Fundamentals of Mobility Transformation Due to Connectivity and Autonomy in Vehicles

SoCal-Japan joint workshop on Advanced traffic management & control in the era of connected and autonomous driving “, UC Irvine, July 7, 2017
Questions of interest

- How will the transportation systems change in the near future, and over the next few decades, as connected, shared and autonomous systems become more prevalent?
- What are the fundamentals of this change, from a mobility theory standpoint?
- What are the possibilities?
Mobility Transformation in Future

• **Transportation systems** are in for a massive transformation in the near future with shared-usage of facilities and will continue to evolve in the next few decades as autonomous systems take hold.

• Changes brought by Uber, Lyft, etc are well known – even without any infrastructural changes.

• **Connected systems** and **autonomous systems** are on the way.

• Current systems based on **old paradigms** of users being unable to communicate in real-time with vehicles, or with each other – About to change in a big way!

• **Shared-use** of transportation facilities is here to stay.

• Shared use will involve user decisions, and infrastructural implications.
Connected Vehicles

- They are aware of each other. They can talk to each other
Autonomous/ Self-driving Vehicles

- They do it themselves. We enjoy life inside.
What are the benefits?

- Crash Elimination,
- Reduced Need for New Infrastructure
- Travel Time Dependability
- Productivity Improvements
- Improved Energy Efficiency
- New Models for Vehicle Ownership
- New Business Models
Mobility Transformation in Future

• Users negotiating with each other or with a facilitating broker

  • “I will pay $2 for a green extension at the intersection right now! Would 10 of you cars wait for 15 seconds and get paid?”
Mobility Transformation in Future

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  - “Can you change lanes for 15 cents, so I can take an exit and leave?”
Mobility Transformation in Future

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• “Can you change lanes for 15 cents, so I can take an exit and leave?”

• Better efficiency is possible, as traffic “knots” can get untied.
Fundamental Concept

- **First-Come-First-Served Order** of Operation and Management is no longer necessary, under full information!
  - It is a fairness paradigm, but there are ways to preserve fairness under peer-to-peer communication

- **Better Efficiency** is possible under other orders of operations, provided fairness can be preserved through exchanges.
Quotes...

• “We look to a future of Personalized and Pervasive Point-to-Point Passenger Pooled Private-Public-Para Transit (PPPPPPPPP)” , R. Jayakrishnan, 1995

• "Cars are today one of the least used assets in our society, being averagely used 50 minutes per day ... Uber and other services like Zipcar and Blablacar are part of a new mobility ecosystem" David Plouffe, Senior VP, Google, 2015
Mobility Transformation in Future

- Users negotiating with each other or with a facilitating broker.

  - “Uger says it is cheaper to pick me up before you. Can I pay you $3 to wait for 10 minutes?”
Mobility Transformation in Future

• Users negotiating with each other or with a facilitating broker.
  
  • “Uger says it is cheaper to pick me up before you. Can I pay you $3 to wait for 10 minutes?”

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Using bilateral trading to increase ridership and user permanence in ridesharing systems

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CrossMark
Mobility Transformation in Future

- Users negotiating with each other or with a facilitating broker.

- [Autonomous Car says] “FemEx will pay me $5 for an urgent package pick-up and drop near your house. Can I give you $2 to wait 10 min?”
Mobility Transformation in Future

- Users negotiating with each other or with a facilitating broker.

- [Autonomous Van says] “Can you three small cars move 2 feet each for me to park here? I’ll pay $2 to each of you.”
Mobility Transformation in Future

- Negotiations on Mobility Portfolios.

- [Autonomous Mobility Service, like your phone company, says] “You have used up all of your 100 hours on a Toyoda 4-seater. You can get 25 hours for 40 hours out of the 75 hours you have on a 2-seater Fjord Focus-mini, or by offering your drive-way for our vehicle parking use for 2 months.”

- “Mobility consultants” like Tax consultants or real-estate agents??
Entrepreneurship

- Transportation sector no longer has massive inertia against change.
- Public sector no longer has full control of the system. Emergence of TNCs (Transportation Network Companies) and MSPs (Mobility Service Providers)
- Cheap real-time communication capabilities to/from/among the users (travelers, shippers) allows innovation in the utilization of infrastructure
- Real-time data is the key. “**The one with the data rules the world**”
- A small firm with a big idea can make a change
  - Data collectors (“The eyes of the system”)
  - Data Maintainers (Infrastructure maintenance is tied to this)
  - Identifying spare infrastructural supply (e.g. Parking for autonomous vehicles)
  - Facilitating supply sharing and exchanges among users
WayTrade

UCI Student Team Finalists, Butterworth Entrepreneurship Competition

Roger Lloret Batlle, Civil Engineering
Felipe de Souza, Civil Engineering
Si-Yuan Kong, Economics
Amine Mahmassani, Economics
Vaibhav Saini, Computer Science/SW Engrg
Everybody has a value of time

$25/hr

$5/hr
Waytrade solution:

Higher value goes and pays money

Lower value waits and gets money
How quickly?

Choose a saved value of time:

- Leisurably - $10.00
- Normal - $25.00
- URGENT - $50.00

Preview my trip!
Your trip

Your value of time: $50.00
Estimated trip time: 23 minutes
Estim. cash transfer: $0.20
ETA adjustment: -2 minutes

Go back  Navigate!
Revenue Model

Installed at no cost to public sector:
• System provided for free to government and users
  WT covers capital costs, maintenance, data services
• Commission from transactions
• Other business models possible

Simulation studies and Projection for 250 intersections (Irvine) estimates transactions of about $15 per month per capita, and $35 million in transactions (about $3.5 million in commission).
• Projected to LA metropolitan area -> $1.5 billion
• Projected trades nation-wide -> $150 billion per year
• Commission at 10% -> $15 billion
• Capital equipment installation cost recovered in a year.
- Redesigning wireless communication as a means to vehicle awareness
- Embracing “right data” over “big data”
- Localized data rather than cloud services
- Designing a roadside infrastructure that helps facilitate intelligent decisions
Technology

- Roadside Communication Network (RCN)
  - Extends Internet of Things (IoT) and Wireless Sensor Networks (WSN)
- Roadside sensor is **low-cost, ultra-low power** and easily programmable
- Street signs, Traffic lights, Railroad crossings, Construction zones, and other road related entities will be able to wirelessly communicate their message to recipients
- Harvest energy from the environment

Patent Pending

UCI Student Project
(Ritchie/ Jayakrishnan)
Sharing is on the rise

### US Adult Transportation Sharing Economy Users and Penetration, 2014-2020

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<td>12.4</td>
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<td>51.4%</td>
<td>20.5%</td>
<td>13.3%</td>
<td>7.2%</td>
<td>6.6%</td>
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<tr>
<td>% of adult internet users</td>
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<td>5.9%</td>
<td>6.9%</td>
<td>7.7%</td>
<td>8.1%</td>
<td>8.6%</td>
<td>8.9%</td>
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<tr>
<td>% of adult population</td>
<td>3.4%</td>
<td>5.0%</td>
<td>6.0%</td>
<td>6.7%</td>
<td>7.1%</td>
<td>7.5%</td>
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Note: individuals ages 18+ who have used their account for a community-based online transportation service (e.g., Uber) at least once during the calendar year

Source: eMarketer, May 2016

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Note: individuals ages 18+ who have used their account for a community-based online service that coordinates peer-to-peer paid access to property, goods and services (e.g., Airbnb, Uber) at least once during the calendar year; excludes crowdsourcing, group buying, incorporated professional services and online marketplaces

Source: eMarketer, May 2016
Peer-to-Peer Ridesharing
(Neda Masoud, R. Jayakrishnan, *Transportation Research Part-B*, 2016)

• “Go-Point” Infrastructure in a city (fixed spots for waiting) and density of such point could dramatically improve efficiency and offer better/cheaper mobility. ("Starbucks Coffee – we offer a wifi hot-spot and 5 Go-spots")

← Go-Points modeled for Caltrans project on Rideshare Feeder Systems for Transit/ Red Line Metro (2015-17)
P2P Ride Exchange
(Neda Masoud, Roger Llorett-Batlle, R. Jayakrishnan, Transportation Research Part-E, 2017)
P2P Ride Exchange

(Neda Masoud, Roger Llorett-Batle, R. Jayakrishnan, *Transportation Research Part-E, 2017*)
Transit-RideShare-CarShare-BikeShare-WalkShare
(N Masoud, D Nam, J Yu, R Jayakrishnan, *Transportation Research Record*, 2017)
Automated Vehicles

- Rides can be matched without spatial proximity of riders.
  - *Because the cars can drive themselves*
- The “Go-points” can be parking spots and residential drive-ways
- Parking infrastructure needs to be the first to change
- Car-ownership portfolios a key
  - “*For $250 a month, get 20 hours a year of a Famborghini, 200 hours of a Hyeondda, 200 hours of a Kawosaki automated-bike, 50 hours of a Fjord Soccer-van. Save 25% if you offer your drive-way for our vehicles o park*”
- Road striping can disappear! Virtual lanes
- Vehicles can move in a negotiated “mixed-bubble” flow
- Have more people in your vehicle, or have smaller vehicle --> easier to pay others for space for your “vehicle bubble” to move on the road.
Conclusions

• The future will be driven by data.
• Shared and autonomous systems are here to stay.
• Peer-to-peer exchange in utilizing supply (infrastructure and its use), can bring in drastic changes.
• The fundamentals exist for successful market mechanisms to prime a transformation – unused capacity exists!
• We need to be on our toes to catch up with where technology will take our transportation infrastructure
• Bottom-up transformation (probably not controlled by the public-sector)

THANK YOU