Autonomous Vehicles, Connected Systems and Market Adoption Factors

Hani Mahmassani
Northwestern University
WHAT IS A DRIVERLESS CAR?
Four Levels of Automation

Kornhauser, 2014

Preliminary Statement of Policy Concerning Automated Vehicles

**Level 0 (No automation)**
The human is in complete and sole control of safety-critical functions (brake, throttle, steering) at all times.

**Level 1 (Function-specific automation)**
The human has complete authority, but cedes limited control of certain functions to the vehicle in certain normal driving or crash imminent situations. Example: electronic stability control

**Level 2 (Combined function automation)**
Automation of at least two control functions designed to work in harmony (e.g., adaptive cruise control and lane centering) in certain driving situations.
Enables hands-off-wheel and foot-off-pedal operation.

*Driver still responsible for monitoring and safe operation and expected to be available at all times to resume control of the vehicle.* Example: adaptive cruise control in conjunction with lane centering

**Level 3 (Limited self-driving)**
Vehicle controls all safety functions under certain traffic and environmental conditions.
Human can cede monitoring authority to vehicle, which must alert driver if conditions require transition to driver control.

*Driver expected to be available for occasional control.* Example: Google car

**Level 4 (Full self-driving automation)**
Vehicle controls all safety functions and monitors conditions for the entire trip.
The human provides destination or navigation input but is not expected to be available for control during the trip. *Vehicle may operate while unoccupied.* Responsibility for safe operation rests solely on the automated system
## Implications of Each Level: User, Market and Society

<table>
<thead>
<tr>
<th>Level</th>
<th>“Less”</th>
<th>Value Proposition</th>
<th>Market Force</th>
<th>Societal Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 “55 Chevy”</td>
<td>Zero</td>
<td>Zero</td>
<td>Zero</td>
<td>Zero</td>
</tr>
<tr>
<td>1 “Cruise Control”</td>
<td>Infinitesimal</td>
<td>Some Comfort</td>
<td>Infinitesimal</td>
<td>Infinitesimal</td>
</tr>
<tr>
<td>2 “CC + Emergency Braking”</td>
<td>Infinitesimal</td>
<td>Some Safety</td>
<td>Small; Needs help From “Flo &amp; the Gecko” (Insurance Industry)</td>
<td>“20+%” fewer accidents; less severity; fewer insurance claims</td>
</tr>
<tr>
<td>3 “Texting Machine”</td>
<td>Some</td>
<td>Liberation (some of the time/places); much more Safety</td>
<td>Consumers Pull, Traveltainment Industry Push</td>
<td>Increased car sales, many fewer insurance claims, Increased VMT</td>
</tr>
</tbody>
</table>
Connected vehicle research is a suite of technologies and applications that use wireless communications to provide connectivity:

- Among vehicles of all types
- Among vehicles and roadway infrastructure
- Among vehicles, infrastructure, and wireless consumer devices
Connectivity

Connected systems (internet of everything)

Ad-hoc networks

Peer-to-Peer (Neighbor)

Receive only

Isolated

Coordinated
- Optimized flow
- Routing
- Speed harmonization

Connected
- Real-time info
- Asset tracking
- Electronic tolling

Cooperative Driving

Autonomous Vehicles

INTELLIGENCE RESIDES ENTIRELY IN VEHICLE

Smart Highways

INTELLIGENCE RESIDES ENTIRELY IN VEHICLE

Automation

Fully manual
Level 0

Fully automated
Level 4
INTELLIGENT VEHICLE-HIGHWAY SYSTEMS

ITS 0.9
- Vehicles
- Highway infrastructure

ITS 1.0
- Buses, trains, multimodal services
- Urban mobility

ITS 2.0 = CS 2.0 CONNECTED SYSTEMS

FOCUS: THE USER
- Mobility as an APP in seamless connected environment

INTELLIGENT TRANSPORTATION SYSTEMS

Digital 6th Sense
- Learns what you like
- Senses local content and services
- Interacts with networks
- Knows you and what is around you
- DisCOVERS things relevant to you
- Filters out irrelevant
Compilation by Pendyala & Bhat, 2014

Elon Musk: Tesla's driverless car will be street-ready in three years

Tesla raises the stakes with a bold about driverless cars.

Volvo plans self-driving cars in 2014, envisions accident-free fleet by 2020

Google cars have successfully driven 500,000 miles

Set 2018 as expected release date for self-driving car

Nissan Sets Goal of Introducing First Self-Driving Cars by 2020
IS IT LEGAL TO “DRIVE” A DRIVERLESS VEHICLE?

• Several states in the US have passed enabling legislation to allow self-driving cars to use public roadways
  – California, Nevada, Florida
• National Highway Traffic and Safety Administration policy statement
  – Policy guidance on licensing, safety, testing
• Autopilot systems council in Japan
  – Safety
  – Mobility
  – Efficiency (time saving, constraint reduction)
• Citymobil2 initiative in Europe
Who will buy?

- WILL CLASSIC ROGERS’ ADOPTION CURVE HOLD?
KEY ADOPTION FACTORS

• ABILITY TO DRIVE
• TRUST
• BENEFIT PERCEPTION
  – Safety
  – Mobility
  – Efficiency (time saving, constraint reduction)
• AFFORDABILITY
• Ability to drive
YOU and DRIVING

• THOSE WHO CANNOT DRIVE
• THOSE WHO PREFER NOT TO DRIVE
• THOSE WHO PREFER TO DRIVE
• THOSE WHO LOVE TO DRIVE
• Ability to drive
• TRUST
TRUST

• THOSE WHO TRUST
• THOSE WHO MAY TRUST FOR CERTAIN SITUATIONS
• THOSE WHO MAY REQUIRE CERTAIN GARANTEES
• THOSE WHO WILL NEVER TRUST
• Ability to drive
• TRUST
Cohort Effect: Increasing trust

Cohort Effect: Increasing need

Time value for parents

Safety value for parents

Safety value for self

Time value for children

Age
TWO KEY ASPECTS

• AUTONOMOUS CAR AS MOBILITY TOOL
  – Greater safety, efficiency, etc...
  – Enables multitasking, short vs. longer spans

• AS ROBOTIC ASSISTANT
  – Go shop, pick up kids— all mobility chores imposed by auto-centric suburban lifestyle
  – For small businesses— go deliver, pick up supplies...
ADOPTION PROPENSITY

TIME CONSTRAINED

MONEY CONSTRAINED

Just as well...
LOW PROPENSITY

Role for Policy?
Discounts, Incentives
Payment plans...

GADGET? TOY?
CONVENIENCE?
SAFETY?

High Value
Can Afford
HIGH PROPENSITY

✔

High Value
Can Afford
HIGH PROPENSITY

?”

✔

High Value
Can Afford
HIGH PROPENSITY

?”

✔

High Value
Can Afford
HIGH PROPENSITY

?”

✔

High Value
Can Afford
HIGH PROPENSITY

Hallucinations:
ADOPTION PROPENSITY

MONEY CONSTRAINED

Stay healthy!

LOW PROPENSITY

TIME VALUE?
CONVENIENCE?
SAFETY?

Role for Policy?
Discounts, Incentives
Family plans
Payment plans...

HIGH PROPENSITY

High Value
Can Afford

HEALTH CONSTRAINED

✔

Can Afford
SUBSTITUTION OR COMPLEMENTARITY?

Possible Hypotheses

• SUBSTITUTE, NO OTHER CHANGE

• SUBSTITUTE, FREE UP TIME, MONEY (individual level) and IMPROVE SAFETY AND CONGESTION (for society)

• START USING CAR FOR ACTIVITIES PREVIOUSLY EITHER NOT DONE, POSTPONED OR CHAINED

• NEW USES OF MOBILITY TOOLS, MAJOR REORGANIZATION OF ACTIVITY PATTERNS, ESPECIALLY for CAREGIVERS (of young people, elderly)
FINAL THOUGHTS

• DON’T FORGET FREIGHT and LOGISTICS
• IDEAL MARKET FOR INTRODUCING TECHNOLOGY AND ADOPTING ON WIDE SCALE
• INITIAL ROLE AS DRIVER-ASSISTANCE
  – Evident safety benefits
  – Potentially large fuel savings (just in driving mode, not including network aspects)
• LAST MILE DELIVERY STILL UP FOR GRABS, AND LIKELY TO BE BITTERLY FOUGHT