The Autonomous Car and our Disrupted Future

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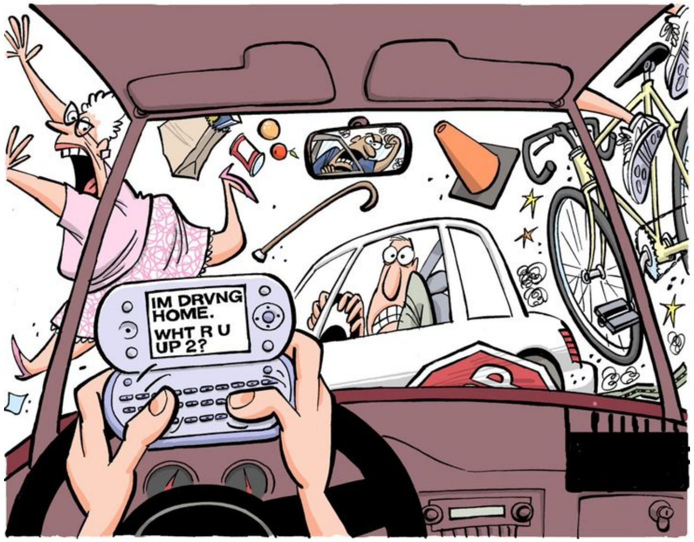
NJDOT

Agenda

- About me
- "AV/CV 101"
- Overview of current state-of-play: What we *know* and what some of us *think*, and what are the big unknowns?
- Highlights of recent research
- Q/A: I will [aim to] stick to a 50-minute speaking slot, to leave time for interactive discussion

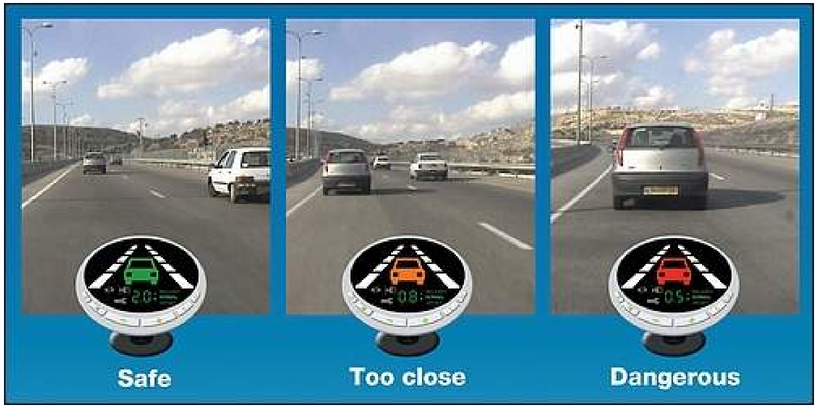


About me

- Assistant Professor (SUNY New Paltz), Urban Planning; Research Associate (Imperial College); Visiting Professor (SWJTU, Chengdu, China)
- Research themes are: Vehicle Automation, Shared-Mobility (e.g. Zipcar, Uber, ReachNow), and ‘Peak Car’
- Serve on National Academies’ Committees on *ITS* and *Emerging Public Transportation Technologies*, Board of Trustees of *Carplus* (www.carplus.org.uk)

Selected writing on Vehicle Automation

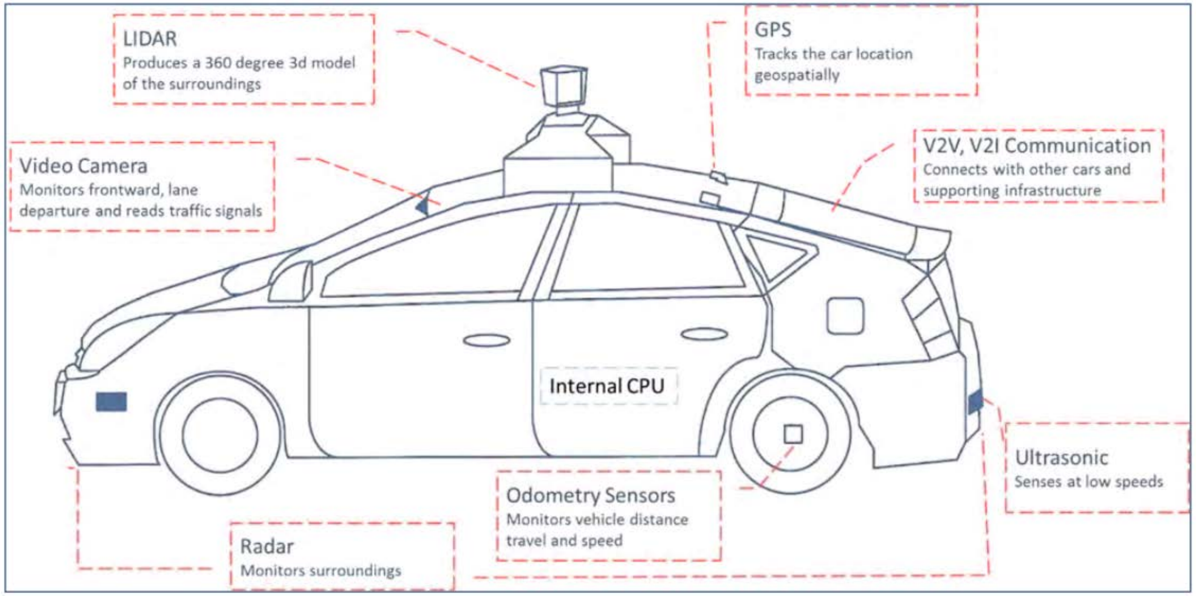
- Overview of Vehicle Automation (general-audience): www.theitc.org.uk/docs/114.pdf
- Ethics and ambiguity in rules-of-the-road (general): www.nytimes.com/roomfordebate/are-we-ready-for-driverless-cars/ethical-and-efficiency-tradeoffs
- Unavoidable trade-offs between traffic-flow efficiency and productive/leisurely use of in-car time (technical): www.citylab.com/tech/2015/01/how-driverless-cars-could-make-traffic-dramatically-worse/384821/ and www.sciencedirect.com/science/article/pii/S0968090X15000042
- Traffic flow at intersections (technical): http://www.sciencedirect.com/science/article/pii/S0968090X15004052
- First fatal crash (general): https://www.transportxtra.com/publications/local-transport-today/comment/49568/
- Decentralized congestion pricing (technical): http://www.sciencedirect.com/science/article/pii/S0965856416308989

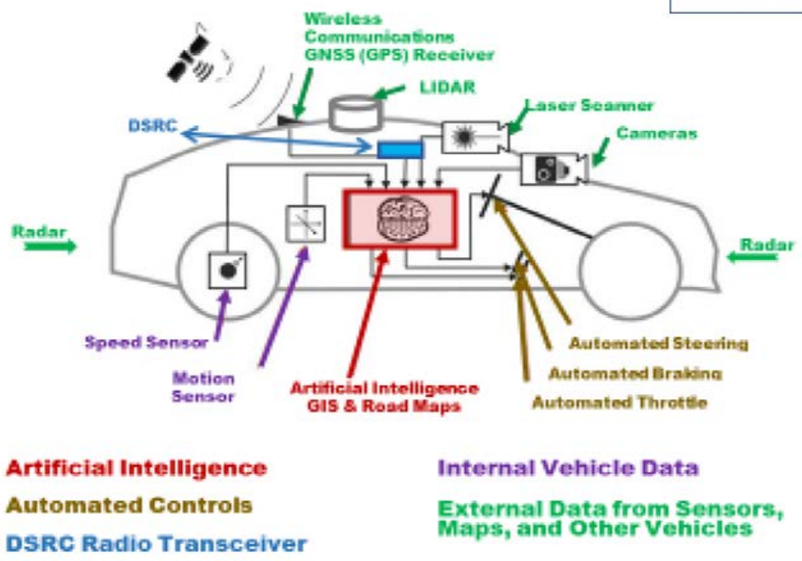


Current State-of-Play

Building blocks of Automation

- Autonomous
- Driverless
- Self-Driving
- **Automated**





- Sensing (the external environment)
- Processing (data streams)
- Decision-making
- Actuation

Levels of Automation

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Connectivity (V2X)

- Connected vehicles (CV) are in communication with each other (V2V), roadside infrastructure (V2I), perhaps pedestrians, etc. (V2X is most general term)
- Connectivity ≠ Automation (concepts are in fact orthogonal)
- 360-deg ‘awareness’; ‘see around corners’
- BSM = Basic Safety Message (using DSRC)
  - Subject of NHTSA’s Dec-’16 NPRM
  - Cars ‘shouting’ at one another 10x/second, with status information (not intent)

Connectivity + Automation = Wow

- “Next-Generation Intersection Control” (Univ of Wisc)
- Intxn controller gives each vehicle unique instructions
- Interesting…practical? Count me as a skeptic
  - Near-100% penetration
  - Near-100% trusted compliance (of all objects)

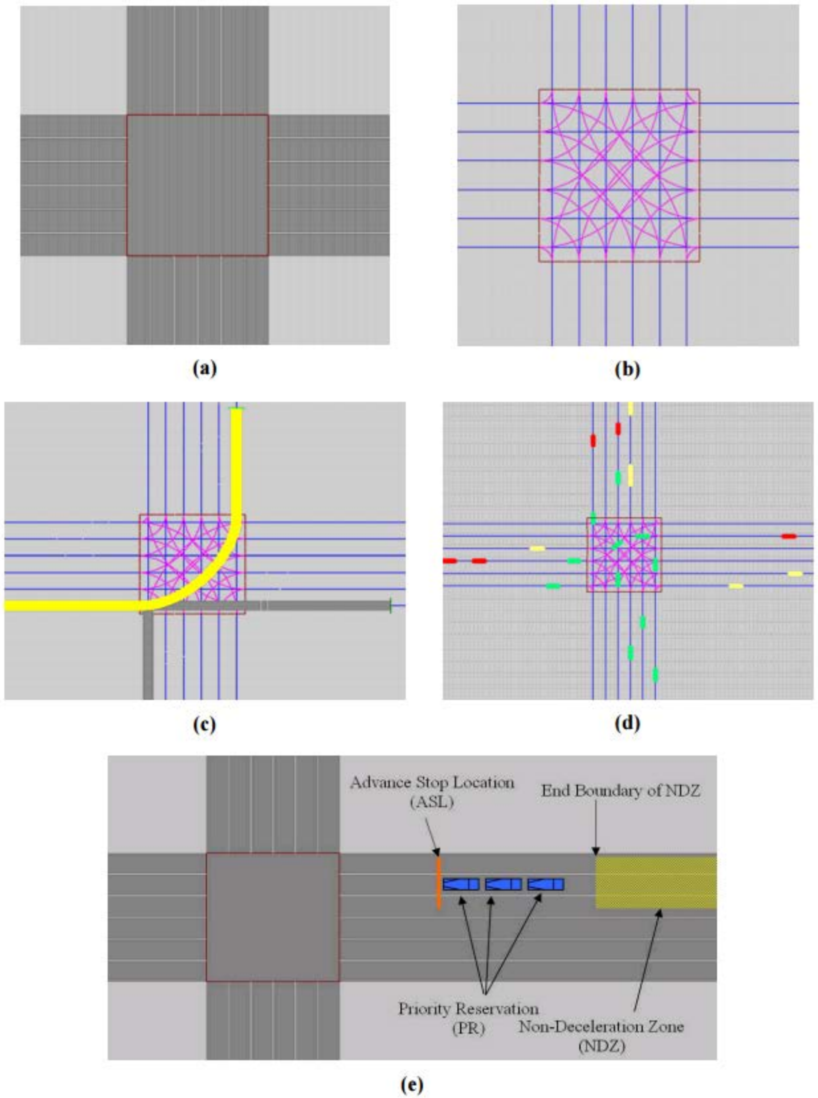
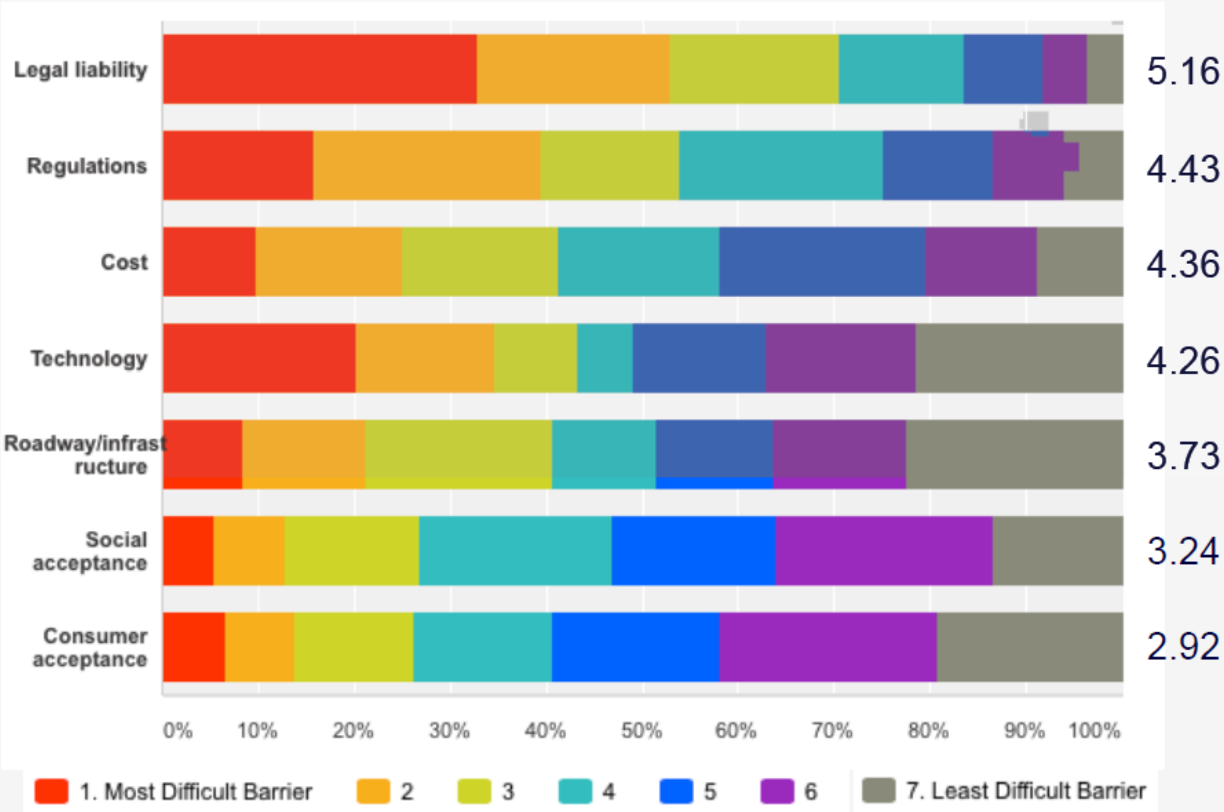


FIGURE 2 Simulation model of ACUTA intersection.

Expert opinion: Attendees of Summer 2014 Conference of Transportation Research Board

Ranking Barriers: Liability, Regulations, Cost, Technology

Q1: What is your ranking of the difficulty of overcoming barriers in fielding SAE Level 5 fully automated vehicles in all environments, with the first column being the most difficult barrier and seventh column the least?

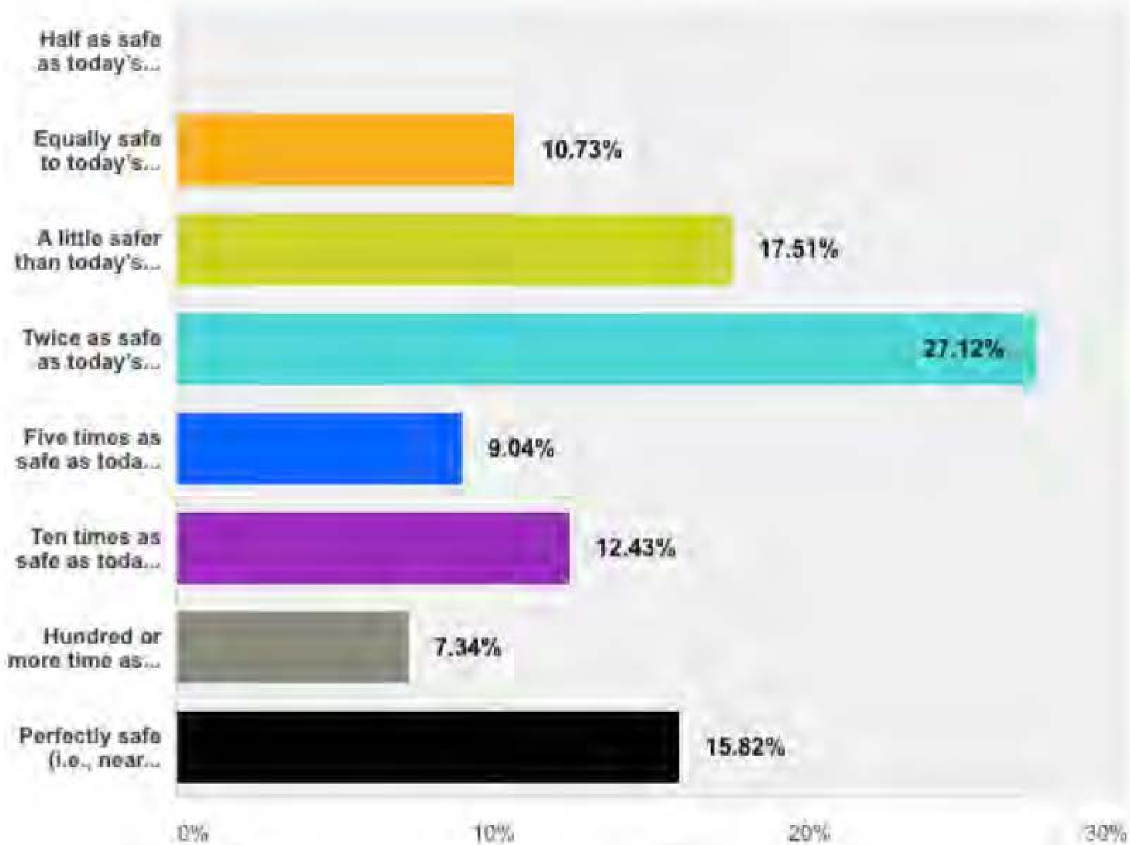


Steve Underwood: www.michigan.gov/documents/mdot/Michigan_CV_Working_Group_October_9th_2014_475344_7.pdf

Expert opinion: Attendees of Summer 2014 Conference of Transportation Research Board

Required Level of Safety: Little Safer to Very Safe

Q2: What level of safety do you believe an automated driving system (at any level of automation) should be required to demonstrate before it is authorized for public use?

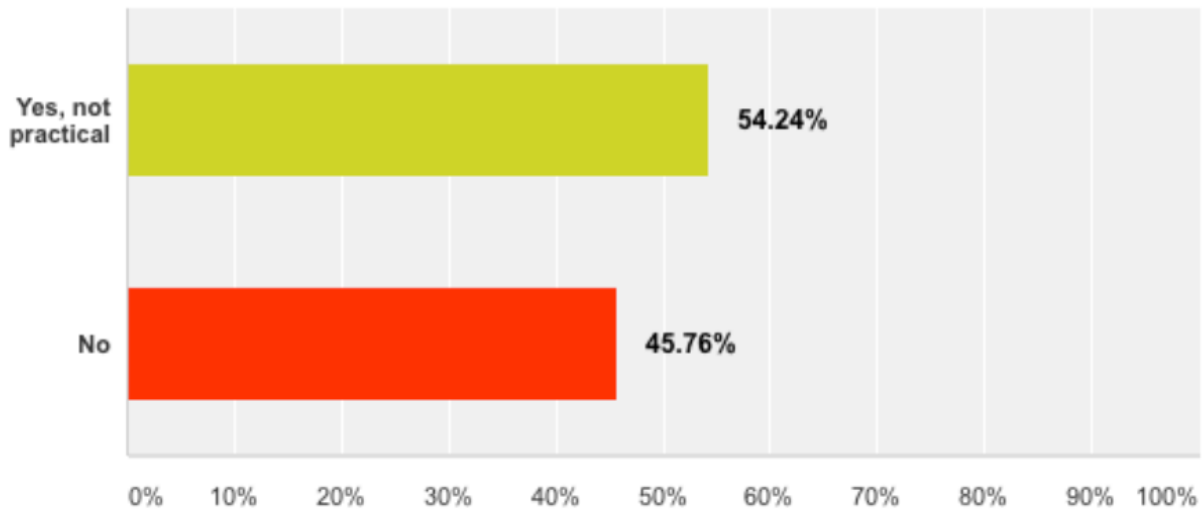


Steve Underwood: www.michigan.gov/documents/mdot/Michigan_CV_Working_Group_October_9th_2014_475344_7.pdf

Expert opinion: Attendees of Summer 2014 Conference of Transportation Research Board

Conditional Automation Not Practical?

Q5: Is SAE Level 3 conditional automation, in which the driver is expected to intervene quickly if needed, not practical or safe because drivers are likely to become complacent with automated operation and not behave as required?



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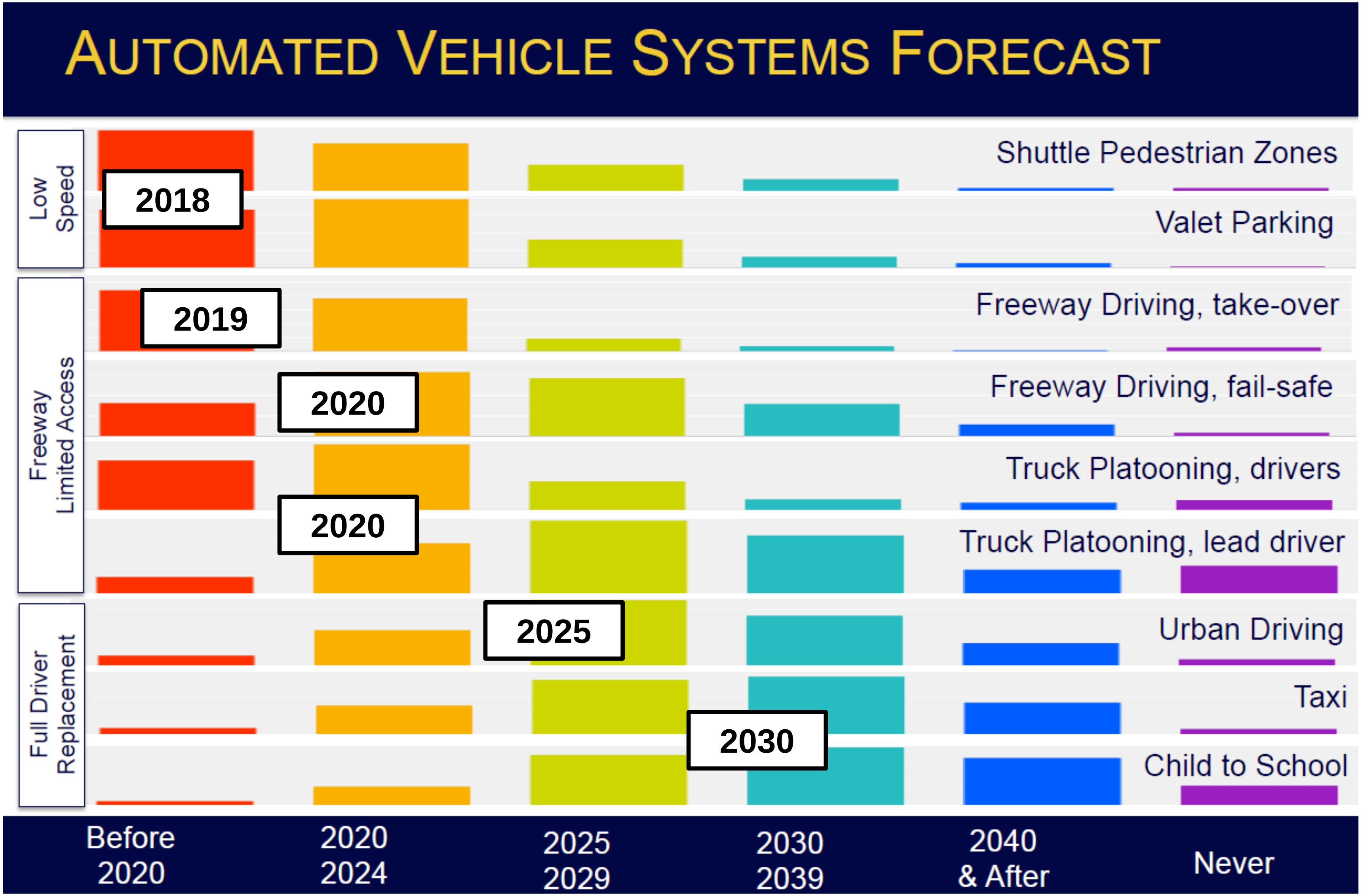

Steve Underwood: www.michigan.gov/documents/mdot/Michigan_CV_Working_Group_October_9th_2014_475344_7.pdf

Online "Delphi" exercise of 45 invited experts (2016) facilitated by Luis Willumsen

	Average	Standard Deviation
	World	
1. Year AVs will be available	**2023**	2.9
2a. AVs will be 10% of the car fleet	**2032**	7.0
2b. AVs will be 20% of the car fleet	**2037**	8.5
3. Premium to be paid for an AV	**$6,677**	$3,816
4. Percentage of AVs owned %	**42**	29
5. Ratio AV_price/Uber_price	**0.9**	0.3
6a. Ratio Freeway Lane Capacity @ 10%AV	**1.0**	0.1
6b. Ratio Freeway Lane Capacity @ 20%AV	**1.1**	0.1
7a. Ratio Urban Lane Capacity @ 10%AV	**1.0**	0.1
7b. Ratio Urban Lane Capacity @ 20%	**1.0**	0.2
8a. Ratio AV Owners VKT/Car owner	**1.1**	0.3
8b. Additional percentage of AV_VKT	**12**	17
8c. Ratio AV Renter VKT/Car owner	**0.9**	0.3
8d. Additional percentage of AV_VKT	**13**	10
9a. Ratio of Bus demand @10% Avs	**0.9**	0.2
9b. Ratio of Bus demand @ 20% Avs	**0.9**	0.2
10a. Ratio of Fixed Track PT demand @10%	**0.9**	0.3
10b. Ratio of Fixed Track PT demand @20%	**0.9**	0.2
11a. Journey to Work: ratio AV_VTTS	**0.9**	0.2
11b. Journeys during work: ratio AV_VTTS	**0.9**	0.2
11c. Other journeys: ratio AV_VTTS	**0.9**	0.3
12a. Journey to Work ratio Social AV_VTTS	**0.9**	0.2
12b. Journeys during work: ratio Social AV_VTTS	**0.9**	0.2
12c. Other journeys: ratio Social AV_VTTS	**0.9**	0.1

BMW' Group's AV-impact predictions (www.ifmo.de)

By 2035, we expect to see about 17% AVs in the private car fleet in Germany, and 11% in the US. Depending on the assumptions that underlie these figures, these shares could be higher, but 42% and 32% (in Germany and the US respectively) are the realistic upper limits for the proportion of AVs in the fleets by 2035.

By 2035, we expect to see a moderate increase in vehicle-kilometres travelled by private cars – about 3% – as a result of the introduction of AVs. Assuming the maximum share of AVs in the private car fleet that is realistic, the upper bound of this increase is estimated at 9%.

Between now and 2035, autonomous car fleets have great potential for increasing the market share of mobility-on-demand systems, taking them up to perhaps 8–10% of all trips in Germany.

KPMG's forecasts

Point of view 2:

A new normal within a decade: Four potential phases of incremental change

No one has a crystal ball to predict the future pace of change. As we synthesized our analyses, we envision there to be potentially four incremental changes to the transformation over the next 25 years, with the foundation laid for a new normal within a decade.

Phase 1 – Training wheels

Introduction to autonomous vehicles as manufacturers roll out some of the underlying technology. High-tech companies express interest in fast-tracking production of fully autonomous vehicles.

Phase 2 – First gear

In 2017, partial driver substitution technology is introduced. A broader set of consumers experience this technology, witnessing firsthand its safety and soundness. This helps shift market perceptions. Likely mandate from NHTSA for V2V communications.

Phase 3 – Acceleration

Five years from now, fully autonomous all-speed vehicles become more common. V2V capabilities are likely to be embedded in all new vehicles and the increase in scale drives down costs, making the technology accessible to a larger segment of consumers.

Phase 4 – Full speed

In 2025, a broad-based transformation begins. All new cars have autonomous capabilities and existing vehicles are potentially retrofitted. Over the next 15 years, integrated driving emerges, a web of information is flowing between vehicles, and infrastructure tightens. A new normal is realized by 2040.

The interaction between the eight core elements will likely be an important dynamic, as advances in one area will likely act as a catalyst for rapid progress in the others.

Ultimately, the alignment across all areas will be needed to realize wide-scale change.

Four potential phases of incremental change

Today – Phase 1 – 2017 – Phase 2 – 2020 – Phase 3 – 2025 – Phase 4 – 2040

	"Training wheels"	"First gear"	"Acceleration"	"Full speed"
Technology	Preliminary passive	Partial driver substitution	Fully autonomous	Converged network – sensor + V2V communications
Capability accessibility	Selective safety options buzz-curiosity/education	Full product suite/ dropping price	Affordable technology	Full car stock conversion
Consumer adoption	Buzz-curiosity/ education	Broad consumer knowledge/initial adoption	Embedded mainstream adoption	Broad market acceptance
Regulatory permission	Leader state adoption	Full state adoption	Rule harmonization V2V mandate	New vehicle/retrofit mandate
Legal responsibility	Conceptual design	Core strategies/ Initial lawsuits	Diversity of opinion/ Cases & appeals	Tort law clarified
Infrastructure	Existing roads	Experimental vehicle-to-infrastructure (V2I)	Broader V2I	Integrated driving
Mobility	Car sharing and ridesharing	Rise of mobility on demand	Autonomous vehicle options	Autonomous fleets on demand
Data management	Vehicle "Black Box" data	Data security protocols	Driving system data Security responses	Privacy rules focus

https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/automobile-insurance-in-the-era-of-autonomous-vehicles-survey-results-june-2015.pdf

Waymo (Google) inviting members-of-public in Phoenix, AZ

From: George Ivanov <georgeivanov@waymo.com>
Date: April 25, 2017 at 4:43:47 AM EDT
To: George Ivanov <georgeivanov@waymo.com>
Cc: Joel Roberson <joel.roberson@hklaw.com>, Marco Crocetti <Marco.Crocetti@hklaw.com>
Subject: Announcing Waymo's early rider program
Reply-To: <georgeivanov@waymo.com>

Hello,

I wanted to make sure you saw the exciting news out from Waymo (formerly Google self-driving cars) today. We just announced that we're launching the first public trial of our self-driving cars. Starting today, anyone in the Phoenix area can apply to be part of Waymo's early rider program. Over time we're looking to add hundreds of people to our program, who want to ride in Waymo's self-driving cars and provide feedback on the experience.

Over the last eight years, Waymo has been focused on refining our self-driving technology: racking up millions of miles of experience, teaching our cars advanced driving skills, and improving the performance of our software. Now, with Waymo's early rider program, we're turning our focus to riders. Everything we learn in this program will help bring us closer to launching a truly self-driving car into the world, and realize the potential of this technology to make it safer and easier for everyone to get around.

If you are interested in learning more about our announcement - please see this blog post, this video of an early rider family, and this one-pager.

Thanks,
George Ivanov

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WAYMO
George Ivanov
Public Policy
Mobile: 336-686-2740
waymo.com

Walt Disney World's planned Self-Driving Pods

Walt Disney World plans to deploy driverless shuttles in Florida

APRIL 28, 2017, 2:25 PM | REPORTING FROM SAN FRANCISCO

Forecasts commissioned from Delft University by Dutch Govt

	First vehicle in the market	
	Conditionally automated	Fully automated
AV ...*in stand by*	2020	2030
AV ...*in bloom*	2018	2025
AV ...*in demand*	2025	2040
AV ...*in doubt*	2028	2045

Table 3: Market introduction year for conditionally and fully automated vehicles according to different scenarios.

	2030		2050	
	Min	Max	Min	Max
AV in vehicles fleet (%)	1	11	7	61
AV VKT in total travel (%)	1	23	10	71
Value of time - AV users (%)	1	18	2	31
Capacity (%)				
Motorways	0	5	-3	25
Regional roads	0	2	0	10
Urban roads	0	1	-1	6
Total VKT (%)	0	3	0	27

Table 4: Range of penetration rates and impacts of automated vehicles in the four scenarios.

Milakis, D., Snelder, M., van Arem, B., van Wee, B., Correia, G.C.H. (2015) *Development of automated vehicles in the Netherlands: scenarios for 2030 and 2050*.

What does the public think? Sivak/Schoettle, UMTRI

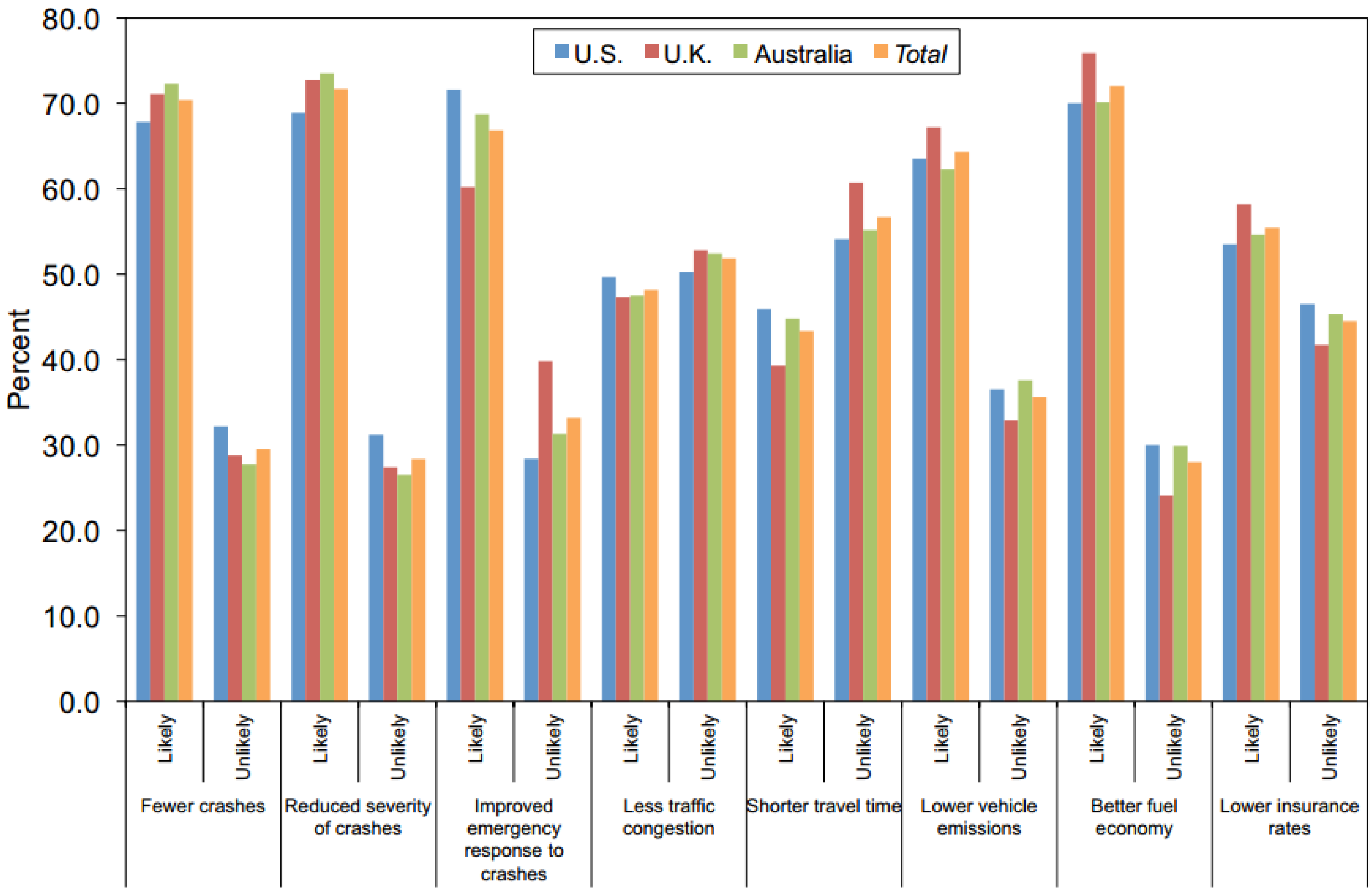


Figure 3. Summary of responses (collapsed), by country, to Q6: "*How likely do you think it is that the following benefits will occur when using self-driving vehicles?*"

http://deepblue.lib.umich.edu/bitstream/handle/2027.42/108384/103024.pdf

What does the public think?
Sivak/Schoettle, UMTRI

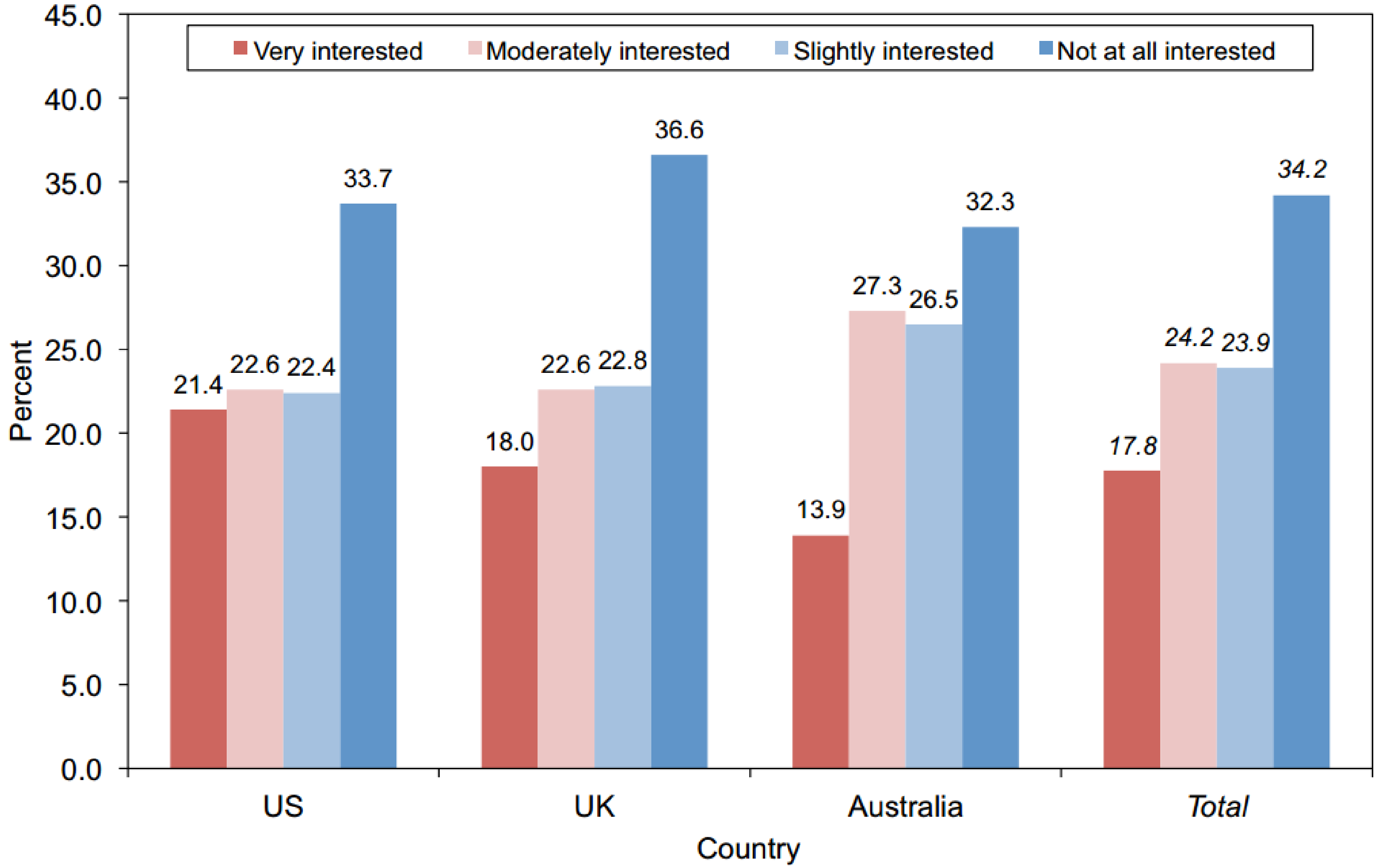


Figure 6. Summary of responses, by country, to Q9: "*How interested would you be in having a completely self-driving vehicle (Level 4) as the vehicle you own or lease?*"

http://deepblue.lib.umich.edu/bitstream/handle/2027.42/108384/103024.pdf

Today's Rules of the Road

- **Assured Clear Distance Ahead:** *When an automobile driver approaches another from the rear, he or she is bound to…exercise reasonable care to avoid colliding with the other vehicle. The driver of a forward vehicle has a right superior to that of the following vehicle's driver.*
- Violation of ACDA to strike livestock in road, even if have just crested a hill
- But "ACDA/do not strike" is subject to limits. *Sudden Emergency* is possibly the most substantial
- Excusable to not anticipate *'children dropping from trees'*
- Driver-in-front sometimes shares liability in a rear-end crash, if (s)he stops suddenly and unreasonably

Human drivers take [silly, non-ACDA] risks

[Just] A matter of scale

2014 SUPERBOWL			DENVER BRONCOS				DENVER BRONCOS			DENVER BRONCOS	
		4	5	3	2	9	8	7	0	1	6
	2	Brenda Dye	Regina Pucket	Darlene DeBaker	Jim Hagen	Jason Sweet	Sarah Earl	Conrad Apodaca	Eddie Bosley	Heather Roeller	Sheryl Blank
	5	Jennifer Schram	Tina Scutter	Marci Hoover	Jim Wilshusen	Karen Puita	Dana Holland	Rachel Knott	Jessica Donaldson	Kathlene Curtis-Ames	Sharon Hill
SEATTLE SEAHAWKS	1	Dick Davis	Bill Hawker	Carol Cork	Gary Clem	Dave Tice	Jennifer Fanning	Jacky Hollingsworth	Michelle Dodd	Karen Lynn	Kathy Murray
	9	Tammy Ryan	Susan Tighe	Tawnya Gonzales	Chris Gonzales	Wendy Ackhart	Katie Burnett	Charlie Simmons	Candy Welch	Emily Puetas	Taylor Cabanero
	6	Danielle O'Compo	Sarah Brooks	Debbie Tuson	Kathy Rousch	Adam Pavlica	Heather Fitzpatrick	Karen Brewer	Angie Morris	Denise Damiano	Susan Highfill
	4	Rusty Rettler	Mickey Russ	Glenn Penland	Tracey Rose	Stacey Wilkins	Phyllis Guaspari	Karen Sawdey	Chris Freeman	Sonya Thompson	Drew Summerfield
	0	Natalie Ackhardt	Dawn Russ	Peggy Hooberry	Carmela Elias	Sunday Rikki	Deena McDaniel				
SEATTLE SEAHAWKS	7	Jamie Umpenour	Jake Javaux	Tim McGee	Monica Carmo	Shelly Reeger	Dawn Glove				
	8	John Schwark	Brent Ballard	Wendy Moore	Debbie Hernandez	Troy Shogren	Emily Vansickle				
	3	Jim Millander	Michelle Smith	Brett Labastida	David Ferraro	Wendy Kelley	Michael Lyons				

Pick any two…

1. Road network as open system
2. ACDA as rule
3. Greatest reduction in congestion

1+2: If you like your road network, you can keep it

1+3: We'd be designing-in chain-reaction collisions (how many?), with no one 'at fault'

2+3: Perhaps line the curb of Manhattan's Avenues and major Cross-streets with cyclone fencing?

What does '1+2' mean for AVs?

- What if the car ahead of you begins emergency braking? It might have a good reason, but your AV can't know this (because maybe its 'vision' is blocked by the car ahead).
- If AVs are prepared to take an 'X' risk of hitting that car, then freeway capacity increases by Y% relative to humans driving
  - One in a million: +70% capacity
  - One in ten thousand: +85%
  - One in a hundred: +105% (i.e. just more than double)
- This conservatively assumes no reliance on 'talking' (i.e. V2V comms). Benefits are *much* greater if V2V signalling of intent can be treated as reliable/complete – hence actionable.
- But can (will?) absence of V2V signals be regarded as actionable? I'm deeply skeptical

A classic ‘Collective Action’ problem

- ACDA-compliance is ‘good’ for safety, but ‘bad’ for congestion
- Close following (platooning) provides very, very little benefit to an AV’s occupant(s), in terms of journey duration (a few seconds here or there, maybe)
- But if all AVs follow closely, congestion would be lower
- Gov’t. clearly has the power to waive the ACDA Rule for AVs, so question is which (safety or reducing congestion) do we elect to prioritize
- At present, we understand very little about this trade-off, so don’t know how to make it

The public's priorities (n=370)

- **Which of these statements best describes your view of how driverless cars should be programmed:**
  - *Driverless cars should be **programmed to follow closely** behind the car ahead of it in traffic, in order to reduce traffic congestion, even if this increases the possibility of rear-ending the car ahead*

9%

  - *The **person riding in a driverless car should have the choice** of whether to leave a large distance behind the car ahead of it, if they wish to reduce the possibility of rear-ending the car ahead, even if this makes traffic congestion worse*

48%

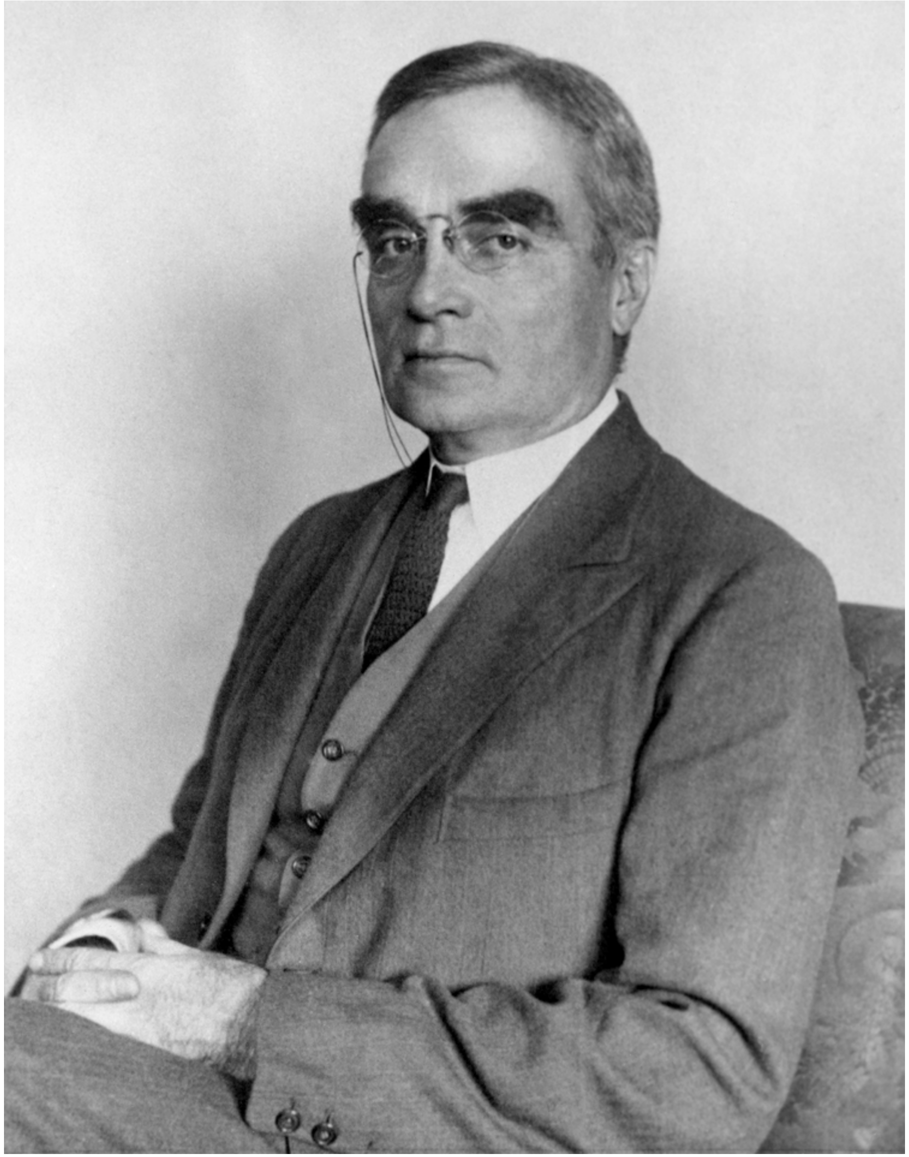
  - *Driverless cars should be **programmed to leave a large distance** behind the car ahead of it, in order to reduce the possibility of rear-ending the car ahead, even if this makes traffic congestion worse*

42%

The public's priority: ____________(n=370)

Which of these is...	Most important				Least Important
<u>Being able to read, sleep, send text messages or do other activities</u> inside the car besides driving, while the car does the driving					
Being able to send a driverless car to **<u>pick up or drop off</u>** packages, groceries, or children, without a human driver inside the vehicle					
Having the highest possible level of **<u>safety</u>** in a driverless car					
Having **<u>traffic congestion reduced</u>**, so that traffic moves more smoothly even when there are many cars on the road					
When there are few other cars on the road, being able to travel much faster (**<u>higher speed</u>**) than drivers are allowed to drive today					

Judge Learned Hand



Google: Maybe we'll record your driving style, and then mimic it…

Patents

Driving pattern recognition and safety control

US 8965621 B1

ABSTRACT

Systems and methods are provided for controlling a vehicle. A safe envelope driving pattern is determined to control the vehicle in an autonomous mode. User identification data and sensor data are received from one or more sensors associated with the vehicle. A driver-specific driving pattern is determined based on the received sensor data and the user identification data. Operation of the vehicle is controlled in the autonomous mode based on the identification of the user in the driver's seat, the safe envelope driving pattern, and the user-specific driving pattern.

Publication number	US8965621 B1
Publication type	Grant
Application number	US 14/134,221
Publication date	Feb 24, 2015
Filing date	Dec 19, 2013
Priority date	Oct 5, 2010
Also published as	CN103339009A, 25 More »
Inventors	Christopher Paul Urmson, Dmitri A. Dolgov, Philip Nemec
Original Assignee	Google Inc.
Export Citation	BiBTeX, EndNote, RefMan

Patent Citations (99), Non-Patent Citations (13), Classifications (15), Legal Events (1)

External Links: USPTO, USPTO Assignment, Espacenet

…and thereby shift liability back to you …maybe

Relax/Work like it's a Plane or High Speed Rail?

What happens when the light turns green?

Transportation Research Part C 62 (2016) 35–54

Contents lists available at ScienceDirect

Transportation Research Part C

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

Automated cars: Queue discharge at signalized intersections with 'Assured-Clear-Distance-Ahead' driving strategies

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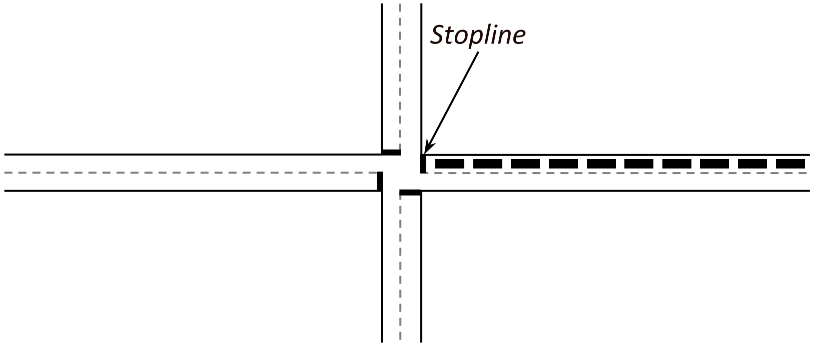
ABSTRACT

This study addresses the impacts of automated cars on traffic flow at signalized intersections. We develop and subsequently employ a deterministic simulation model of the kinematics of automated cars at a signalized intersection approach, when proceeding forward from a stationary queue at the beginning of a signal phase. In the discrete-time simulation, each vehicle pursues an operational strategy that is consistent with the 'Assured Clear Distance Ahead' criterion: each vehicle limits its speed and spacing from the vehicle ahead of it by its objective of not striking it, regardless of whether or not the future behavior of the vehicle ahead is cooperative. The simulation incorporates a set of assumptions regarding the values of operational parameters that will govern automated cars' kinematics in the immediate future, which are sourced from the relevant literature.

We report several findings of note. First, under a set of assumed 'central' (i.e. most plausible) parameter values, the time requirement to process a standing queue of ten vehicles is decreased by 25% relative to human driven vehicles. Second, it was found that the standard queue discharge model for human-driven cars does not directly transfer to queue discharge of automated vehicles. Third, a wet roadway surface may result in an *increase* in capacity at signalized intersections. Fourth, a specific form of vehicle-to-vehicle (V2V) communications that allows all automated vehicles in the stationary queue to begin moving simultaneously at the beginning of a signal phase provides relatively minor increases in capacity in this analysis. Fifth, in recognition of uncertainty regarding the value of each operational parameter, we identify (via scenario analysis, calculation of arc elasticities, and Monte-Carlo methods) the relative sensitivity of overall traffic flow efficiency to the value of each operational parameter.

This study comprises an incremental step towards the broader objective of adapting standard techniques for analyzing traffic operations to account for the capabilities of automated vehicles.

What happens when the light turns green: ~25% benefit (relative to human drivers)



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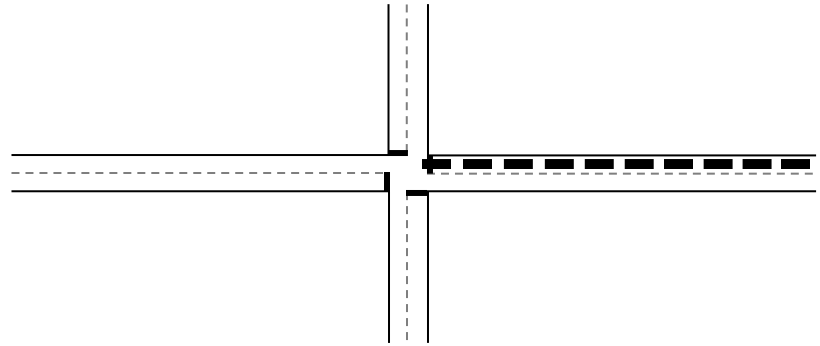

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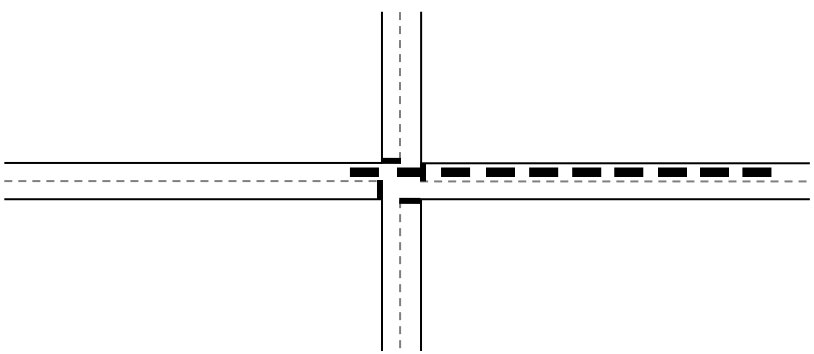

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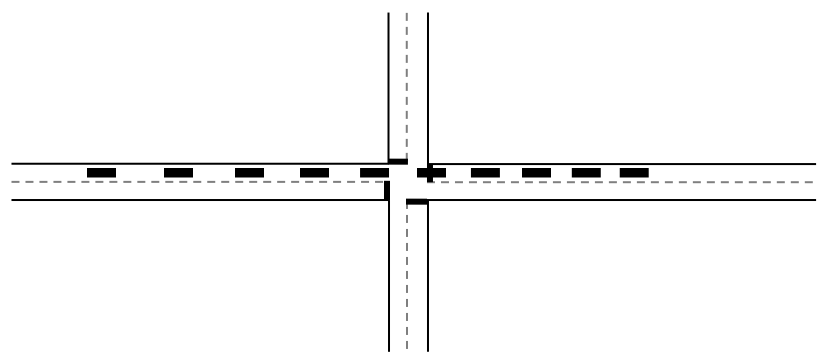


t=10 seconds

Others' perspectives

- **Bryant Walker Smith** (Univ. of South Carolina Law School): W*hen an AV driving developer shares its safety philosophy with the public through data and analysis, automated driving will be truly imminent.*
- **Steve Shladover** (UC Berkeley): *The auto industry and the press have oversold the automated car. Simple road encounters pose huge challenges for computers, and robotic chauffeurs remain decades away.*
- **Anthony Foxx** (Obama's Fed Transp. Sec): *If we can reduce fatalities by 80%, that justifies adoption*
- **Sarah Hunter** (Google 'X'): *Cold, dry text of regulation will be outdated by the time it's published*




State-of-Practice at large MPOs (Erick Guerra, U-Penn)

PLANNING FOR SELF-DRIVING CARS

For the most part, MPOs do not incorporate self-driving cars or similar technologies into their long-range plans. Of the 25 largest, only San Diego and Philadelphia's MPOs mention autonomous, self-driving, or connected vehicles.

TABLE 1. Summary of the Reaons MPO Planners Reported for not Including Autonomous Vehicles in Most Recent Regional Transportation Plans.

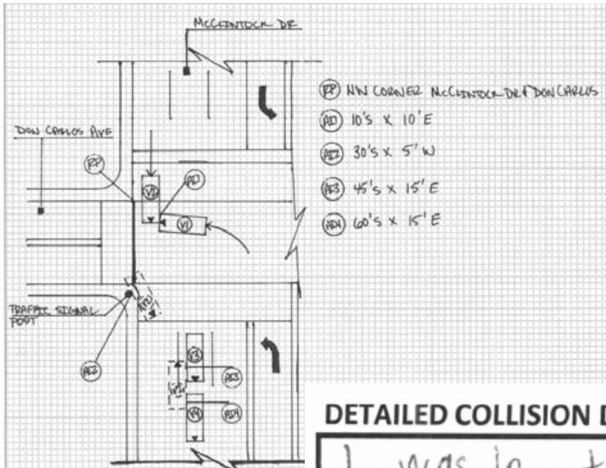
Reason	Influence	Summary
Unawareness	Very weak	Planners are well aware of the technological progress, regulatory environment, and potential impacts of driverless cars. That said, many planners were less aware when they began the regional transportation plans, as many as seven or eight years ago.
Skepticism	Weak	Most planners believe that the impacts are likely, though not certain, to be profound. Several see the probable impacts as small and marginal, though still fairly uncertain.
Uncertainty	Very Strong	There is a great deal of uncertainty about what technologies will prevail, how much and when they will penetrate the market, whether regulation will hinder or support deployment, what the direct impacts will be on capacity or safety, and how consumers will respond. Possibilities range from a marginal improvement in the comfort and convenience of driving to a radical transformation in car-ownership and travel patterns with potentially positive and negative effects.
Too far-removed	Strong	Driverless cars and their potential impacts are too far removed from decisions about whether and how to invest in and maintain transportation infrastructure.
One of many potential game-changers	Strong	Vehicle automation is just one of a number of radical changes that could influence regional transportation over the next 30 years. Staff also mentioned changes in federal transportation funding, 3D printers, improvements in telecommunications, and the impacts of and policies to address climate change as potential game-changers.

http://amonline.trb.org/trb57535-2015-1.1793793/t028-1.1808001/437-1.1802515/15-4167-1.1809210/15-4167-1.1939173

MPOs and Automated Vehicles

- MPOs with early efforts to quantify (‘model’) impacts of automated vehicles:
  - Atlanta (ARC: Guy Rousseau)
  - Seattle (PSRC: Billy Charlton)
  - San Francisco (MTC: Stanford/Google’s Michael Gucwa)
- Lower ‘value-of-time’, greater vehicle-capacity per lane, higher speeds, fewer accidents, less land dedicated to parking, lower emissions (smoother driving cycles), etc.
- All of these would be nice – but whether they’ll actually be achieved is unknown, and it is likely that there will be trade-offs between them

Tempe Self-Driving Uber crash (3/24/17)



DETAILED COLLISION DESCRIPTION

I was in the left turn lane of Northbound McClintock turning onto Westbound Don Carlos. The lane closest to me and the middle of Southbound McClintock were stopped as traffic across the intersection was stopped. The light was green and there ~~was~~ were about 5 seconds left on the crosswalk timer. As far as I could tell, the third lane had no one coming in it so I was clear to make my turn. Right as I got to the middle lane about to cross the third I saw a car flying through the intersection but couldn't brake fast enough to completely avoid collision. I braked as much as possible but still collided with the oncoming car and my airbag deployed. [redacted] I sustained no immediate injuries because my vehicle was not moving fast. After the collision I put my emergency ~~vehicle~~ brake on and put my car in park. I was wearing my seatbelt at the time of collision.

Ford: AV/Drone in tandem

United States
Patent Application Publication
Stanek et al.

AUTOMOTIVE DRONE DEPLOYMENT SYSTEM (52)

Applicant: **Ford Global Technologies, LLC**, Dearborn, MI (US)

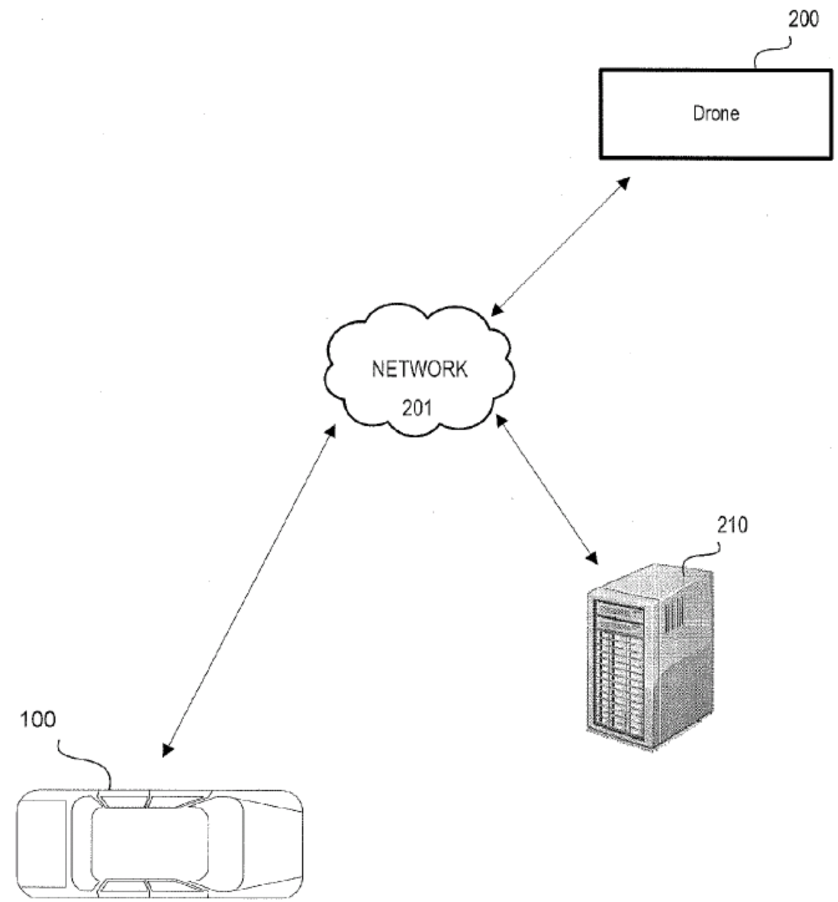
Inventors: **Joe F. Stanek**, Northville, MI (US); **John A. Lockwood**, Canton, MI (US)

Appl. No.: **15/231,579** (57)

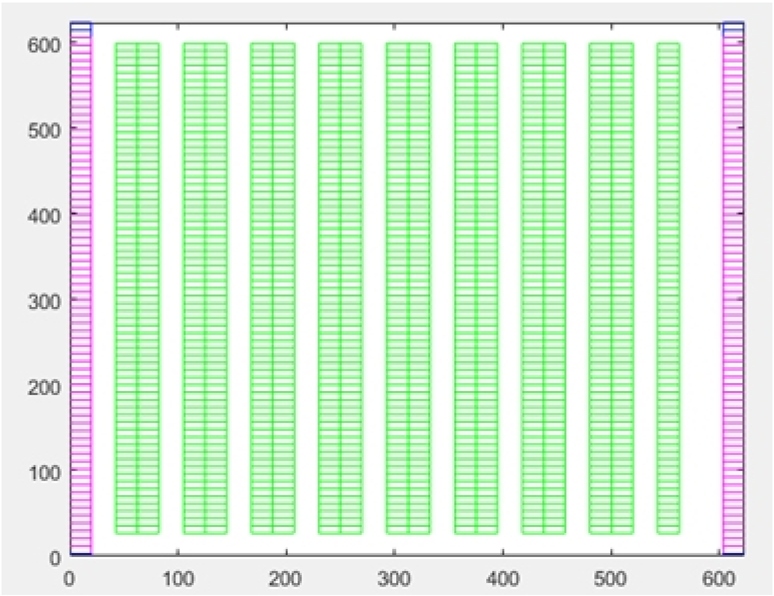
Filed: **Aug. 8, 2016**

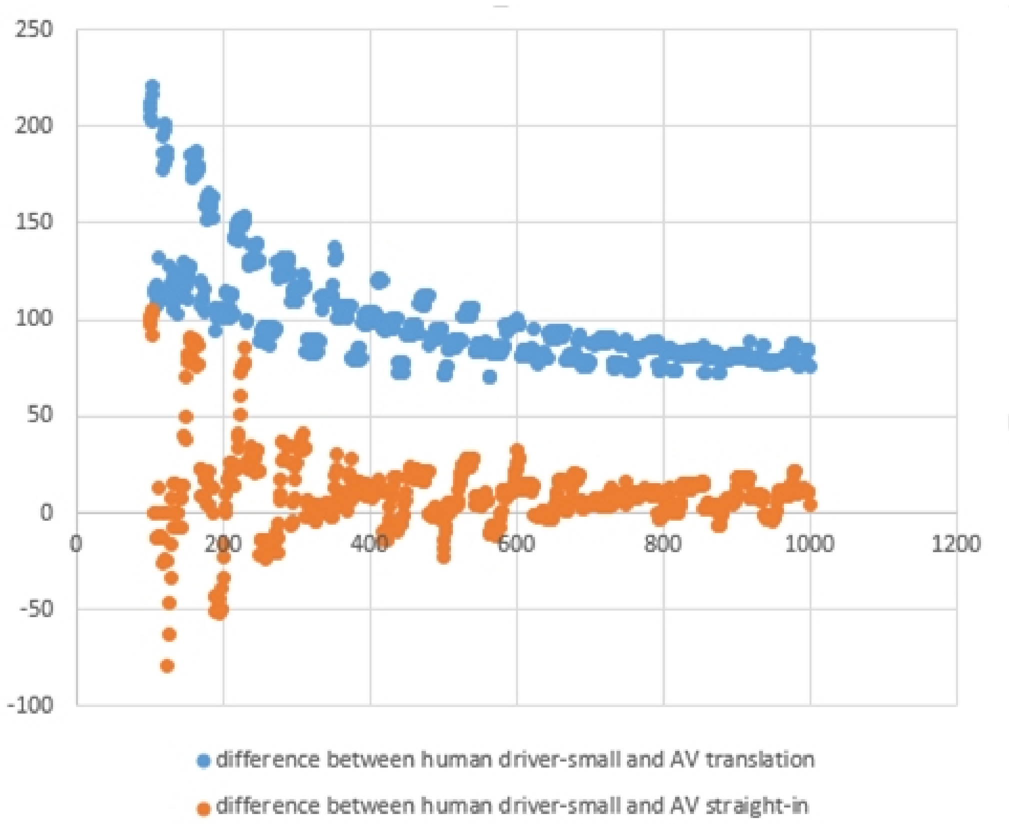
(57) **ABSTRACT**

This disclosure generally relates to an automotive drone deployment system that includes at least a vehicle and a deployable drone that is configured to attach and detach from the vehicle. More specifically, the disclosure describes the vehicle and drone remaining in communication with each other to exchange information while the vehicle is being operated in an autonomous driving mode so that the vehicle's performance under the autonomous driving mode is enhanced.



Impacts on parking: Area (sq-ft) requirement per parking space (PhD work of Ms. Kong You)





To conclude...

- Many, many thanks to UTRC (www.utrc2.org) for support of this line of research, and colleagues/collaborators (Kong You, Lijuan Lai, Xiaobo Liu, Yugang Liu, Paulina Lustgarten, John Polak, Alireza Zolfaghari, Fangfang Zheng)
- Some of what we don’t know: Tech development / commercialization, what actions government will take, interpretations by legislatures/judiciary/juries of standards such as ‘reasonable’, ‘duty of care’, public (over)reaction to initial incidents, etc.
- My wish for coming year: Driving-tech and business-side communities spend more time ‘jamming’
- Papers referenced are accessible via: hawksites.newpaltz.edu/levines