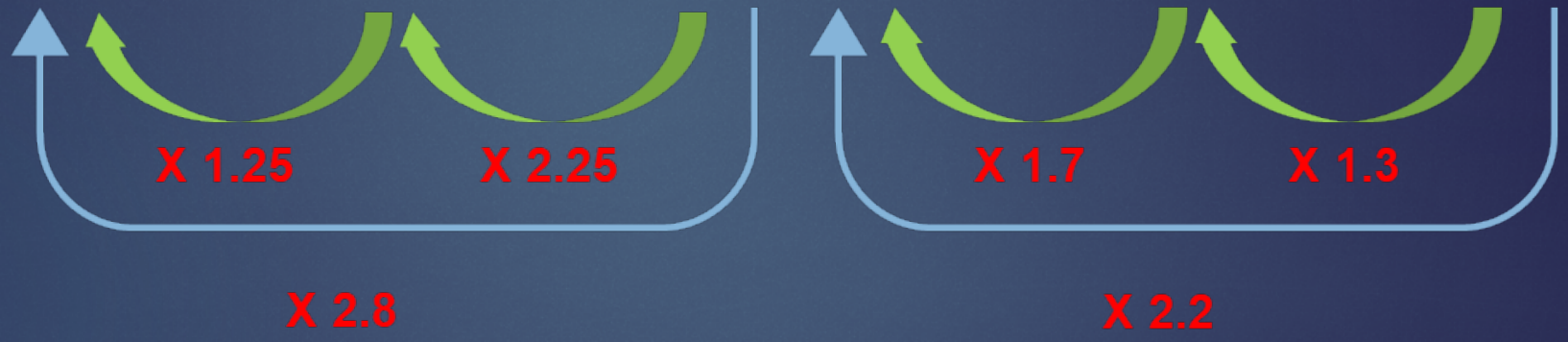
- Malokin et al. (2015) showed that engaging in productive activities such as using a laptop significantly increased utility
- Berliner et al. (2015) found that users with longer commutes who traveled via commuter rail and ridesharing had the highest propensity to engage in various activities
- Additional multi-tasking related factors: age, gender, income, distance, education level, attitudes and preferences towards the adoption of technology, familial obligations, and time use expectations

RP-SP Study (Bergman & Shiftan, 2017)

MNL	3A-M4			4A-M4			
	PC	CP	RAIL	PC	CP	RAIL	AV
Time	-0.085*** (-7.64)	-0.106*** (-13.00)	-0.09*** (-11.18)	-0.086*** (-6.65)	-0.0817*** (-9.15)	-0.078*** (-10.47)	-0.0825*** (-7.86)
Cost	-0.033*** (-4.54)	-0.052*** (-9.25)	-0.097*** (-6.63)	-0.016*** (-2.19)	-0.026*** (-3.72)	-0.032** (-1.98)	-0.026*** (-5.17)
Prop_Eat	-	**2.47*** (7.37)**	**0.68*** (2.42)**	-	**1.51*** (5.88)**	**0.88*** (3.26)**	-
Prop_Laptop	-	-	**1.16*** (2.96)**	-	-	**1.24*** (3.60)**	-
Prop_Read	-	-	-	-	**-1.07*** (-3.02)**	-	-
Prop_Rest	-	**0.86*** (3.21)**	-	-	**1.36*** (6.33)**	-	-
Prop_Call	**1.09*** (3.26)**	-	-	**1.20*** (3.54)**	-	-	-

Bergman and Shiftan – Values of Times

MNL	3A-M4			4A-M4			
	PC	CP	RAIL	PC	CP	RAIL	AV
VOT (NIS/hr)	~ 154	~ 123	~ 55	~317	~188	~145	~189



Value of time by propensity to multitask

	PC	CP	Rail
VOT [Nis/hr] (High propensity)	42	37	34
VOT [Nis/hr] (Low propensity)	117	150	70

Demand

- Reduce driver burden (stress, fatigue, productive time
- No need to park

Reduced cost (operators)

Reduced cost (traveler)

- Travel time budget, VOT
- Travel money budget

New services and modes

Increased flexibility

- Longer commute
- Travel distance to other purposes
- Changes in activity patterns
- More travel

- New opportunities
  - To all
  - To pop. who can't drive
- More options to accomplish tasks

Demand

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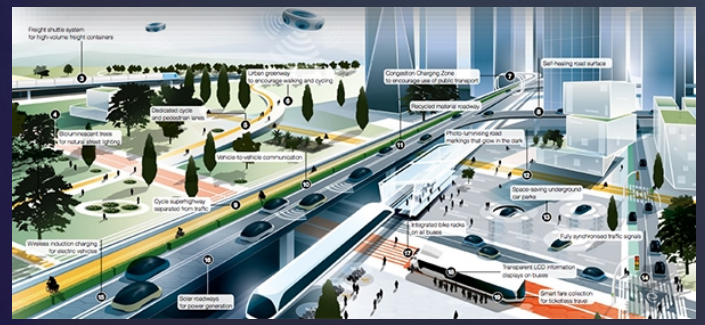

- Residential location
- Land use
- City expansion
- Value of aggloremation

- New opportunities
  - To all
  - To pop. who can't drive
- More options to accomplish tasks

AV and Land Use - Key Questions

- Will the changes brought by AVs be structural or they will just magnify/reduce effects that we have already been observing?
  - Non-structural: continued sprawl
  - Structural: accelerated sprawl vs. densification (return to the city)
    - VTT reduction vs. no need to park

Research & Data Requirements

- Longitudinal data
- Time-use data
- Alternatives
  - Qualitative data
  - Ask retrospective questions about what people value
    - What was the most important factor when choosing your current residence?
    - What are the aspects of your residential location that you are least happy about?
  - Can we design appropriate SP surveys?

Type of car purchased

Less walking – heath effect

General Modeling Challenges of Adoption

- Changes in the utility of various modes
- New modes of driverless vehicles
- Substitution between modes
- Changes in value of time
- New range of attributes (cost)
- Change in attitudes/preferences
- The role of societal and cultural factors
- The role of control seeking/driving fond/trust in safety and security/ethics
- The role of policy
- The penetration/adoption phase

Decision Makers

- Driverless cars and driverless services can be used virtually by **anyone**/**anything** at any time
- Who makes the decision of buying or riding a driverless car and how these decisions are made?

Alternatives / Choice Set / Ownership

- New modalities and business models: **dynamic evolution** + **cost restructure**
- Ownership (**purchase**) or on-demand services (**membership**)? (Or both)

Tesla Board Member: Uber CEO Wants To Buy Half A Million Autonomous Cars From Us In 2020

By Alyssa Pereira

July 7, 2015 4:07 PM

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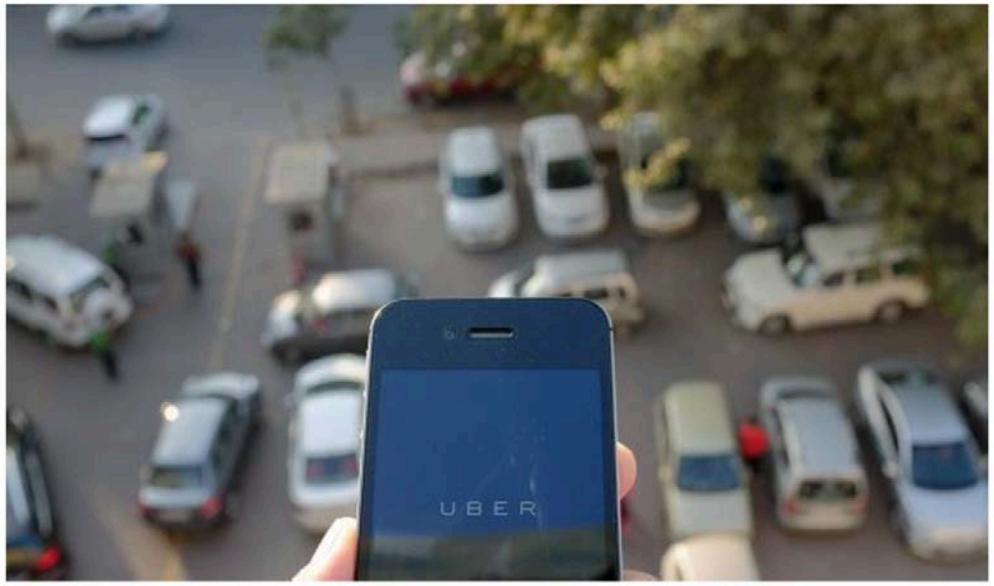


> "Incumbent players rarely do well when industries disrupt."
>
> – *Larry Burns, Co-Author of Reinventing the Automobile: Personal Urban Mobility for the 21st Century*

Decision Rules

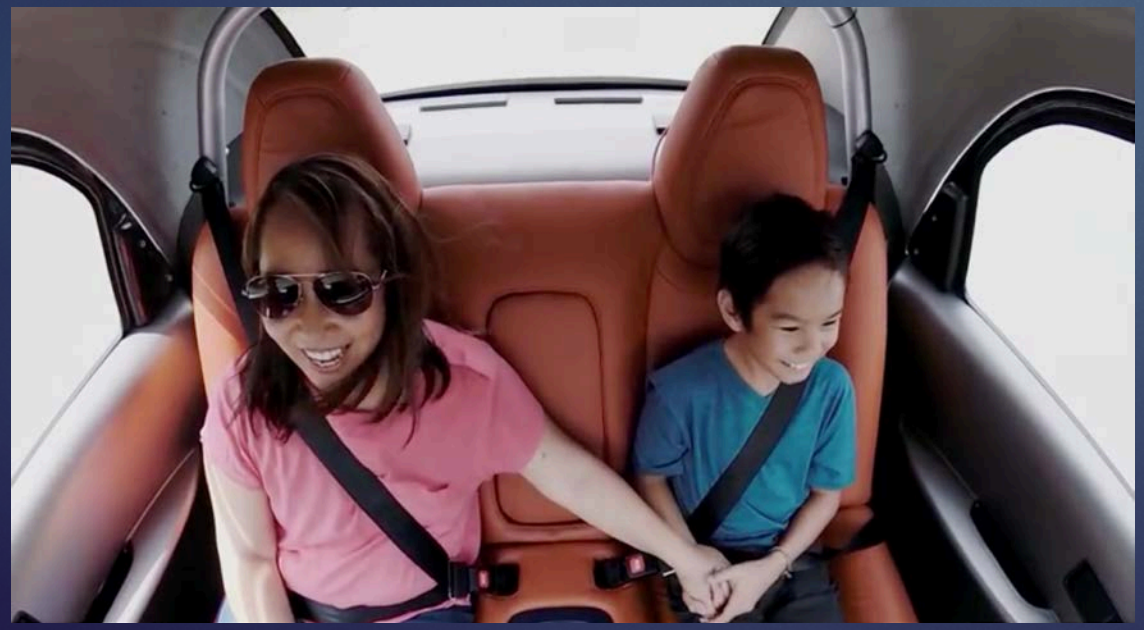
- Goal: **better capturing how decisions are made**
- Evolution of the decision context to model (cf. traditional ownership)
- Need for models that allow for **dynamics**, **systems integration**, **flexibility**, and **heterogeneity**
- Processing information about uncertain outcomes
- Intertemporal preferences
- Route choice no longer a modeling issue?
- How do we model the complex choice of letting the car make the decisions versus taking control back of the car?

Lack of Knowledge/Experience

- **Awareness**, **knowledge**, and **experience** are all important concepts when modeling adoption of any kind of new technology
- How do we avoid behavioral bias when trying to measure adoption intentions?
- Use of movies/simulators/virtual reality: how to best explain/recreate the experience of an automated ride?

Choice Experiments for Automation

- Experimental attributes in a traditional DCE setting: entry-level automated features are easy, but what about **higher levels**?
- How do we deal with the lack of experience?
- Use of **movies / simulators** / **gaming / virtual reality**
- Controlled, extended test rides: before & after case studies
- Look for **existing analogies** to infer behavior and provide **tangible experience**



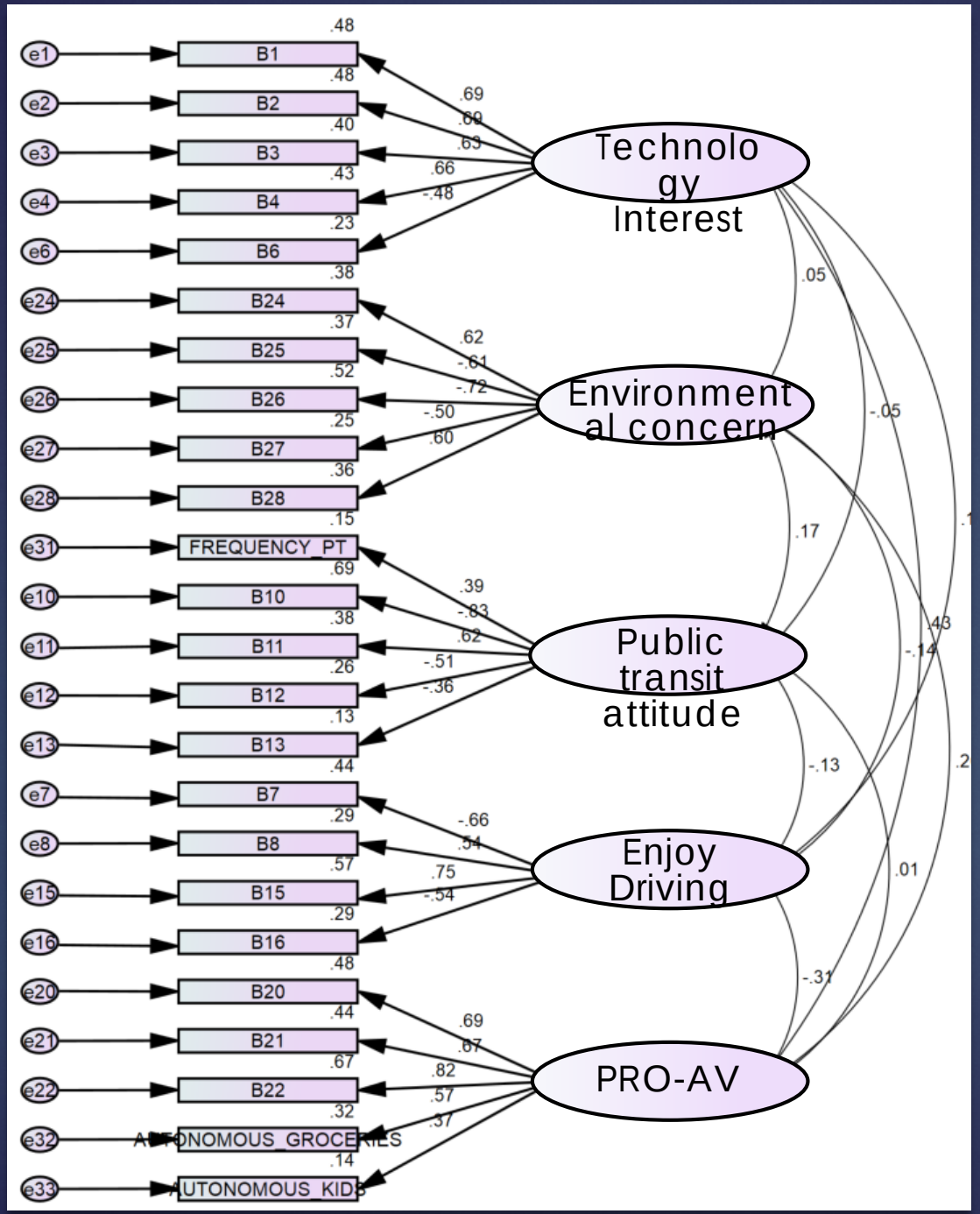
SP Design

Given the following characteristics, which option would you choose for your commute?

	Current car	Private autonomous vehicle	Shared autonomous vehicle
Purchase cost	30000$	34500$	--
Yearly membership cost	--	--	0$ /year
Trip cost (per direction of commute)	1.50$	1.27$	2.50$
Parking cost	4$	1.20$	--

Which option would you choose to use for this trip?

Current vehicle ○ Private autonomous vehicle ○ Shared autonomous vehicle ○

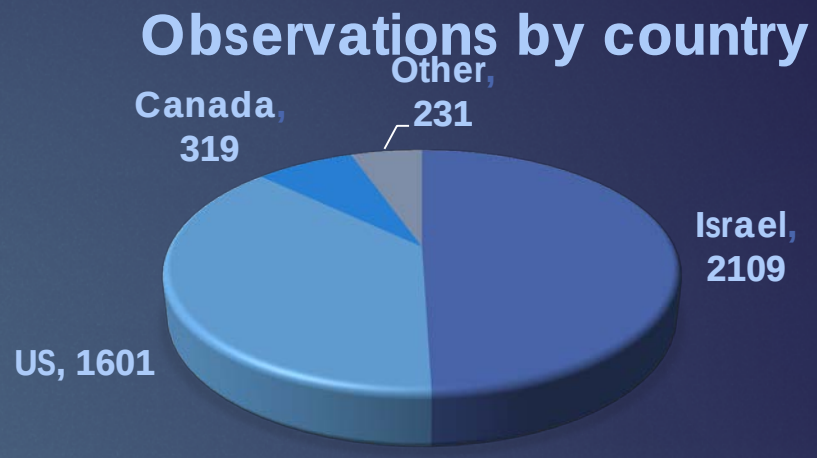


CONFIRMATORY FACTOR ANALYSIS

Generated using SPSS AMOS

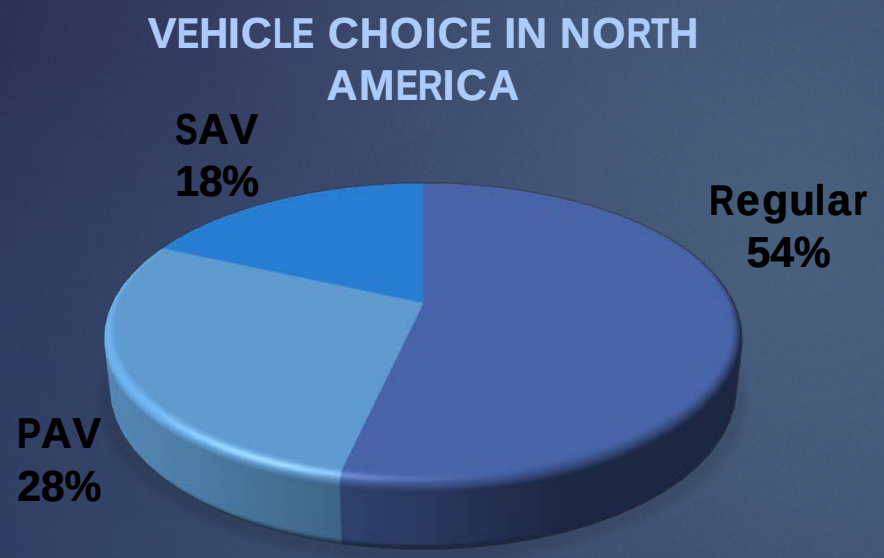
RESPONDENTS

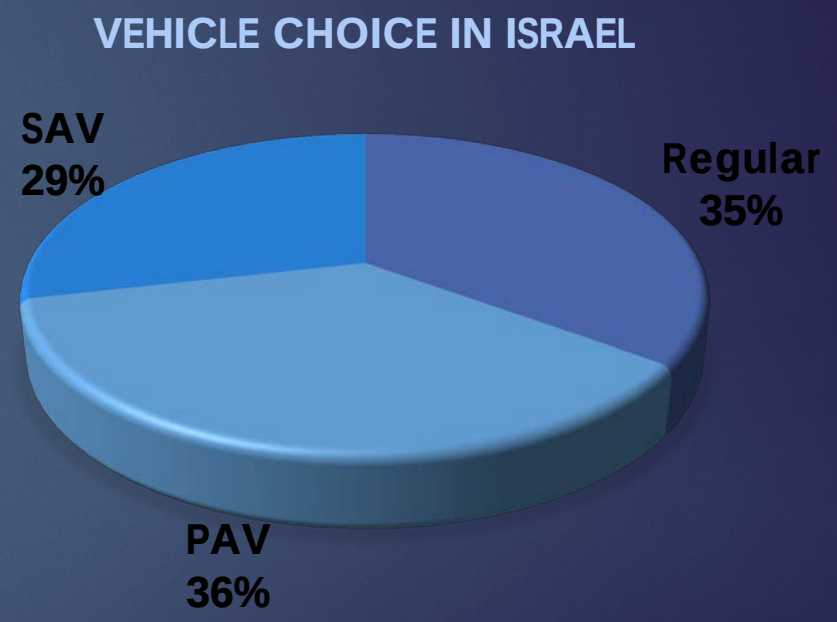
Total respondents	720
Total choice decisions	4260



Total Observations		
Regular	PAV	SAV
44.1%	32.4%	23.5%

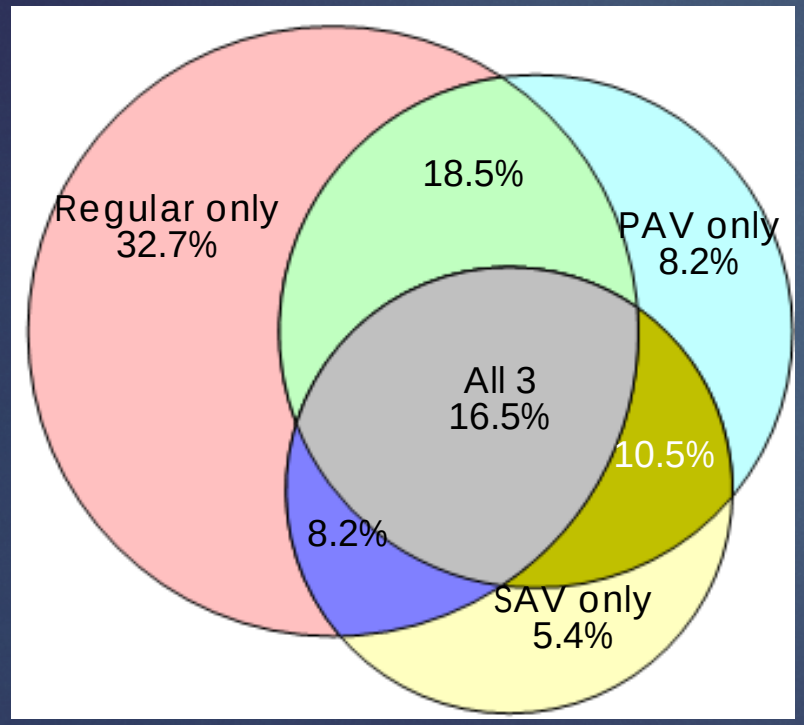
Differences by Location



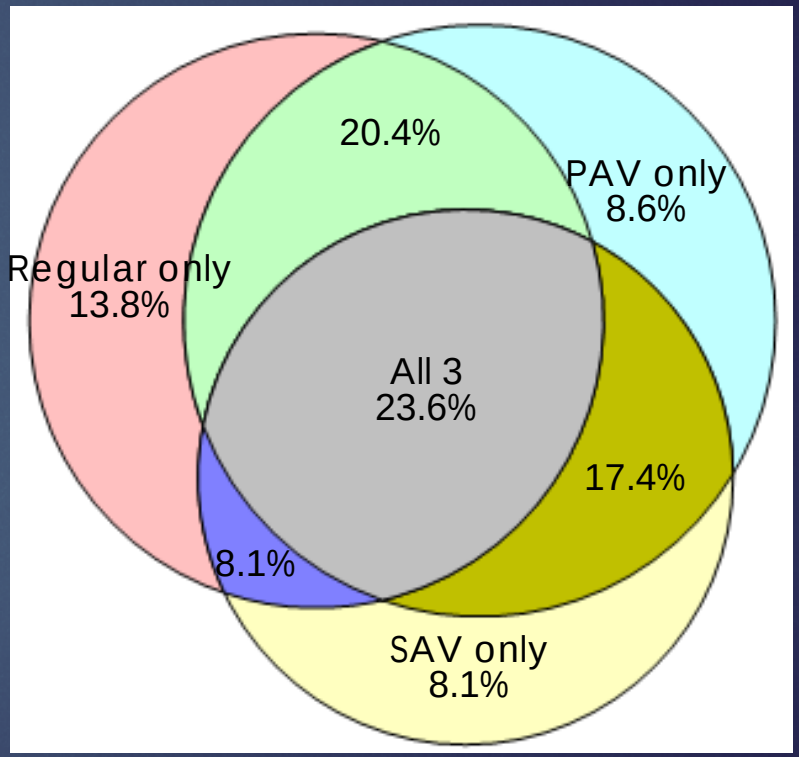


Consistent individuals

North American individuals



Israeli individuals



36% of individuals were always consistent in their choices

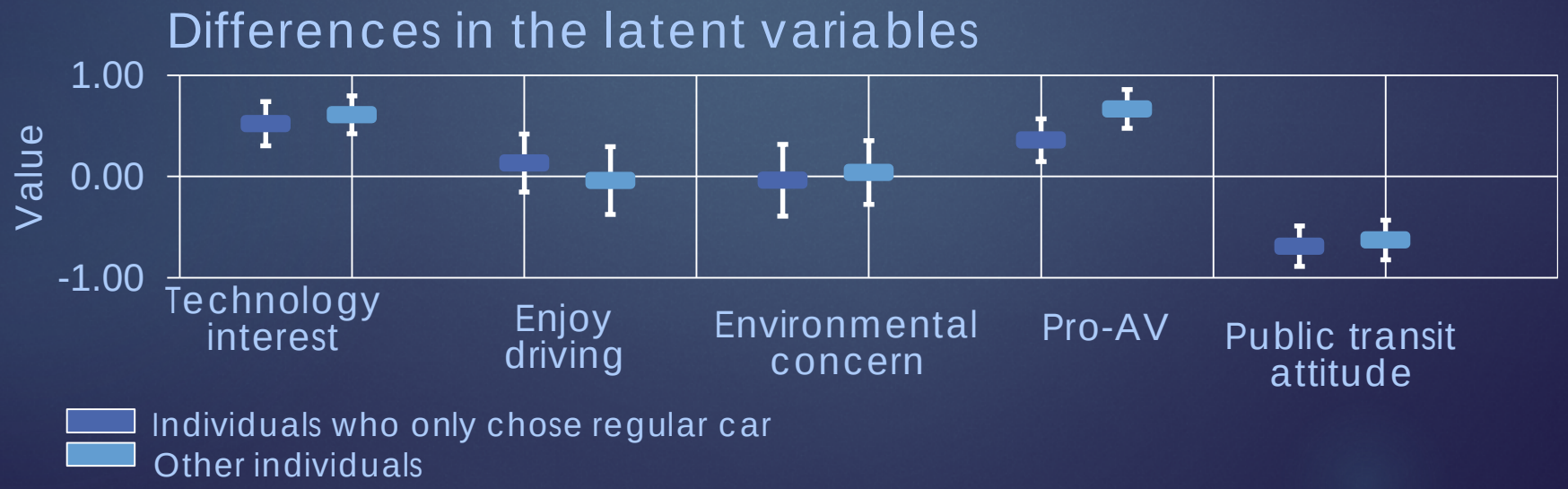
Market Segmentation

North America	Israel
Constant	More negative for NA individuals
Control	Sig. only in NA
Gender	Sig. only for Israelis
Education	More positive in NA
Errands	Sig. only for Israelis
Environmental concern	Sig. only for Israelis
Age	More significant in NA
Income and costs	Israelis place more importance on income and costs. Israelis care more about marginal costs and less about capital costs

Consistent Individuals

An examination of the 166 individuals who always chose regular cars

- **Older, less likely to have young children**
- **More likely to be female**
- **Less educated**
- **Lower income**
- **Willing to spend less on a new car**
- **Less willing to let others drive their cars**
- **Answered the survey faster**



Multinomial Logit (MNL) Model

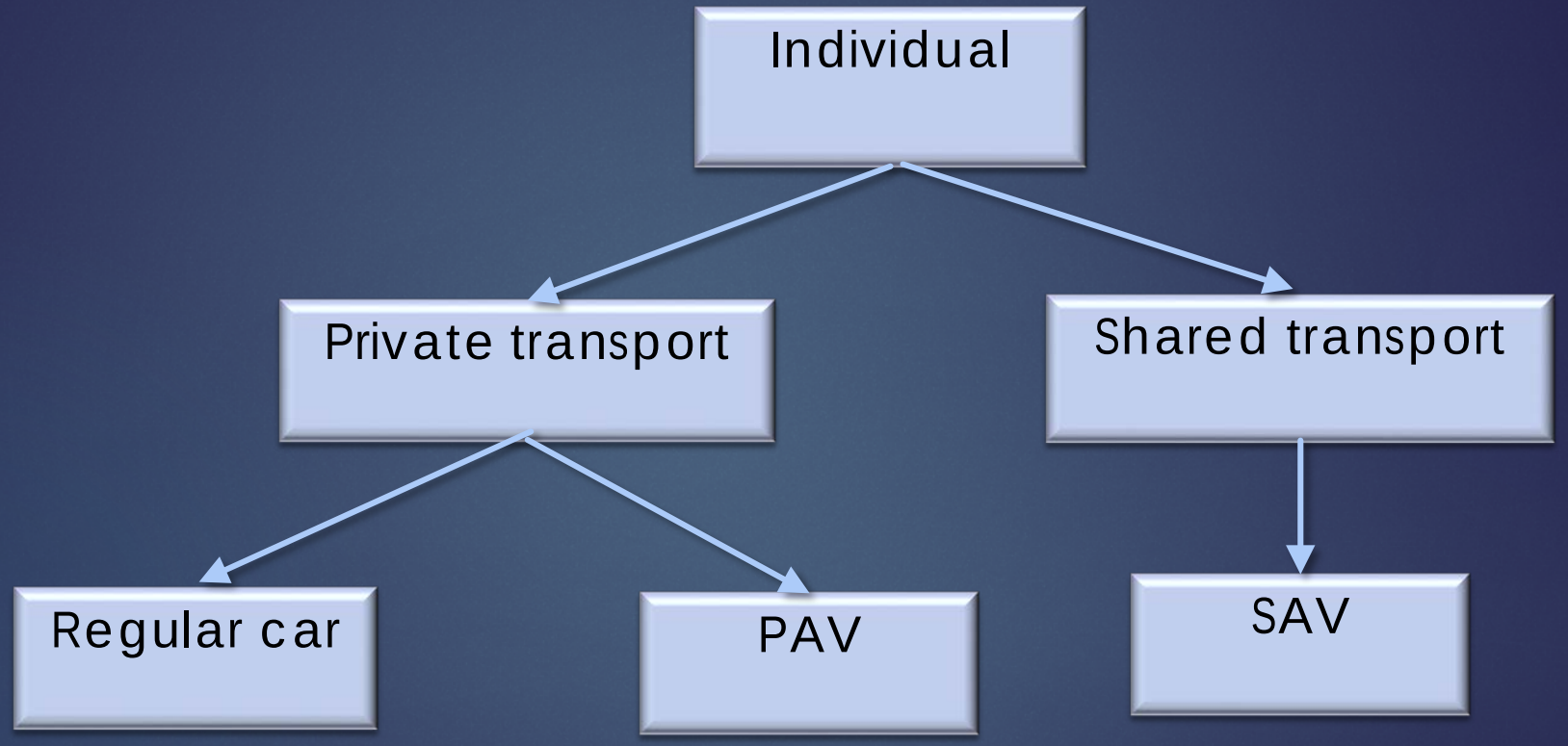
	Regular	PAV	SAV
Number of observations		4260	
Number of estimated parameters		30	
Null Log-likelihood		-4680	
Final Log-likelihood		-3508	
Constant		-4.88	-4.88
Travel time		0.00761	0.00761
Control of the AV		0.259	0.259
Education		0.279	0.279
Frequency of errands	0.148		
Store items in car [-0.82, -0.2,]			-0.821
Student (dummy variable)		0.239	0.239
Never uses PT (dummy variable)			-0.257
Number of days they commute			-0.170
Number of young children			0.172
Enjoy driving (ED) [-1, 0.5]	0.761		
Environmental concern (EC) [-1, 0.7]			0.661
PRO-AV attitude [0, 1]		5.36	5.36
Technology Interest (TI) [0, 1]		0.550	0.550

* All parameters are significant at the 95% level

MNL Model

		Regular	PAV	SAV
Purchase price (ratio)	If Purchase price PAV > REG		-0.806	
	If Purchase price PAV < REG		0.263	
Subscription cost (not-ratio)	Israel			-0.123
	North America			-0.575
Trip cost (ratio)	If trip cost PAV > REG		-0.249	
	If trip cost PAV < REG		0.364	
Trip cost (not-ratio)	Israel			-0.0106
	North America			-0.0165
	0 trip cost			0.762
Increase in parking price	Israel	-0.0946		
	North America	-0.111		
Age	Young			0.490
	Old		-0.293	-0.293
	Very old		-0.586	-0.586
Female		0.291	0.291	
Income			-0.205	
Km driven per year			0.0680	0.0680

Nested Logit Model



Unobserved shared attributes exist between the regular car and PAV

Capacity

Automated vehicles:

- require less headway, narrower lane widths
- drive at higher speeds → travel time reduction

- Estimates of increase capacity vary from 20% to 270% for full connected automated vehicle penetration

Implication for Infrastructure Investments

- Impact on future infrastructure planning and current infrastructure utilization, reducing the need to build new roads/rail systems?

- More and longer trips (in addition to increase population and urbanization)
- Higher capacity
- The cheap and convenient emerging services
- Require behavioral change even under optimistic technology scenarios

Re-thinking Transit Services - MAAS

- Mobility As A Service (MAAS)
- Transit services should be integrated with MAAS
- New mobility services should complement mass transit (last mile, access and egress, local trips)

Policy Implications

- Rethinking the current parking paradigm
- Policies to encourage sharing
- More intensive use of pricing policies
- Policies for limiting unnecessary travel by zero occupancy vehicles.
- Planners must consider taking actions today to prepare cities for driverless vehicles and sharing economy.

SUMMARY

- IABTR 2015 – Windsor, UK
- AV 2016 – San Francisco
- AV 2017 – San Francisco

- Next:
- AV 2018 – San Francisco
- IATBR 2018 – Santa Barbara

Motivation

- *Impact on Behavior!!!*
- *AV will change the way we: travel, make activity, lifestyle…..*
- *Land use/residential*
- *Impact on congestion/people livability*
- *Impact the industry*
- *Policy implications*

Behavior is a key to Impact

- **Can be a silver bullet – all will share…..**
- **Can result in hell – all will travel more…..**

- **Need to understand what policies/scenarios will move people from SOV**

Typology of Research Objectives

- Ownership/Use
- Travel behavior/Mode
- Activity/Lifestyle
- Land use

Typology of Approaches

1. Perform simulation based/scenario analysis studies
2. Stated Preference Surveys
3. Virtual reality/Games/Simulators
4. Revealed Preference/Analog modes/naturalistic experiments/Chauffer
5. Panel/longitudinal analysis
6. Qualitative/Focus groups/in-depth interviews
7. Integrated approaches: data/disciplines

Key Action Items

- Integrated approach of methods presented can answer the questions.
- Better ways to provide experience and knowledge to respondent
- Preferences, knowledge, awareness will change over time, must collect consistent data over time and across geographies.
- Coordination and collaboration with rest of AVS (HMI).
  - Leverage field tests for behavioral research. ALL field tests should also consider travel, activity, attitude, behavioral angles.
- Standards: generate set of standard questions (brief) to ask consistently across experiments. Ask before and after.

Thank You !!!