TRAVEL BEHAVIOR IMPLICATIONS AND MODELING OF AUTOMATED VEHICLES

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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).
Driverless Cars Ahead

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

Commissioned by Clear Channel
Some Terms

- Automated/autonomous/driverless
- Connected/unconnected automated vehicles
NHTSA and SAE Levels of Automation

Level 1: Function-specific Automation
- Driver Assistance

Level 2: Combined Function Automation
- Partial Automation

Level 3: Limited Self-Driving Automation
- Conditional Automation

Level 4: High Automation
- Full Self-Driving Automation

Level 5: Full Automation
- NHTSA Level 4
- SAE Level 5
Into the Future: Technology Roadmap

Source: KPMG analysis based on publicly 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

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, Bosch, Tesla, Nissan Mercedes-Benz, Uber and Audi have already begun testing self-driving cars on public roads.

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)
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.”
Tesla driver killed in crash with Autopilot active, NHTSA investigating

by Jordan Golson | @jgolson | 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.
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 exceed 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

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-us/news-releases/fergy-

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.”
Security Nightmare of Driverless Cars

TRIPWIRE GUEST AUTHORS (HTTP://WWW.TRIPWIRE.COM/STATE-OF-SECURITY/FEATURED/GUEST-AUTHORS/)
OCT 5, 2015 | FEATURED ARTICLES (HTTP://WWW.TRIPWIRE.COM/STATE-OF-SECURITY/FEATURED/FEATURED)
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)
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 million truckers out of work. Also, they may eventually lead to a 90% drop in roadway accidents. Robocars could add $7 trillion to the global economy.
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
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."

(Photo: Ford)
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)

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.)


New York

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

Schaller Consulting, 2017
Figure 13. TNC mileage by geographic area, 2016

**Citywide**
- 600 million miles added VMT
- 3.5% of citywide VMT

**Manhattan and inner ring**
- 352 million miles added VMT
- 7% of VMT

**Outer neighborhoods and airports**
- 248 million miles added VMT
- 2% of total VMT

Source: TLC odometer and trip files.
### Initial Evidence From Previous Studies of Emerging Services (Analog Modes)

<table>
<thead>
<tr>
<th>Author(s) and Year</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaheen and Cohen, 2013</td>
<td>North American car-sharing members reduced their driver distance by 27%</td>
</tr>
<tr>
<td>Martin et al., 2010</td>
<td>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.</td>
</tr>
<tr>
<td>Firnkorn &amp; Müller, 2015</td>
<td>Having driven an electric-car2go increased car2go-users’ willingness to forgo a private car purchase.</td>
</tr>
<tr>
<td>Becker et al., 2015</td>
<td>Free-Floating Car Sharing (FFCS) - the car can be returned in any legal parking space.</td>
</tr>
<tr>
<td>Kopp et al., 2015</td>
<td>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.</td>
</tr>
</tbody>
</table>
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 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

<table>
<thead>
<tr>
<th>Location</th>
<th>Assumptions</th>
<th>Scenarios</th>
<th>Range of Impacts</th>
</tr>
</thead>
</table>
| **Atlanta**| • 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% |
| Kim et al. (2015) | | | |
| **Puget Sound** | • 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 |
| Childress et al. (2015) | | | |
| **MTC** | • 50% reduction in VOT  
• No parking cost  
• 50% reduction in parking cost | | • 8-24% increase in VMT |
| Gucwa (2014) | | | |
- Reduce driver burden (stress, fatigue, productive time)
- No need to park

- Travel time budget, VOT
- Travel money budget

Reduced cost (traveler)

Reduced cost (operators)

New services and modes

Increased flexibility

Source: DHL Trend Research
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)

<table>
<thead>
<tr>
<th>MNL</th>
<th>3A-M4</th>
<th>4A-M4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PC</td>
<td>CP</td>
</tr>
<tr>
<td>Time</td>
<td>-0.085*** (-7.64)</td>
<td>-0.106*** (-13.00)</td>
</tr>
<tr>
<td>Cost</td>
<td>-0.033*** (-4.54)</td>
<td>-0.052*** (-9.25)</td>
</tr>
<tr>
<td>Prop_Eat</td>
<td>-</td>
<td>2.47*** (7.37)</td>
</tr>
<tr>
<td>Prop_Laptop</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Prop_Read</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Prop_Rest</td>
<td>-</td>
<td>0.86*** (3.21)</td>
</tr>
<tr>
<td>Prop_Call</td>
<td>1.09*** (3.26)</td>
<td>-</td>
</tr>
<tr>
<td>MNL</td>
<td>3A-M4</td>
<td>4A-M4</td>
</tr>
<tr>
<td>-------</td>
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<td>----------</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>CP</td>
</tr>
<tr>
<td>VOT (NIS/hr)</td>
<td>~154</td>
<td>~123</td>
</tr>
</tbody>
</table>

![Diagram with arrows and multipliers](https://via.placeholder.com/150)
<table>
<thead>
<tr>
<th></th>
<th>PC</th>
<th>CP</th>
<th>Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VOT [Nis/hr]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(High propensity)</td>
<td>42</td>
<td>37</td>
<td>34</td>
</tr>
<tr>
<td><strong>VOT [Nis/hr]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Low propensity)</td>
<td>117</td>
<td>150</td>
<td>70</td>
</tr>
</tbody>
</table>
Demand

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

Reduced cost (traveler)
- Travel time budget, VOT
- Travel money budget
- Longer commute
- Travel distance to other purposes
- Changes in activity patterns
- More travel

Reduced cost (operators)
New services and modes
Increased flexibility

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

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

Reduced cost (traveler)
- Travel time budget, VOT
- Travel money budget

Travel time budget, VOT
- Longer commute
- Travel distance to other purposes
- Changes in activity patterns
- More travel

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

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

New services and modes

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

Reduced cost (operators)
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 – health 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
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)

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

<table>
<thead>
<tr>
<th></th>
<th>Current car</th>
<th>Private autonomous vehicle</th>
<th>Shared autonomous vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase cost</td>
<td>30000$</td>
<td>34500$</td>
<td>--</td>
</tr>
<tr>
<td>Yearly membership cost</td>
<td>--</td>
<td>--</td>
<td>0$ /year</td>
</tr>
<tr>
<td>Trip cost (per direction of commute)</td>
<td>1.50$</td>
<td>1.27$</td>
<td>2.50$</td>
</tr>
<tr>
<td>Parking cost</td>
<td>4$</td>
<td>1.20$</td>
<td>--</td>
</tr>
</tbody>
</table>

Which option would you choose to use for this trip?

- Current vehicle
- Private autonomous vehicle
- Shared autonomous vehicle
CONFIRMATORY FACTOR ANALYSIS
RESPONDENTS

Total respondents | 720
Total choice decisions | 4260

Observations by country:
- Israel, 2109
- US, 1601
- Canada, 319
- Other, 231

Total Observations:
- Regular: 44.1%
- PAV: 32.4%
- SAV: 23.5%
Differences by Location

VEHICLE CHOICE IN NORTH AMERICA
- Regular: 54%
- SAV: 18%
- PAV: 28%

VEHICLE CHOICE IN ISRAEL
- Regular: 35%
- SAV: 29%
- PAV: 36%
Consistent individuals

North American individuals

- Regular only: 32.7%
- PAV only: 18.5%
- SAV only: 10.5%
- All 3: 16.5%

Israel individuals

- Regular only: 13.8%
- PAV only: 20.4%
- SAV only: 8.1%
- All 3: 23.6%

36% of individuals were always consistent in their choices
Market Segmentation

North America
- Constant
- Control
- Gender
- Education
- Errands
- Environmental concern
- Age
- Income and costs

Israel
- More negative for NA individuals
- Sig. only in NA
- Sig. only for Israelis
- More positive in NA
- Sig. only for Israelis
- Sig. only for Israelis
- More significant in NA
- 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

Differences in the latent variables

<table>
<thead>
<tr>
<th>Value</th>
<th>Technology</th>
<th>Enjoy driving</th>
<th>Environmental concern</th>
<th>Pro-AV</th>
<th>Public transit attitude</th>
</tr>
</thead>
</table>

- Individuals who only chose regular car
- Other individuals
## Multinomial Logit (MNL) Model

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

* All parameters are significant at the 95% level
## MNL Model

<table>
<thead>
<tr>
<th></th>
<th>Regular</th>
<th>PAV</th>
<th>SAV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purchase price (ratio)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If Purchase price PAV &gt; REG</td>
<td>-0.806</td>
<td></td>
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</tr>
<tr>
<td>If Purchase price PAV &lt; REG</td>
<td>0.263</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subscription cost (not-ratio)</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Israel</td>
<td></td>
<td></td>
<td>-0.123</td>
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<tr>
<td>North America</td>
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<td></td>
<td>-0.575</td>
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<tr>
<td><strong>Trip cost (ratio)</strong></td>
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<tr>
<td>If trip cost PAV &gt; REG</td>
<td></td>
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</tr>
<tr>
<td>If trip cost PAV &lt; REG</td>
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<td>0.364</td>
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</tr>
<tr>
<td><strong>Trip cost (not-ratio)</strong></td>
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<tr>
<td>Israel</td>
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<td></td>
<td>-0.0106</td>
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<tr>
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<td></td>
<td>-0.0165</td>
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<tr>
<td>0 trip cost</td>
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<td>0.762</td>
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<tr>
<td><strong>Increase in parking price</strong></td>
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<td>-0.0946</td>
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<td>North America</td>
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<tr>
<td><strong>Age</strong></td>
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<td></td>
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<tr>
<td>Old</td>
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<tr>
<td>Very old</td>
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<tr>
<td><strong>Female</strong></td>
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<tr>
<td><strong>Income</strong></td>
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<tr>
<td><strong>Km driven per year</strong></td>
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<td>0.0680</td>
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</tbody>
</table>
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 !!!