Multimodal Traffic Management:
- Monitoring Control
- Space Allocation
- Congestion Pricing
Modal Competition
Passenger mobility
Smart control

Multimodal Urban network

Space competition

Mode conflict

Parking limitation

Smart controls

Passenger measures
Multimodal networks

- Movement conflicts in multimodal urban traffic systems of shared space
- Transit stops affect the system like variable red signals in a single lane (instead of blocking all lanes)
- Increasing bus frequency decreases the flow of vehicles but can increase the flow of passengers.
- Monitoring congestion and developing more sustainable cities

Performance Measures
- Vehicle Hours Traveled
- Vehicle Kilometers Traveled
- Passenger Hours Traveled
- Passenger Kilometers Traveled

Mobility (Accessibility)
- Emissions (Environ. Impacts)
- Costs (Users, Providers, etc.)
- Road Space Used

MULTIMODAL CITIES
- Competing modes
- Parking
- Pax vs. veh throughput
Multimodal traffic flow characteristics and control
Bi-modal 3D MFD (car and bus)

Simulated data – Downtown SF, 400 links (signalized), 30 bus lines, frequency 3-20min
Contour plot
MFDs: vehicle vs. passenger

Simulated data – Downtown SF
Traffic management
Perimeter flow control

\[ \beta(t) = \hat{\beta} - K[n(t) - \hat{n}] \]
To think…

What types of traffic data do we need to monitor and control multimodal networks?

How could we obtain such data?
Space allocation policy for multimodal urban networks
People travel with different modes compete for limited urban space. We need to understand:
- How this space is used
- How it can be managed to improve
  - Accessibility
  - Sustainability
- Macroscopic methodology to model traffic with different modes
- How throughput of passengers depends on system characteristics
- How to allocate city space to different transportation modes
Infrastructure unequally available over a city

Queues form at locations with limited capacity, but spill-over to other locations.
Need not provide special lanes everywhere

Example
Streets for only buses in a dense urban network.

Provide bypasses for more efficient modes around much (if not all) congestion.
Multimodal multi-region system

\[
\frac{dn_{ij}}{dt} = q_{ij} - \sum_{k=1}^{N} q_{i \rightarrow k}^{j} + \sum_{k=1}^{N} q_{k \rightarrow i}^{j}
\]

\[
q_{i \rightarrow k}^{j} = \begin{cases} 
\min \left( x_{ik}^{*} \cdot a_{i \rightarrow k}^{j}, C_{ik} (n_{k}) \cdot a_{i \rightarrow k}^{j}, V_{i} (n_{i}) \cdot \frac{n_{ij}}{l_{ij}} \right), & \text{if } \delta_{i \rightarrow k}^{j} \neq 0, \\
0, & \text{otherwise.}
\end{cases}
\]
Congestion pricing schemes for urban networks
Concept

- Direct charge for road use (time, area, distance)
- Discourage use of vehicles (class, fuel, polluting)
- Revenue generation (infrastructure, public transport)
- Traffic management on externalities (travel time, emission, noise)
Basic principle

- Who use who pays
- Economic rationale
Basic principle

- Who use who pays
- Economic rationale
Types of pricing

- Variable lanes (HOV)
- Corridors/roadways
- Cordon pricing (Stockholm)
- Area pricing (London, Singapore)
To think...

Which type of pricing works better under each of the goals below?

- To reduce congestion in the CBD region?
- To reduce general congestion with fairer toll?
- To encourage high-occupancy pooling travel?
Real life case - London

- Area pricing
- Powerful transit system
- Congestion no better...
(Bad space reallocation)
Real life case - Stockholm

- Cordon pricing
- Wide acceptance
  - Traffic reduction
  - Reasonable prices
Real life case - Singapore

- Dynamic pricing
- Regular adjustment (v~[30 40km/h])
- High operation cost
Limited field implementation (low acceptance)

- Insufficient traffic reduction
- Costly to apply (operation, data)
- Insufficient effort on public transport
- Non-equitable policies and incentives
Sustainable pricing

- Applicable at city-level
- Capture congestion dynamics
- Control congestion efficiently
- Incentivize public transport

- MFD-based pricing
- Incentivize public transport
MFD-based pricing scheme
MFD-based pricing scheme

![Network production (vehs) vs. vehicle density (veh/km)]

- Estimated MFD

![Network density over time]

- $K_{cr}$
MFD-based pricing scheme
MFD-based pricing control

- Drivers adaptation
- Monitor $K_t$, Set $Toll_t$, Monitor, Adjust price ……

- Feedback-controlled dynamic pricing scheme

  $$Toll_t(n + 1) = Toll_t(n) + c(K_t(n) - K_{cr})$$

  - $n$ : the $n$-th price adjustment (e.g. every month)
  - $K_{cr}$ : control objective
  - $c$ : control gain parameter
MFD-based pricing control

- Drivers adaptation
- Monitor $K_t$, Set $Toll_t$, Monitor, Adjust price ……

- Feedback-controlled dynamic pricing scheme

\[Toll_t(n + 1) = Toll_t(n) + c(K_t(n) - K_{cr})\]

- $n$: the $n$-th price adjustment (e.g. every month)
- $K_{cr}$: control objective
- $c$: control gain parameter
Test environment: agent-based simulator MATSim

- Activity-based plan
- Complex utility
- User heterogeneity
- Behavioral adaptivity
- Made in Suisse
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Case study 1: Cordon Pricing in Zurich
Density reduction over toll adjusts

network density (veh/km)

K_cr

no pricing

intermediate

final pricing

2$

8$

time
Comparison of speed at 19pm

Before Pricing

After Pricing
To think...

what are the advantages of MFD-based pricing?

How to develop efficient pricing strategy?
Questions and discussions