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

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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
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
- 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

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

DATA
- Technology adoption models (e.g. Bass Model)
- Survey in DFW area

Technology adoption models (e.g. Bass Model) → Overall AV Adoption → Optimistic / Pessimistic

Overall AV Adoption → AV Ownership model

AV Ownership model → TAZ HH Characteristics

TAZ HH Characteristics → Trip rates for AV HH

Trip rates for AV HH → AV HH Trips

Induced ride-hailing trips → Non AV HH Trips

Non AV HH Trips
Trip Distribution

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)

DATA
Survey in DFW area
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

\[ \gamma_{IVTT} = \frac{\text{Value of IVTT NonAV DA}}{\text{Value of IVTT AV DA}} \]

• 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

\[ \gamma_{IVTT} = \frac{\text{Value of IVTT NonAV DA}}{\text{Value of IVTT AV DA}} \]

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

\[ U_{DA} = \beta_{DA} + \frac{\beta_{IVTT}}{\gamma_{IVTT}} IVTT_{DA} + \beta_{cost} \text{Cost}_{DA} + \cdots \]

\[ U_{\text{DriveBus}} = \frac{\beta_{IVTT}}{\gamma_{IVTT}} IVTT_{\text{Drive}} + \beta_{IVTT} IVTT_{Bus} + \beta_{cost} (\text{Cost}_{\text{Drive}} + \text{Cost}_{bus}) + \cdots \]
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

\[
PCE = \frac{4}{4} \quad \text{(Red)}
\]

\[
PCE = \frac{4}{5} \quad \text{(Green)}
\]

\[
PCE = \frac{4}{6} \quad \text{(Blue)}
\]
Mixed Traffic with AVs

**Case**

- **Non-AV following non-AV**
- **AV following non-AV**
- **AV following AV**
- **Non-AV following AV**

**Inter-vehicle spacing based on**

- Average human time distance
- Sensing time, emergency deceleration of front vehicle and comfortable deceleration of AV
- Same as above
- Average human time distance

Ref: Tientrakool et al. (2011)
Mixed Traffic with CAVs

Case

Non-AV following non-AV

CAV following non-AV

CAV following CAV

Non-AV following CAV

Inter-vehicle spacing based on

Average human time distance

Sensing time, emergency deceleration of front vehicle and comfortable deceleration of CAV

Communication-based shared deceleration

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?

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