Automobile, Mobility … Why Not Just “Cars”? 

Mobility = Mobility Device + Mobility Consumer

or: Mobility = Transportation + Recreational Driving
Personal Mobility = Usage of Automobiles

Source: U.S. Transportation and Energy since 1920, A. Schäfer, Sustainable Transportation Seminar, Stanford University, 09/14/2012
Problems Resulting from Personal Mobility

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>Motor vehicle crashes led to 34,080 fatalities in 2012(^1), in 95% of the cases human error was at least a contributing factor(^2)</td>
</tr>
<tr>
<td>Pollution</td>
<td>Economic impact of health damages from motor vehicle emissions in the U.S. totals to over $40b ($64b) per year(^3)</td>
</tr>
<tr>
<td>Consumption</td>
<td>9m barrel every day (10% of the global petroleum production) are consumed as gasoline in U.S. light duty vehicles(^4)</td>
</tr>
<tr>
<td>Congestion</td>
<td>Average commuter gets delayed 36 hrs per year due to congestion(^5), 30% of inner city traffic due to parking search(^6)</td>
</tr>
</tbody>
</table>

Opportunities to Address Challenges

- Electrification
- Integration
- Automation
- Communication
Opportunities to Address Challenges: Part 1

Electric components substitute / replace combustion engine & tank.

Electrification
Overview Alternative Energy - Fuel Diversity

Gasoline | Diesel | Electricity | Bio Fuel | Hydrogen | Natural Gas | Propane
---|---|---|---|---|---|---

Source: http://www.afdc.energy.gov/ (adapted)
Different Levels of Vehicle Electrification

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Electrified</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE Powered Vehicle (CV)</td>
<td>ICE Powered Vehicle (CV)</td>
</tr>
<tr>
<td>ICE</td>
<td>ICE</td>
</tr>
<tr>
<td>Tank</td>
<td>Battery</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ICE Powered Vehicle (CV)</th>
<th>Hybrid Electric Vehicle (HEV)</th>
<th>Plug-In Hybrid Electric Vehicle (PHEV)</th>
<th>Battery Electric Vehicle (BEV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE</td>
<td>EM</td>
<td>EM</td>
<td>EM</td>
</tr>
<tr>
<td>Battery</td>
<td>Tank</td>
<td>Battery</td>
<td>Battery</td>
</tr>
</tbody>
</table>

Note: The diagrams illustrate various levels of electrification in vehicles, from conventional ICE-powered vehicles to fully electric vehicles. The symbols and arrows indicate the power flow from the power source ( ICE, EM) to the battery and/or tank.
Focus on Vehicle Electrification

Under which conditions will electrified vehicles:

• slow down global warming?
• decrease dependence on (foreign / scarce) resources?
• decrease air pollution?
• integrate into electric infrastructure?
• become the better alternative for consumers?

⇒ There is (probably) not just one answer!
What would the “best” vehicle based on the average usage look like?
What would the “best” vehicle based on the average usage look like?
Consumer Choice: Average vs. Extreme Case
Challenges for EVs – Range, Charge, Cost

Challenges US consumers see regarding electric vehicles [1]
28% range and battery life
20% availability of charging stations
17% total cost/affordability
9% high [purchase] cost of vehicles

Challenges EU industry experts see regarding electric vehicles [2]
65% range
57% availability of charging stations
55% total cost/affordability
30% not suitable for everyday driving

Analysts expect EVs to have 2% to 3% share of the new-car market by 2020 [3]

More Battery Capacity = More Autonomy

More / Faster Charging = More Autonomy

<table>
<thead>
<tr>
<th>Type</th>
<th>Power supply</th>
<th>Voltage</th>
<th>Max current</th>
<th>Charge Time*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Single phase - 1,9 kW</td>
<td>120 VAC</td>
<td>16 A</td>
<td>12-16 hours</td>
</tr>
<tr>
<td>Level 2</td>
<td>Single phase - 3,3 kW</td>
<td>230 VAC</td>
<td>16 A</td>
<td>6-8 hours</td>
</tr>
<tr>
<td>Level 2</td>
<td>Single phase - 7 kW</td>
<td>230 VAC</td>
<td>32 A</td>
<td>3-4 hours</td>
</tr>
<tr>
<td>Level 2</td>
<td>Single phase - 18 kW</td>
<td>230 VAC</td>
<td>80 A</td>
<td>1-2 hours</td>
</tr>
<tr>
<td>Level 3</td>
<td>Three phase - 10 kW</td>
<td>400 VAC</td>
<td>16 A</td>
<td>2-3 hours</td>
</tr>
<tr>
<td>Level 3</td>
<td>Three phase - 24 kW</td>
<td>400 VAC</td>
<td>32 A</td>
<td>1-2 hours</td>
</tr>
<tr>
<td>Level 3</td>
<td>Three phase - 43 kW</td>
<td>400 VAC</td>
<td>63 A</td>
<td>20-30 min</td>
</tr>
<tr>
<td>Level 3</td>
<td>Direct current - 50 kW</td>
<td>400-500 VDC</td>
<td>100 - 125 A</td>
<td>20-30 min</td>
</tr>
<tr>
<td>Level 3</td>
<td>Direct current** - 90 kW</td>
<td>480 VDC</td>
<td>200 A</td>
<td>15 min</td>
</tr>
<tr>
<td>Gasoline</td>
<td>Gas station - ≈10MW</td>
<td>--</td>
<td>20 l/min</td>
<td>1 min</td>
</tr>
</tbody>
</table>

*) Time to recharge 25kWh (≈ 75mls range), except “Gasoline” (≈ 300mls range)
**) Tesla Supercharger

### Average Driving and Foregone Trips

<table>
<thead>
<tr>
<th>Persona#</th>
<th>Annual MPG</th>
<th>MPGe (Approximate)</th>
<th>MPGe</th>
<th>MPGe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persona1</td>
<td>49</td>
<td>60</td>
<td>72</td>
<td>skip 8 trips</td>
</tr>
<tr>
<td>Persona2</td>
<td>49</td>
<td>71</td>
<td>70</td>
<td>skip 5 trips</td>
</tr>
<tr>
<td>Persona3</td>
<td>50</td>
<td>105</td>
<td>99</td>
<td>106</td>
</tr>
<tr>
<td>Persona4</td>
<td>50</td>
<td>59</td>
<td>73</td>
<td>106</td>
</tr>
<tr>
<td>Persona5</td>
<td>49</td>
<td>61</td>
<td>85</td>
<td>skip 3 trips</td>
</tr>
<tr>
<td>Persona6</td>
<td>49</td>
<td>62</td>
<td>90</td>
<td>skip 2 trips</td>
</tr>
<tr>
<td>Persona7</td>
<td>50</td>
<td>53</td>
<td>49</td>
<td>skip 54 trips</td>
</tr>
<tr>
<td>Persona8</td>
<td>50</td>
<td>67</td>
<td>99</td>
<td>106</td>
</tr>
<tr>
<td>Persona9</td>
<td>50</td>
<td>56</td>
<td>61</td>
<td>skip 5 trips</td>
</tr>
<tr>
<td>Persona10</td>
<td>50</td>
<td>53</td>
<td>49</td>
<td>skip 138 trips</td>
</tr>
</tbody>
</table>

1: urban dweller no commute by car, weekend trips 200mls, vacation 350mls
2: photographer, coaches students, visits son in Davis quarterly
3: teacher 20mls commute, run errands 10mls
4: employee 50mls commute, weekend at family villa 100mls
5: employee 60mls commute, weekend errands 15mls, vacation 300mls
6: employee 36mls commute, weekend errands 15mls, vacation 350mls
7: sales person 90-145mls p. day, vacation 300mls
8: employee 50mls commute, weekend errands 15mls, vacation 80mls
9: employee with 40mls commute, shuttle kids 60, vacation 300mls
10: consultant commute 45 / 150 / 300mls, weekend 40mls
Challenges for EVs – Range, Charge, Cost

Challenges US consumers see regarding electric vehicles [1]
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17% total cost/affordability
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The Range Solution – Today and Tomorrow

Larger Battery (a little extra charge)  Range Extender (onboard generator)

Dynamic Charging (charge as you go)
**Assumption:** Daily commute is 40 mls round trip and doing that electrically is the “cleaner” option, but consumers want to have peace of mind that they can drive 300 mls with their vehicle without “complicated” recharging.

**Question:** What is the “lightest” option for the extra 260 mls?

<table>
<thead>
<tr>
<th></th>
<th><strong>Gasoline Range Extender</strong></th>
<th><strong>Larger Battery Pack</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (miles)</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>Energy Required (kWh)</td>
<td>66.3</td>
<td>66.3</td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.4 x 0.85</td>
<td>-</td>
</tr>
<tr>
<td>Gasoline / Battery Weight (kg)</td>
<td>15.5</td>
<td>522.4</td>
</tr>
<tr>
<td>Equipment Weight (kg)</td>
<td>engine, fuel system, exhaust</td>
<td>117</td>
</tr>
<tr>
<td><strong>Total Additional Weight (kg)</strong></td>
<td><strong>132.5</strong></td>
<td><strong>522.4</strong></td>
</tr>
</tbody>
</table>

Alternative Range Solution: Battery Trailer

Source: http://www.youtube.com/user/ebuggy01
Lifetime Externalities for Electrified Vehicles

PEV vs. BEV – A Minimum Winning Game?

Battery Only Electric

Plug-In Hybrid Electric

Consumer

Manufacturers

Utilities

Environment
Expectation: Shift from BEV to PHEV and REV
Outlook: From Liquid to Electric

- **Electric Only**
  - ✔ Catalytic Converter
  - ✔ Lead Acid
  - ✔ NiMH
  - ✔ Ethanol
  - ✔ Fuel Cell Trials
  - ✔ Wireless Charging (static)
  - ✔ Li-Ion
  - ✔ Start/Stop (Micro Hybrid)
  - ✔ Downsizing
  - ✔ Natural Gas
  - ✔ Range Extended BEV
  - ✔ Plug-In Hybrid
  - ✔ Mild Hybrid
  - ✔ Full Hybrid
  - ✔ Swappable Range Extender
  - ✔ Wireless Charging (dynamic)
  - ✔ Metal Air
  - ✔ Additional Efficiency Measures
  - ✔ Swappable Range Extender
  - ✔ H₂ Mass Market

- **Hybrid Electric**
  - ✔ DI-Diesel
  - ✔ Ethanol
  - ✔ NiMH
  - ✔ Range Extended BEV
  - ✔ Fuel Cell Trials
  - ✔ Wireless Charging (static)
  - ✔ Start/Stop (Micro Hybrid)
  - ✔ Downsizing
  - ✔ Natural Gas
  - ✔ Plug-In Hybrid
  - ✔ Mild Hybrid
  - ✔ Full Hybrid

- **ICE Only**
  - ✔ DI-Diesel
  - ✔ Ethanol
  - ✔ NiMH
  - ✔ Range Extended BEV
  - ✔ Fuel Cell Trials
  - ✔ Wireless Charging (static)
  - ✔ Start/Stop (Micro Hybrid)
  - ✔ Downsizing
  - ✔ Natural Gas
  - ✔ Plug-In Hybrid
  - ✔ Mild Hybrid
  - ✔ Full Hybrid
  - ✔ Swappable Range Extender
  - ✔ H₂ Mass Market

Source: Author's own observation, except [1]:http://www.eia.gov/oiaf/aeo/tablebrowser/, reference case 2035, EIA, 2013
Two Main Trends in Electrification

**Improved Technology and Infrastructure**
- Electrified Vehicles Becoming Viable -
  e.g. battery, extender, charge network

**New Mobility Solutions and Behavioral Changes**
- Consumers Adapting to Limitations -
  e.g. e-commuter + sharing, apps
Opportunities to Address Challenges: Part 2

Computer takes over (in part) driving task from human.
### Definitions for Automated Vehicles

<table>
<thead>
<tr>
<th>NHTSA level</th>
<th>SAE level</th>
<th>SAE name</th>
<th>SAE narrative definition</th>
<th>Execution of steering and acceleration/deceleration</th>
<th>Monitoring of driving environment</th>
<th>Backup performance of dynamic driving task</th>
<th>System capability (driving modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>Human driver monitors the driving environment</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Assisted</td>
<td>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</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Partial Automation</td>
<td>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</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automated driving system</td>
<td>(&quot;system&quot;) monitors the driving environment</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>Conditional Automation</td>
<td>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</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>High Automation</td>
<td>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</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Full Automation</td>
<td>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</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

Source: Summary of SAE International's Draft Levels of Automation for On-Road Vehicles, July 2013
Focus on Automated Driving

Under which conditions can automated vehicles:

- become affordable for mainstream consumers?
- make people feel safe and comfortable while being driven?
- release the driver from the need to monitor the car?
- interact with human controlled vehicles?
- be deployed without massive infrastructure investments?

→ Vision and reality might be worlds apart!
Stanford’s Prof. Thrun’s Automated Car, 2007
Stanford’s Prof. Gerdes’ Automated Car, 2012

Robotic Race Car Pushes the Limits
Google’s Automated Car, 2012

Source: Google
The Vision of Automated Driving
The Reality of Automated Driving
The Situation is:

- Nevada, Florida, and California are currently the only states to expressly regulate “autonomous vehicles”
- Legislators or regulators in many states are aware of and interested in this topic
- Lobbying determines the fate of these bills

The Situation is NOT:

- These three states have “legalized” autonomous vehicles
- These vehicles are illegal elsewhere
- The legal status of autonomous vehicles is entirely clear in any state

Source: “State of the States on the State of the Art”, Bryant Walker Smith, 12/5/2012
Other Automated Ground Vehicles

Consumer and Commercial Equipment

Public and Private Shuttle Systems

Agricultural and Mining Vehicles
Outlook: From Assistance to Automation

1980s  1990s  2000s  2010s  2020s  Future Vision

**Warning Information**
- ✔ Navigation
- ✔ Parking Aid System
- ✔ Night Vision
- ✔ LDW – Lane Departure Warning

**Assisted Driving**
- ✔ TCS – Traction Control System
- ✔ ABS – Anti Lock Braking System
- ✔ ACC – Adaptive Cruise Control
- ✔ ESC – Electronic Stability Control

**Partially Automated Driving**
- ✔ LDW – Lane Departure Warning
- ✔ TCS – Traction Control System
- ✔ BAS – Brake Assist System
- ✔ ACC – Adaptive Cruise Control
- ✔ ESC – Electronic Stability Control

**Fully Automated Driving**
- ✔ Fully Automated On-Demand Mobility
- ✔ Automated Valet Parking
- ✔ Automated HWY Driving
- ✔ Automated Stop-and-Go
- ✔ Fully Automated Personal Vehicle

**Future Vision**
- ✔ Automated Parallel Parking
- ✔ Automated Parking
- ✔ Automatic Emergency Braking
- ✔ Lane Keep Assistance
- ✔ BAS – Brake Assist System
- ✔ ACC – Adaptive Cruise Control
- ✔ ESC – Electronic Stability Control
- ✔ Pedestrian Detection
- ✔ Blind Spot Warning
- ✔ Traffic Sign Detection
- ✔ Collision Warning
- ✔ Driver Monitoring
- ✔ Automated Parallel Parking
- ✔ Automated Valet Parking
- ✔ Automated HWY Driving
- ✔ Automated Stop-and-Go
- ✔ Fully Automated Personal Vehicle
- ✔ Automated Parallel Parking
- ✔ Automated Valet Parking
- ✔ Automated HWY Driving
- ✔ Automated Stop-and-Go
- ✔ Fully Automated Personal Vehicle
Two Main Trends in Automation

Driver Assistance in Personal Vehicles - Systems Taking Over Driving Tasks - e.g. traffic jam assist, auto parking

Personalization in Public Transportation - Fewer Staff, Modular, On-Demand - e.g. automated tram, driverless pod
Vehicles communicate with one another and with infrastructure.
Two Ways to Communicate - Cellular / DSRC

Public Cellular Based Communication

Pros: existing & evolving network + standards, coverage, cost
Cons: security, reliability, centralized base-station network

Dedicated Short Range Communication

Pros: security, reliability, decentralized ad-hoc network
Cons: no existing network, coverage for V2I very unclear, cost
Focus on Vehicle Communication

How can an online data connection to vehicles:

- improve safety, efficiency by sharing data among vehicles?
- improve productivity, enjoyment without distraction?
- benefit from existing communication infrastructure?
- utilize crowd sourcing for mobility specific needs?
- enable a seamless and sustainable mobility experience?

⇒ The internet is already in the car – but needs to be more integrated!
How Smart is Your Car?

Smart Phone

Dumb Car?
Modern Automobile – Really so Dumb?

Up to 80 controllers
- Powertrain: ignition, injection, emission, transmission…
- Safety: airbag, seatbelts, pre-tensioners…
- Chassis: steering, brakes, dampers…
- Driving Aid: parking, night vision…
- Entertainment: MP3, CD, radio…
- Information: navi, traffic, src…
- Body: seats, doors, roof…
- Cabin: ventilation, heating, cooling, filtering,…
- Vision: lights, wipers, mirrors,…


Up to 20 Communications Networks
- CAN: Powertrain, safety, chassis, driving aid
- MOST: Entertainment and information
- LIN: Body, vision, HVAC

Up to 35-40% of vehicle cost
- >100M lines of code
- > 4200 signals
Different App Categories for Internet of Cars

- Maintenance / Repairs
- Entertainment / Communication
- Service / Information
- Safety / Efficiency
Considerations for Connected Vehicles

- **LTE**
- **DSRC**
- **3G**
- **GPRS**

Transmission Time:
- **msec**
- **sec**
- **min**
- **hr**

Data Amount:
- **kB**
- **MB**
- **GB**

- **Collision Avoidance**
- **Voice Communication**
- **Audio Streaming**
- **Video Streaming**
- **Routing & Driving Information**
- **Road & Traffic Safety Warning**
- **Text Social**
- **Maintenance Data Upload**
- **Software Update**
- **Sensor-based Driver Assistance Systems**

- **Safety**
- **Efficiency**
- **Communication**
- **Entertainment**
- **Service**

Author’s depiction, only for qualitative comparison.
<table>
<thead>
<tr>
<th>Year</th>
<th>Car Phone</th>
<th>Mobile Phone</th>
<th>In-Car Navigation</th>
<th>Portable Navigation</th>
<th>Satellite Radio</th>
<th>Mobile Media Streaming</th>
<th>In-Car Hot-Spot</th>
<th>OEM Portal</th>
<th>Service, SW Update</th>
<th>Internet of Cars</th>
<th>Safety Information</th>
<th>V2X</th>
<th>Vehicle-to-Infrastructure</th>
<th>Vehicle-to-Vehicle</th>
<th>Complementary WiFi Link</th>
<th>Flash Download</th>
<th>Home-Vehicle Integration</th>
<th>Internet of Cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980s</td>
<td>✔</td>
<td>✔</td>
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<td>1990s</td>
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<td>2000s</td>
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<td>2010s</td>
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<tr>
<td>Future Vision</td>
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</tr>
</tbody>
</table>
Two Main Trends in Communication

Infotainment Apps via Public Network
- Mobile Internet with Central Servers -
  e.g. media stream, traffic info, service

Safety Functionalities via Private Network
- Exclusive Network between Vehicles -
  e.g. collision avoidance, traffic light
Opportunities to Address Challenges: Part 4

Automobiles become integral part of an intermodal mobility system.
Focus on Mobility Integration

Which relationship will consumers have with their vehicles regarding:

- access to vs. ownership of an automobile?
- the automobile as status symbol?
- new needs for the aging society?
- new values of the young generation?
- impact of mass motorization in emerging countries?

→ Considerations depend heavily on regional differences!
Decreasing Interest in the Automobile?

- **1978 in US**
  - 50% of 16-year-olds had driver’s license
  - ~12 M teenagers total had license

- **2010 in US**
  - 30% of 16-year-olds had driver’s license
  - ~10 M teenagers total had license

**Disruptions: For Teenagers, a Car or a Smartphone?**

*The New York Times*

**Auto industry predicts younger people will buy cars again once finances improve**
Mobility Solutions – Many Different Options

Vehicle Ownership

Social Interaction

- Private Car
- Carpooling
- Shared Van
- Taxi
- Peer-to-Peer Sharing
- Carsharing
- Mass Transit
Outlook: From Freedom to Care-Free

Rideshare
- ✔ Carpooling since 1940s
- ✔ Early carsharing since 1948 in CH

Carshare
- ✔ Zipcar
- ✔ VW Quicar
- ✔ BMW Drive Now
- ✔ Daimler Car2Go
- ✔ Hertz
- ✔ Avis / Zipcar

P2P Carshare
- ✔ Flightcar
- ✔ Wheelz
- ✔ Getaround
- ✔ Relay Rides
- ✔ Consolidated ridesharing app
- ✔ Consolidated carsharing app
- ✔ Integration car- / ridesharing with public transportation as one seamless service
Two (One?) Main Trend(s) in Integration

- **Automobile Stays Symbol of Independence and Personality**
  - Personal Mobility More than Just A-to-B
    - e.g. personalized vehicles, self identification

- **Automobile Just One out of Many Mobility Options**
  - Integrated Personal / Public Mobility
    - e.g. car- / ridesharing, on-demand
Summary: The Future of Personal Mobility

**Electrification**

- ✓ Technology is evolving to enable long-distance travel with EVs
- ? Consumer adoption and infrastructure deployment unclear

  ➔ Deployment path: range extender > improved battery > infrastructure

**Automation**

- ✓ Technology would be ready to automate vehicle control very soon
- ? Mix of standard and automated vehicles imposes many challenges

  ➔ Deployment path: stop&go > hwy > parking > dedicated lanes > A-B

**Communication**

- ✓ Technology would be ready to connect vehicles with one another
- ? Cost for dedicated vehicle-infrastructure communication network immense

  ➔ Deployment path: X2V cellular > V2V WiFi > V2X multi-standard

**Integration**

- ✓ Alternative transportation systems evolve, especially sharing opportunities
- ? Automobile’s dominance continues because of its flexibility / independence

  ➔ Deployment path: car / ride sharing > integration personal-public transport > multi-modal mobility network
Vision: Electric-Automated-Connected-Public

- Connected via WiFi, Cellular
- Public and On-Demand
- Automated incl. Infrastructure
- Electric and Wirelessly Powered
Use Cases – Different Solutions Needed

Population Density

Infrastructure Readiness