Incorporating Connected and Autonomous Vehicles and Ride-Hailing Services in the Traditional Four Step Model

Gopindra Nair, Felipe Dias, James Kuhr, Natalia Ruiz Juri & Chandra Bhat
The University of Texas at Austin

Arash Mirzaei
North Central Texas Council of Governments

North Central Texas Council of Governments

Goals and approach

- Capture the impact of new technologies within the framework used by most MPOs for long range planning

- Framework approach
  - Flexibility to take advantage of new data as it becomes available
  - Clear identification of assumptions to facilitate sensitivity testing

Impact of new technologies on activity-travel behavior

New technologies

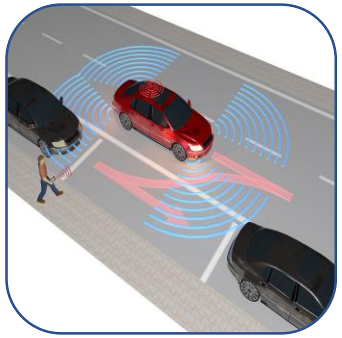
Convenience

Infrastructure

Virtual Accessibility

AV/Drone Delivery

Improved time use



Parking

Network Capacity

MaaS

Time and how we spend our time is the key

- Time is the background canvas – the background tapestry – onto which individuals paint, weave, and drape their activity-travel patterns

- Technologies enhance our toolbox to paint, weave, and drape our activity-travel patterns, but the background time canvas remains a fixity

Need for Activity-Based Models

- Notion of time is central to activity-based modeling
  - Explicit modeling of activity durations (daily activity time allocation and individual episode duration)
  - Treat time as “continuous” and not as “discrete choice” blocks
- Activity engagement is the focus of attention
  - Travel patterns are inferred as an outcome of activity participation and time use decisions
  - Continuous treatment of time dimension allows explicit consideration of time constraints on human activities
- Reconcile activity durations with network travel durations (feedback processes)

- ABM should…
  - Capture the central role of activities, time, and space in a continuum
  - Explicitly recognize constraints and interactions
  - Represent simultaneity in behavioral choice processes
  - Account for heterogeneity in behavioral decision hierarchies
  - Incorporate feedback processes to facilitate integration with land use and network models
- CEMDAP ABM developed at UT Austin

Framework overview

Trip generation → **Trip Distribution** → **Mode Choice** → **Traffic Assignment**

Trip generation

- Distinguish between households w/wo AVs.
  - Different trip production rates
- Allow for the generation of additional ride-hailing trips

Trip Distribution

- Consider changes in impedance sensitivity
  - HHs that own AVs
  - Ride-hailing trips

Mode Choice

- Include ride-hailing in the choice set.
- Consider changes in sensitivity to in-vehicle travel time.

Traffic Assignment

- Consider the impact of AVs in roadway capacity

Trip Generation
Home-Based Trips

DATA

Technology adoption models (e.g. Bass Model)

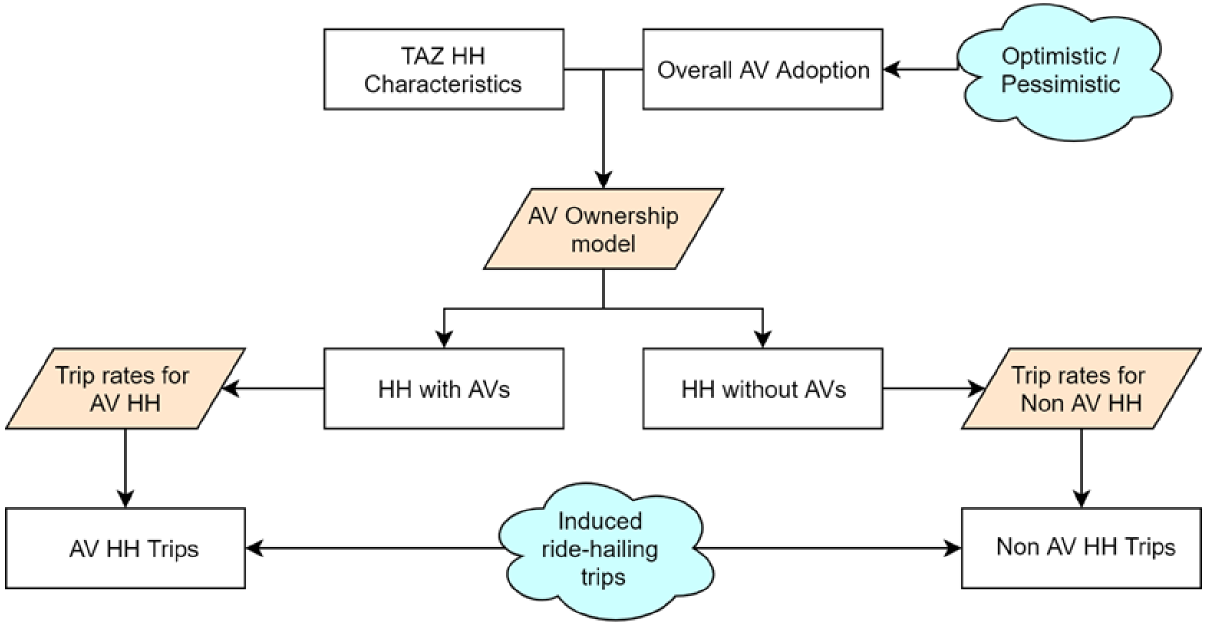
Survey in DFW area

Assumptions

- Overall AV adoption
- Fraction of induced ride-hailing trips
- Change in trip rates for AV HHs

Highlights

- Two HH categories
  - Non-AV HHs
  - AV HHs
- Additional trips due to existence of ride-hailing



Trip Distribution

DATA

Survey in DFW area

Assumptions

- Decreased sensitivity towards trip impedance for HH with AVs

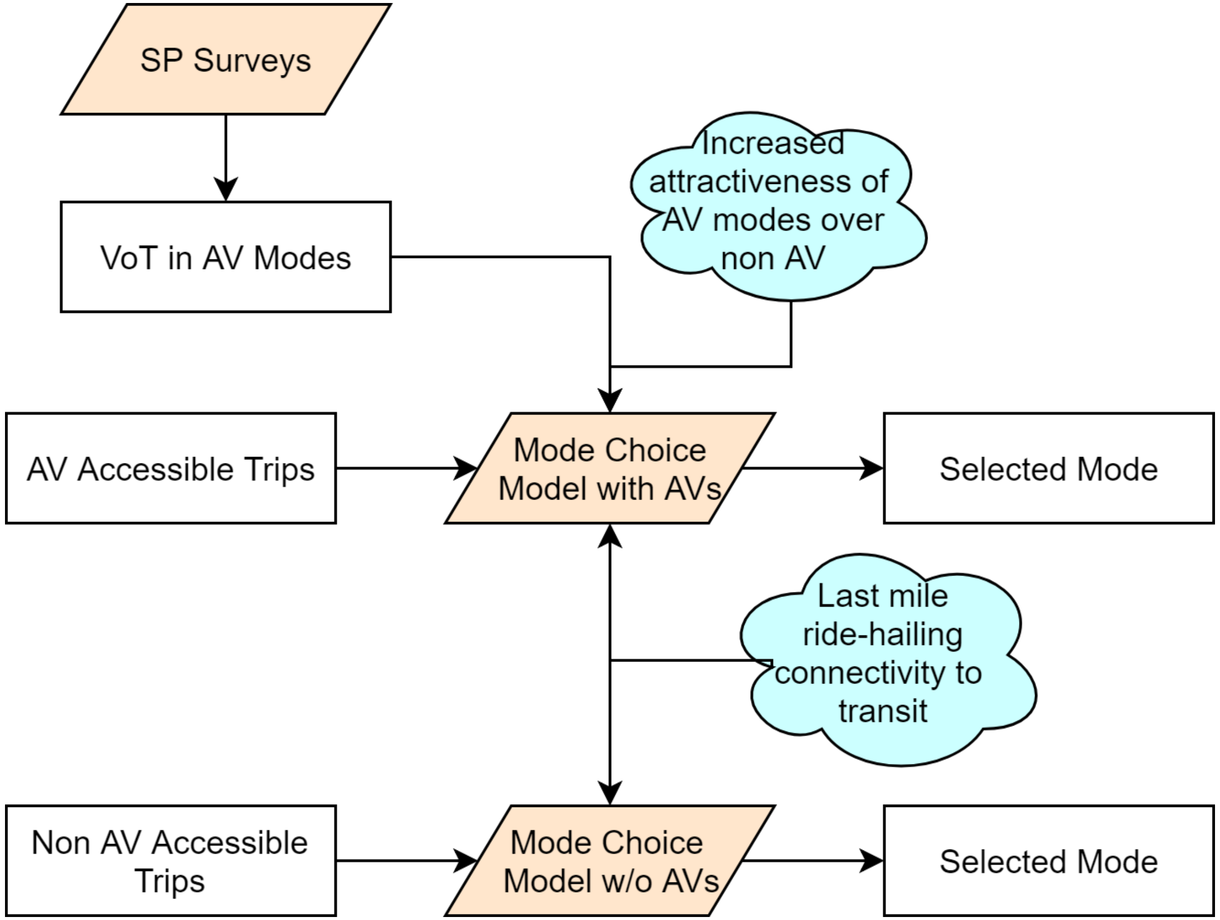
Highlights

- Two trip categories
  - Trips by HH w/o AVs (existing trip impedance sensitivity value)
  - Trips by HH with AVs (modified trip impedance sensitivity value)

COLLABORATE. INNOVATE. EDUCATE.

Mode Choice

- Ride-hailing is added to the choice set
- Drive+Transit alternatives have increased attractiveness due to the presence of ride-hailing
- For AV accessible trips
  - Modes involving drive have increased attractiveness
  - Sensitivity to IVTT is altered



Modification of value of IVTT

- Ratio of Value of IVTT in regular vehicle to value of IVTT in AV estimated from Dallas Survey

$$\gamma_{IVTT} = \frac{Value\ of\ IVTT\ NonAV\ DA}{Value\ of\ IVTT\ AV\ DA}$$

- Utilities for DA and Drive-Bus of HH without AV

$$U_{DA} = \beta_{DA} + \beta_{IVTT} IVTT_{DA} + \beta_{cost} Cost_{DA} + \cdots$$

$$U_{DriveBus} = \beta_{IVTT} IVTT_{Drive} + \beta_{IVTT} IVTT_{Bus} + \beta_{cost}(Cost_{Drive} + Cost_{bus}) + \cdots$$

Modification of value of IVTT

- Ratio of Value of IVTT in regular vehicle to value of IVTT in AV estimated from Dallas Survey

$$\gamma_{IVTT} = \frac{Value\ of\ IVTT\ NonAV\ DA}{Value\ of\ IVTT\ AV\ DA}$$

- Utilities for DA and Drive-Bus of HH with AV

$$U_{DA} = \boldsymbol{\beta_{DA}} + \frac{\beta_{IVTT}}{\boldsymbol{\gamma_{IVTT}}} IVTT_{DA} + \beta_{cost}\boldsymbol{Cost_{DA}} + \cdots$$

$$U_{DriveBus} = \frac{\beta_{IVTT}}{\boldsymbol{\gamma_{IVTT}}} IVTT_{Drive} + \beta_{IVTT} IVTT_{Bus} + \beta_{cost}(\boldsymbol{Cost_{Drive}} + Cost_{bus}) + \cdots$$

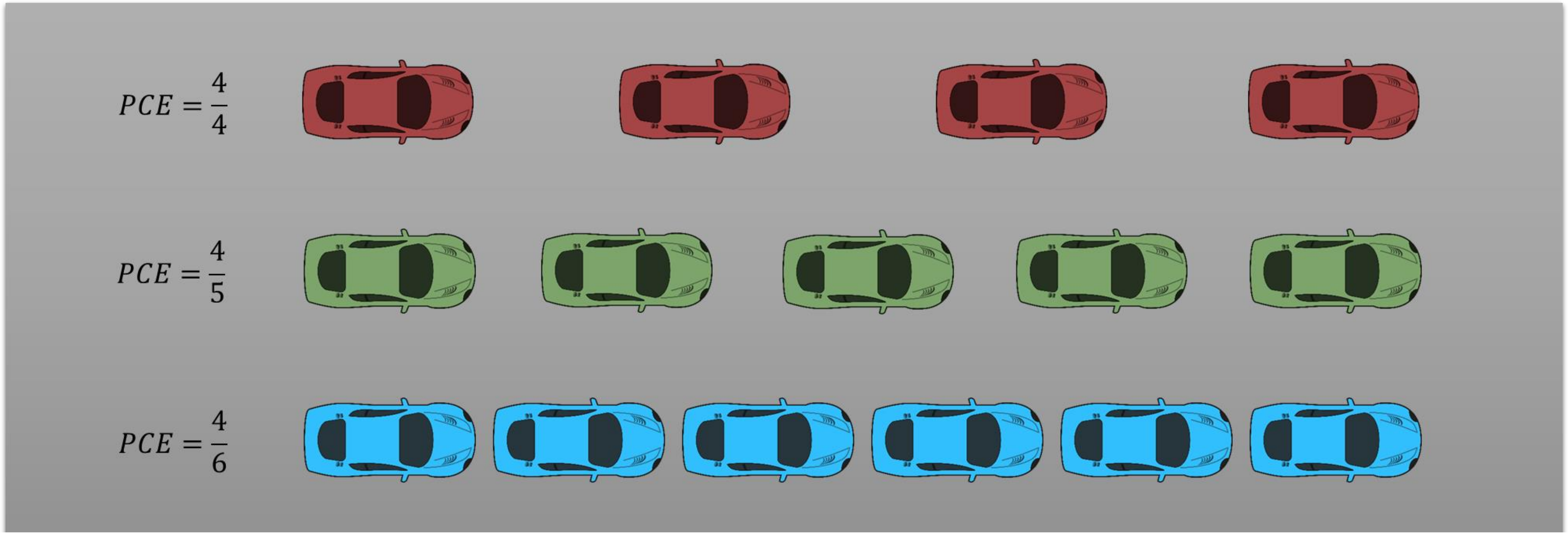
Traffic assignment

Assumptions

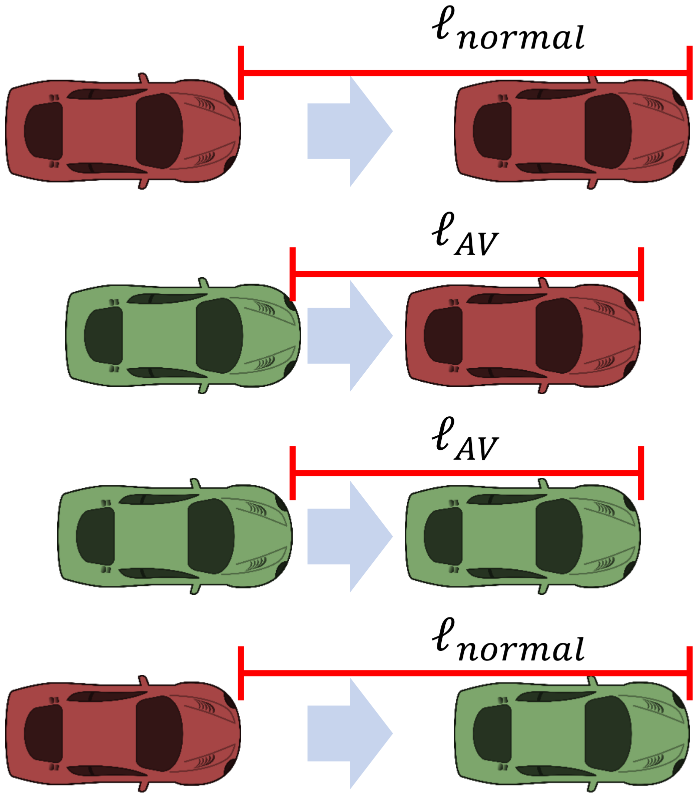
- Average Non-AV Passenger Car Equivalent for AVs

Highlights

- Using concept of Passenger Car Equivalent to model impact of AVs on capacity.
- Capacity impacts may vary across links depending on the corresponding number of AVs



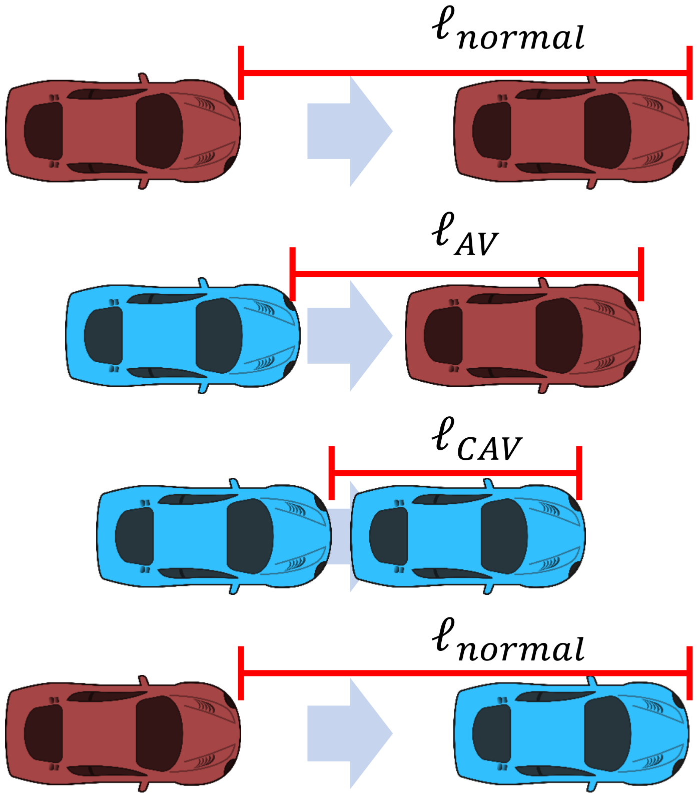
Mixed Traffic with AVs



Case	**Inter-vehicle spacing based on**
Non-AV following non-AV	Average human time distance
AV following non-AV	Sensing time, emergency deceleration of front vehicle and comfortable deceleration of AV
AV following AV	Same as above
Non-AV following AV	Average human time distance

Ref: Tientrakool et al. (2011)

Mixed Traffic with CAVs



Case	**Inter-vehicle spacing based on**
Non-AV following non-AV	Average human time distance
CAV following non-AV	Sensing time, emergency deceleration of front vehicle and comfortable deceleration of CAV
CAV following CAV	Communication-based shared deceleration
Non-AV following CAV	Average human time distance

Ref: Tientrakool et al. (2011)

Summary

- External overall AV adoption
- Household-level AV adoption based on DFW survey
- Modified trip rates for HHs with AVs
- Inclusion of induced trips due to ride-hailing
- Modified sensitivity towards trip impedance
- Ride-hailing added to choice set
- Increased attractiveness of drive-related modes for individuals with AVs
- Modified sensitivity towards IVTT
- Use of non-AV passenger car equivalent for AVs

Thank you!

Questions?

Contact: bhat@mail.utexas.edu