Data-Driven Network Modeling for Efficient Transportation

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A Growing Field: Transportation
Smart Cities
Challenge of Smart Cities

- Data Analytics
- IoT
- Control
- Networking
- Security
- Verification
- Design
- Policy
- Human Behavior
- Information Management
- Autonomy
- Networking
- Medical
- Material
- Automotive
- Energy
- Manufacturing
- Agriculture
- Aeronautics
- Civil
- Smart & Connected Communities
- Medical
- Material
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- Smart & Connected Communities
Data-Driven Decision Making

Data to Information
- Agent-based Modeling
- Applied Statistics
- Machine Learning

Minimize Cost or Maximize Profit
- Optimization
- Spatial Analytics

Information to Action
- Network Analytics
- Policy Inference

Intelligent Transportation Systems: integration research challenges unsolved

Growing complexity and dynamics: heterogeneity, uncertainty, scale, …
Domain: Transportation System

- Bar chart showing population growth from 1982 to 2014 for small, medium, large, and very large population groups.
- Images of a train and bicycle-sharing system.
- Scene of a traffic accident.
- Icons and symbols related to transportation and technology.
Casual Carpooling

- **Slugging**
  - Informal and flexible type of carpooling
  - Make use of High Occupancy Toll (HOT) lane and High Occupancy Vehicle (HOV) lanes

- Allow people to form one-time carpools in the morning and evening to **capitalize** on the benefits of HOV/HOT lanes and reduce their commute times

- Drivers pick up passengers at specific locations to **meet the occupancy requirement** or **avoid toll**

- **Free** to riders
Motivation

FHWA Project: Technological Enhancements to Improve and Expand Casual Carpooling in New Corridors

Demonstrate a working prototype of one or more tools and/or approaches that catalyze casual carpooling in a corridor
Problem and Goal

Identify potential corridor and station locations where casual carpooling can be a viable alternative for commuters

1. Casual carpooling demand estimation
2. Potential station selection

Challenges: uncertainty, scale
Matching Mechanism
Demand Estimation
Casual Carpooling

- Successful casual carpooling environment
  - Centralized activity center with a congested corridor leading to it
  - Presence of HOV/HOT lanes
  - Readily available, parallel, alternative modes of transportation
  - Parking at key interchanges along the corridor, easily accessible to commuters in suburban areas
  - Expensive or limited destination parking
  - Demand for casual carpooling

- Now Available in
  - Washington, D.C. metropolitan area
  - San Francisco
  - Houston
Methodology

• Agent-Based Modeling (ABM)
  ➢ Simulate complex system composed of decentralized individual agents
  ➢ Interaction between autonomous agents
  ➢ Interaction between agents and the environment
Methodology

Station selection
- Close to freeway
- Park-and-ride or transit station

Trip request generation
- Estimated future traffic demand between TAZs
- Trip request/ per minute is randomly generated
- Origin TAZ, pick-up station, drop-off station, destination TAZ

$\frac{1}{k+1} < r \leq \frac{2}{k+1}$

Autonomous casual carpooling matching
- Queuing process at each station
- First come first serve
- Probability of using three nearest stations
Casual Carpooling

- Washington, D.C. (I-95, I-66, I-270)

Choose a corridor that has the most potential for catalyzing casual carpooling
Casual Carpooling
Public Transportation System

Wasatch Front Region
UTA's Network

Location
Trip Origin → Bus Stop → Rail Station → Rail Station → Trip Destination

Trip Attribute
Access Walk → Wait Time → In-Vehicle Travel Time → Transfer Walk → Transfer Wait → Transfer Penalty → In-Vehicle Travel Time → Egress Walk

Transit Stops per TAZ
- 20 - 30
- 14 - 19
- 9 - 13
- 5 - 8
- 2 - 4
- 0 - 1

Light-Rail: Blue Line
Light-Rail: Red Line
Light-Rail: Green Line
Commuter-Rail: FrontRunner
BRT: 35 Max
Public Transit Performance Assessment

- First mile last mile problem in transit system
- Bus Rapid Transit (BRT) transit signal priority modeling
- Paratransit electrification
- Transit performance evaluation for operational efficiency and assess equity
- Transit accessibility/connectivity analysis
- Strategic planning for electric bus deployment
Public Transit Accessibility (PTA)

Transit Accessibility

- The ease of travel for an individual to reach a desired destination by public transport
- Helps transit agencies and planners identify areas in need of transit service improvements and prioritize transit investments

Challenges: heterogeneous data, scale

Measure transit accessibility
Underlying reason for transit inaccessibility

Missing temporal dimension -> only focus on specific time-of-day -> overly optimistic evaluation

Transit inaccessibility can be caused by inefficient services or geographical disadvantage.
Public Transit Accessibility (PTA)

- WATT as PTA Measure (weighted average travel time)
  \[ WATT_{i,t} = \frac{\sum_{j=1}^{J} O_j \cdot tt_{ij,t}}{\sum_{j=1}^{J} O_j}, \quad j = 1,2,\ldots,J, \quad i \in J \]
  - \( WATT_{i,t} \) is the weighted average travel time of stop \( i \) at departure time \( t \)
  - \( O_j \) is the number of opportunities available at stop \( j \)
  - \( tt_{ij,t} \) is the travel time from stop \( i \) to stop \( j \) at departure time \( t \)
  - \( J \) is the total number of stops

- WATT is of *Travel time* Nature
Public Transit Accessibility (PTA)

Temporal Fluctuation of PTA

- PTA for specific time-of-day (e.g. 8:00 AM)
- Ignoring the temporal fluctuation of PTA
- Biased results
- Solution: Travel Times for all ODs must be calculated for all times of day

Contributions:
Capture the dynamics of WATT
Identify the causes of poor PTA
Dynamic PTA Algorithm
Public Transit Accessibility (PTA)

Quality of service is affected by the probability of WATT for each random departure being closer to minimum as compared to maximum.

(a) Stop No. 11, AMWR = 1.0347

(b) Stop No. 5492, AMWR = 1.0379

(c) Stop No. 13123, AMWR = 0.9984

(d) Stop No. 22208, AMWR = 0.9923
Public Transit Accessibility (PTA)

- How to identify poor accessibility regions where transit service is inadequate?
Public Transit Accessibility (PTA)

- Transit Gap Caused by Poor Quality of Service:

**Need for Public Transit Improvement (NPTI):**

\[ PTAG_{TAZ_i} = WATT_{TAZ_i} \times \text{Norm}(NPTS_{TAZ_i}) \]

\[ NPTI_{TAZ_i} = \frac{PTAG_{TAZ_i}}{(AMWR_{TAZ_i})^n} \]
Freeway Performance Assessment

- Network (freeway & arterial) reliability modeling
- Non-recurrent congestion analysis

- Dynamic evolution of incident
- Convoluted impact of non-recurrent vs. recurrent congestions
Research Team

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Journal Publications Resulted from the Sponsored Research since 2013


Thanks!

Questions or Comments?

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