Cloud Commuting and Mobility-as-a-Service

David Levinson
University of Minnesota
University of Sydney

The End of Traffic & the Future of Transport

David M. Levinson & Kevin J. Krizek
Climbing Mount Auto: The Rise of Cars in the 20th Century
Figure 1.1: Climbing Mount Auto

Vehicle Kilometers Travelled Per Capita

Passenger Trips by Public Transit Per Capita

Unlinked Passenger Journeys by Public Transport Per Capita

- Vehicle Kilometers of Travel Per Capita
- Passenger Journeys by Public Transport Per Capita
- Unlinked Passenger Journeys by Public Transport Per Capita
Figure 1.4 Total Time Spent Traveling per capita (minutes)

- Leisure and Sports
- Organizational, Civic, and Religious
- Education
- Work
- Care and Help Non-household Members
- Care and Helping Household Members
- Goods and Services
- Household Activities
- Eating and Drinking
- Personal Care
Figure 1.5 Person Trips per Day by Age and Year of Birth

Figure 1.6 Average Trip Distance by Age and Year of Birth Cohort (Miles, All Purposes)
Less Traffic is a Good Thing

- Cars Crash
- Cars Pollute
- Noise Annoy
- Cars Consume Lots of Space (US Parking = Virginia)
- Cars Isolate

Table 1: Deaths per 100,000 people

<table>
<thead>
<tr>
<th></th>
<th>Road injury + other transport injury</th>
<th>Total air pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths per year</td>
<td>15</td>
<td>36</td>
</tr>
<tr>
<td>Years of life lost per year</td>
<td>653</td>
<td>565</td>
</tr>
</tbody>
</table>
What Killed America’s Traffic?
Changing Demographics

Figure 3.1 Population of Age Groups in US 2014
Changing Nature of Work

Figure 3.2 US Labor Force Participation Rate: 1948-2015
At Home Working

Figure 3.4 Telecommuting in Minneapolis-St. Paul Region

- Never
- Once a year
- A few times per year or more
- Once per month or more
- Once per week or more
- 4-5 days per week

Years:
- 2001
- 2011
Online Shopping

Figure 3.5 Time Spent Shopping per Day in Minneapolis St. Paul Region (minutes)

- Female Nonworkers
- Male Nonworkers
- Female Workers
- Male Workers
Figure 11.1 East Brainerd Mall on Black Friday (28 Nov 2014)
Figure 11.2 Food and alcohol expenditures (by share)
Virtual Connectivity

Figure 3.7 Travel by Purpose per household (km)
A License to Roam
Competing Modes

Figure 3.9 Mode Shares in Minneapolis - St. Paul Region, Summer 2001 vs. Summer 2011

- **Auto**
- **Transit**
- **Bike**
- **Walk**
- **School Bus**
- **Other**

Mode Share, all trip purposes

<table>
<thead>
<tr>
<th>Year</th>
<th>Auto</th>
<th>Transit</th>
<th>Bike</th>
<th>Walk</th>
<th>School Bus</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>
Figure 3.10 Billions of Pieces of Mail Handled Per Year: US Post Office (1926-2009)
5. Transitioning Toward Electric Vehicles
Figure 5.2 Lithium Ion Battery Pricing by Cell Type (2009-2020) ($/kWh)
Norwegian Electric Vehicle Market Share

Norwegian Electric Vehicle Association,

Figure 5.1 US Sales of Electric Vehicles

- **Plug-in EV and Extended Range EV**
- **Battery EV**
- **Hybrid EV**

Sales data from 1999 to 2015, showing an increase in sales over time.
Autonomous Autos
Benefits and Consequences

- Safety
- Vehicle Form
- Parking
- Capacity
- Cars without People
- Mobility for the Immobile
- Costs
- Right-of-Way Retrofit
- Roadspace Reallocation
- Nomadism
- Ownership
- Activity-in-Motion
- Status

Box 7.1: NHTSA (2013) Policy on Automated Vehicle Development

**No-Automation (Level 0):** The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.

**Function-specific Automation (Level 1):** Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.

**Combined Function Automation (Level 2):** This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.

**Limited Self-Driving Automation (Level 3):** Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. Google’s converted test vehicles are an example of limited self-driving automation.

**Full Self-Driving Automation (Level 4):** The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. Google’s new “bug-like” car design without a steering wheel or brakes is an example.
Figure 7.1 Cumulative km traveled in Autonomous Mode by Google Self-Driving Car
• Level 2, 2.5 Now (Tesla Auto-Pilot, etc.)

• Level 3 ("limited self-driving automation") autonomous vehicles will be on the market by 2020.

• Level 4 will be available in 2025 and required in new US cars by 2030, and required for all cars by 2040.

• In other words, human driven vehicles will eventually be prohibited on public roads (aside from special events).
New Activities in Motion

- A limited set of personal care activity including dressing & grooming, health-related self care, personal/private activities;
- A limited set of child care activities including reading to/with children, home schooling, and arts and crafts with children;
- Eating and drinking;
- Tobacco and drug use; and
- Participation in religious practices.

New activities becoming possible after self-driving cars (minutes)

- Eating and drinking: 66.6522
- Tobacco and drug use: 0.3672
- Participation in religious practices: 2.5532
- Child care: 3.155
- Personal care: 46.0118

Fan (2016)
A Cambrian Explosion of Vehicle Forms

“Google Car”
Shape-Sifting

MIT “Stackable City Car” Concept
Smaller

Toyota iRoad

GM Lean Machine

Gogoro
And Bigger

“Toyota Swagger”
with Fewer Wheels?
Impacts: Longer trip distances & durations

Mokhtarian and Salomon (2001): Excess travel is more likely to occur as people increase the perceived positive utility of activities.
MaaS Transport
Comparing Nice Ride's service area in 2010, the first year of operation, and 2014, the most recent year of operation.
Figure 8.3 Growth of Bike Sharing Systems Globally

- Cumulative
- Number Added
Figure 8.2 North American Carsharing Growth
Cloud Commuting

- Smaller, more modern fleet (fleet in motion more, wears out faster)
- Coverage, logistics (wider coverage than transit, MaaS best serves non-work trips, load-balancing and dead-heading issues)
- Costs (lowered labor costs)
- Electrification (less range anxiety)
- Street Design (accommodate pick-up/drop-off … the network as a taxi-stand)
Land Use Consequences (MaaS + AVs)

Up and Out: The Future of Travel Demand and Where We Live
• **Up**: Less vehicle ownership with increased use of MaaS in cities, raising the value of cities.

• Driverless cars which can be summoned on demand allow people to avoid vehicle ownership altogether.

• This will reduce vehicle travel, as people will pay more to rent by the minute than they do when they own.

• Since total expenditures on transport are saved, additional funds are available to pay for rent in cities, and more trips are by walk, bike, and transit.

• People who seek the set of urban amenities (entertainment, restaurants, a larger dating pool) will find these amenities increasing in response to the population.

• The greater value in cities with the new more convenient technology leads to more and taller development. (Hence the use of the word “Up”.)
• **Out**: More vehicle travel with increased exurbanization.

• Fast, driverless cars that allow their passenger to do other things than steer and brake and find parking impose fewer requirements on the traveler than actively driving the same distance.

• Decreases in the cost of traveling (i.e., availability of multitasking) makes travel easier.

• Easier travel means increases in accessibility and subsequently increases in the spread of development and a greater separation between home and work, (pejoratively, sprawl), just as commuter trains today enable exurban living or living in a different city.

• This reinforces the disconnected, dendritic suburban street grid and makes transit service that much more difficult (as if low density suburbs weren't hard enough).

• People will live farther “Out”.

Out
Reduce, Reuse, Bicycle

• Most roads are under-used most of the time. There is ample capacity outside the peak.

• Most of the pavement is unused even at peak times; there are large gaps between vehicles both in terms of the headway between vehicles and the lateral spacing between vehicles. Americans drive 6 foot wide cars in 12 foot lanes, often on highways with wide shoulders.

• Most seats in most cars are unoccupied most of the time.

• Most cars contain far more weight than required to safely move the passenger. While bigger cars might be safer for the occupants, they are less safe for non-occupants. This is an inefficient arms race.

• Many roads are so wide we use them for storage of vehicles most of the day.

• There is excessive delay at traffic lights, especially during off-peak periods, wasting time and space.
Dimensions

- Vehicle width/ Lane width
- Vehicle weight
- Vehicle occupancy
- Traffic signals and stop signs

Figure 12.1 Narrowly marked street lane in Palermo, Italy.
Redeeming Transport

• How can we still get the gains of auto-mobility without the costs?

• Change from outside rather than inside (DOT follows, does not lead)
Policy Implication:

- Increased throughput per square meter of pavement (along with flattened demand) indicates fewer square meters of pavement are required.
Thank You

• Questions???

• David Levinson: dlevinson@umn.edu

• davidlevinson.org

• transportist.org

• Twitter: @trnsprtst