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Transportation Modeling and Simulation

—— Some recent topics and a parking simulation

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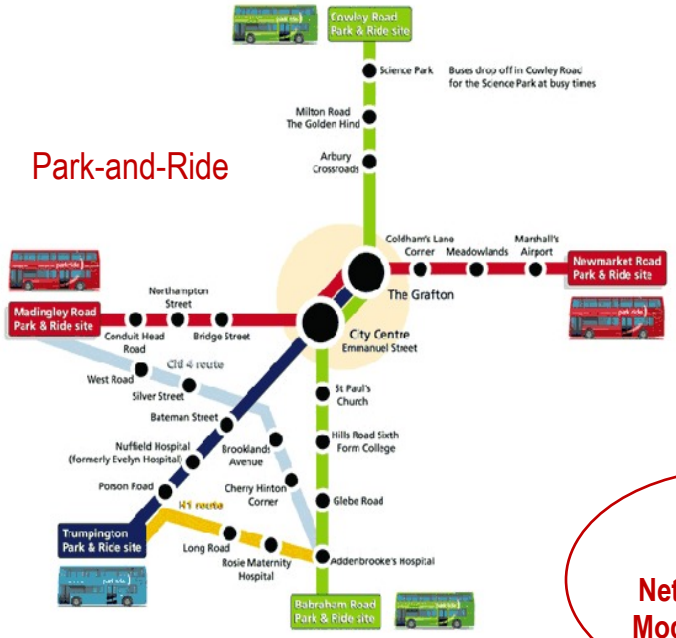
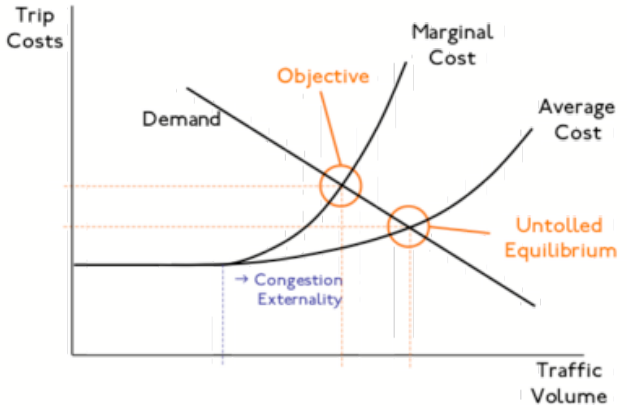
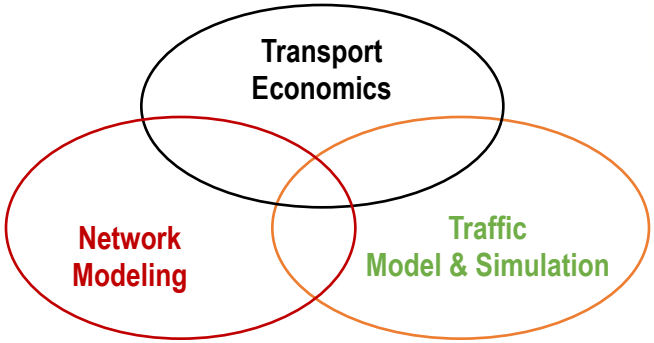
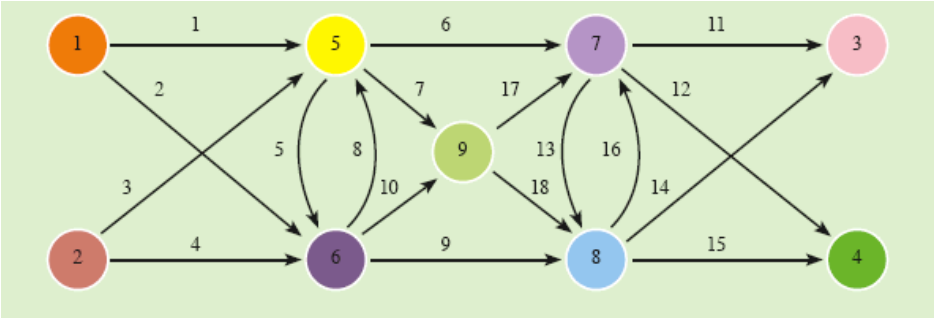
Research Interests

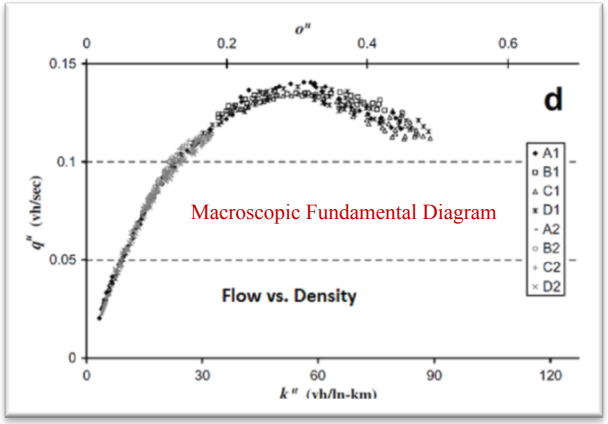
Park-and-Ride









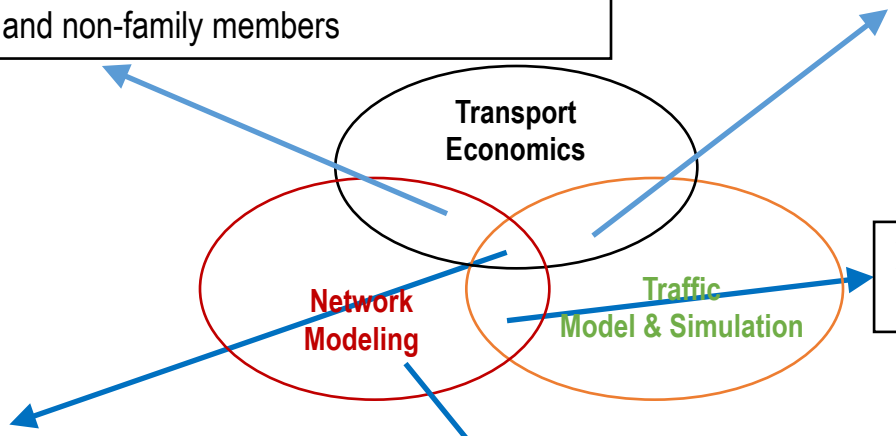


$$\sum_{a\in A}\left(t_a\left(v_a^{so}\right)+v_a^{so}t'_a\left(v_a^{so}\right)\right)\left(v_a-v_a^{so}\right)-\sum_{w\in W}B_w\left(d_w^{so}\right)\left(d_w-d_w^{so}\right)\geq 0,\qquad \forall(d,f,v)\in\Omega$$

Transportation Modeling and Simulation

- ✓ Morning Commute Problem with Parking Space Constraints
- ✓ Expirable Parking Reservation for Managing Traffic
- ✓ Hybrid Scheme of Plate Number based Rationing and Pricing
- ✓ Ride-sharing of family and non-family members

- ✓ Cruising-for-parking Reshapes Morning Commute
- ✓ Variable Speed Limits for Reducing Capacity Drop in the Context of Moring Commute



- ➢ Parking information provision, parking search and parking lot assignment

- ➢ Modeling and managing evolution of traffic dynamics from day to day
- ➢ Modeling traffic evolution with information provision where information updates over time

- ➢ Fleet Management for Planning and Operation of Autonomous Vehicles
- ➢ Emission Pricing, Pricing Zone Topology, and EV Charging Location
- ➢ Planning of charging lanes and stations in transportation system
- ➢ Modeling and Optimizing High-speed Railway Operations

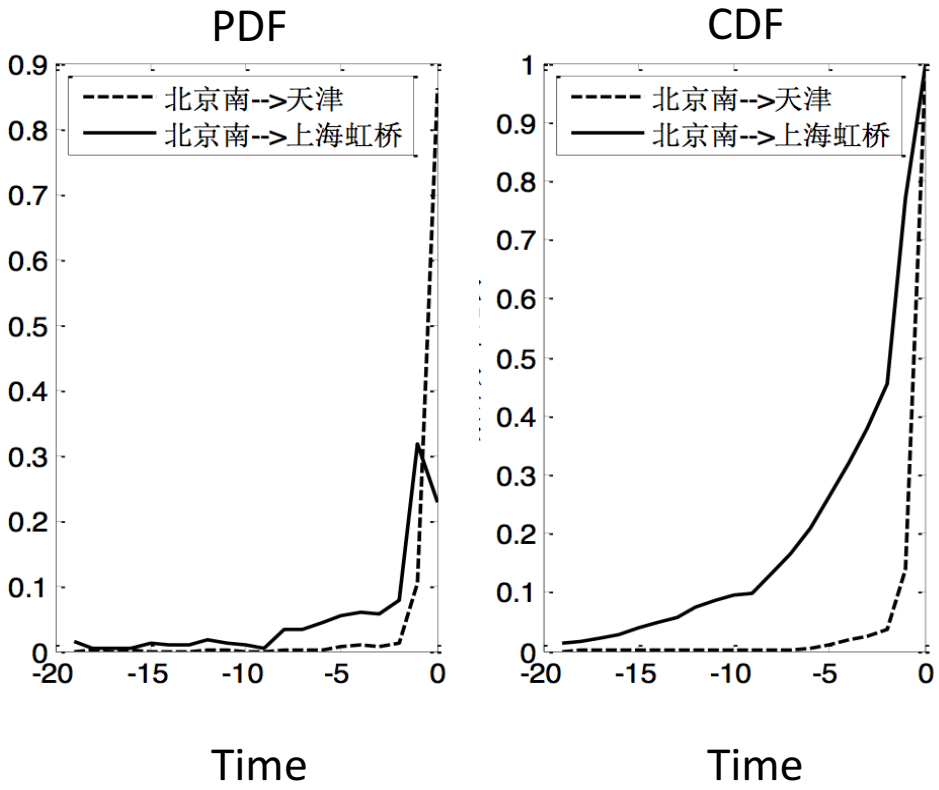
Transportation Modeling and Simulation

- Selected Recent topics
  - ✓ High-speed Railway Operation
  - ✓ Dynamics of Dynamics
  - ✓ Emission and Electric Vehicles
- Parking Modeling and Simulation
  - ✓ Overview
  - ✓ A Simulation Example

High-speed Railway Operation

❑ Modeling and Optimizing High-speed Railway Operations

- For given scheduling and seat-allocation scheme, to model and analyse choices of passengers and patterns of traffic in HSR system when considering ticket booking time choice.
- To optimally design the joint scheme of scheduling and seat allocation to maximize the revenue or consumers' surplus, or to achieve Pareto frontier of multi-objective problem.



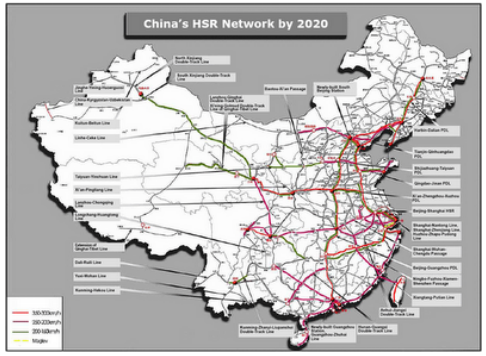
Trade-off: flexibility and risk of losing option

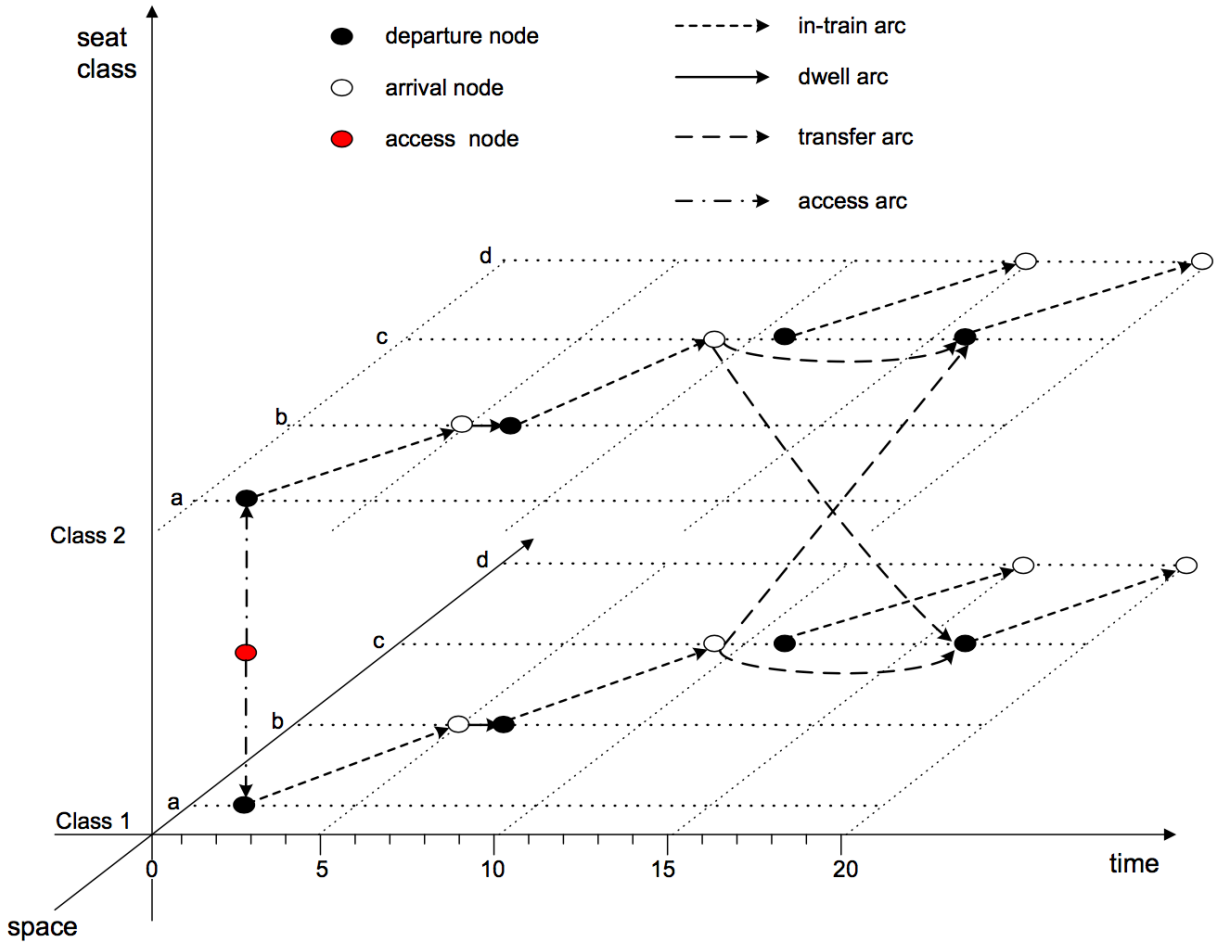
High-speed Railway Operation

❑ Modeling and Optimizing High-speed Railway Operations

A **three-dimensional network** of time, space, and seat class based on schedule is constructed.

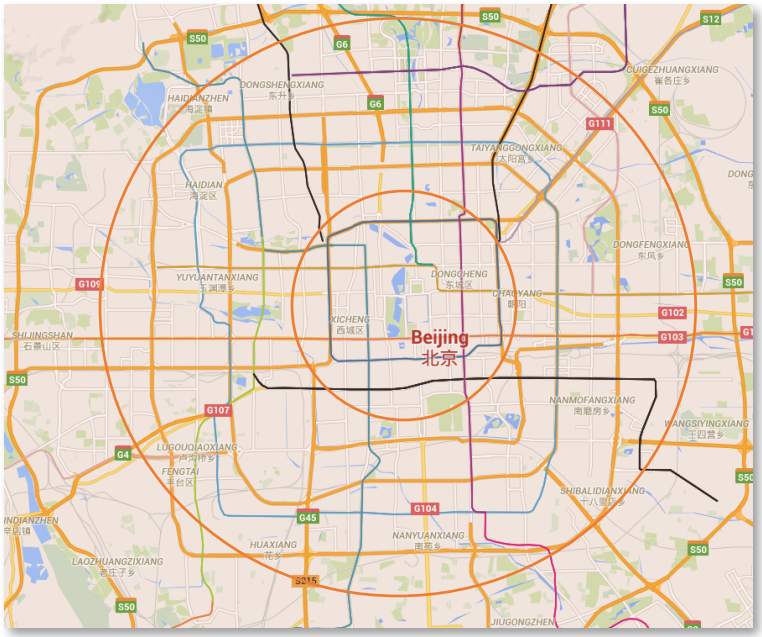
Large-scale network: e.g., as of September 2016 over 20,000 km of route in service



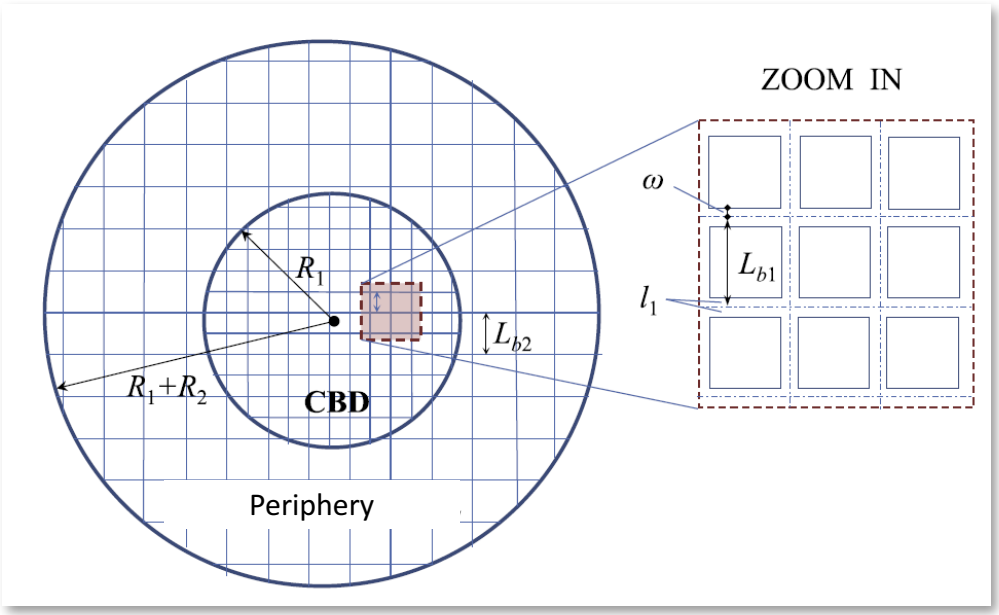


Evolution of Traffic Dynamics

- **Modeling and managing evolution of traffic dynamics in a day-to-day context**
  - Multi-modal transportation system
  - Modeling of traffic dynamics based **large-scale traffic models**



Example of real network: Beijing



Multi-modal network with time- and space- dependent demand

Why area-based models?

Evolution of Traffic Dynamics

- Part I: Given the *spatiotemporal demand*:
  - planning of park-and-ride facilities at CBD boundary
  - optimizing the public transit service
  - optimizing the congestion pricing in CBD

→

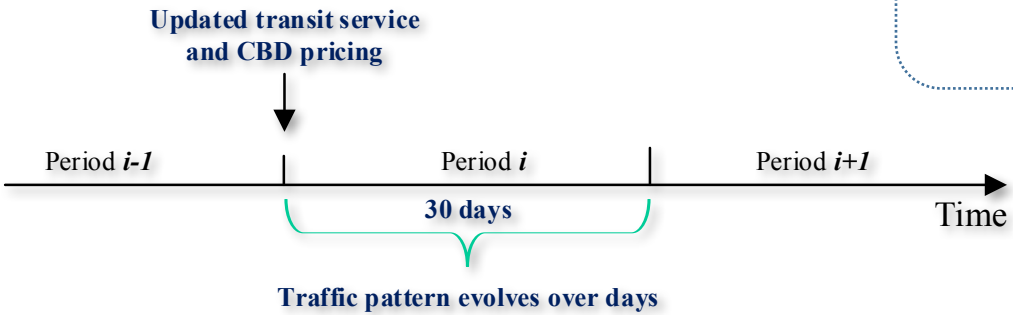
- Different objectives:
  - Reduce traffic congestion
  - Reduce travel cost of users
  - Reduce social cost including user costs and transit operating cost

- Part II: Day-to-day traffic evolution:
  - Travelers
    - learn from **day-to-day experience**
    - have access to **time-dependent traffic information**
    - **update modal choices** from day-to-day

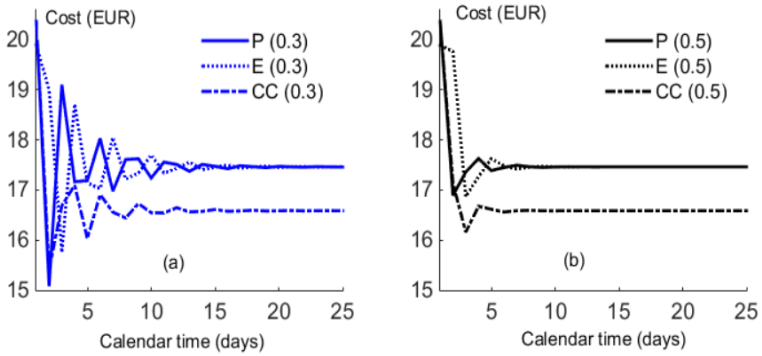
→

$$c_i^{p,m+1}(x_1,x_2,t) = (\omega \cdot c_i^{p,m}(x_1,x_2,t) + (1-\omega)\cdot c_i^{e,m}(x_1,x_2,t)) + \rho\cdot(c_i^{m+1}(x_1,x_2,t) - c_i^{m}(x_1,x_2,t))$$

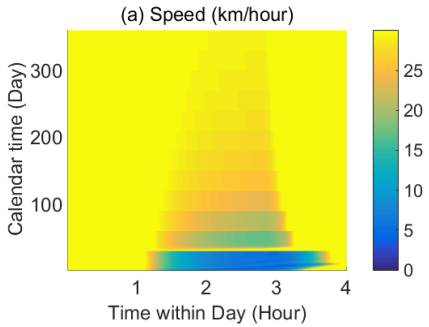
Prediction | Experience | Current information



Day-to-day example



System Planner/Operator: optimize transit service and/or congestion pricing from period to period



Emission and Electric Vehicles

❑ Emission Pricing, Pricing Zone Topology, and EV Charging Location

- **network traffic pattern with multi-type vehicles**
  - diesel vehicle
  - battery-only electric vehicle
  - plug-in hybrid electric vehicle

  different travel choices in the network and are priced differently;

- **optimize the joint design of**
  - emission pricing
  - cordon topology for pricing
  - public charging station deployment

- explore the evolution of the travel choices of multi-type vehicles over the time horizon and propose a period-to-period adaptive emission pricing scheme

Emission and Electric Vehicles

❑ Planning of charging lanes and stations in transportation system

- ➢ Decisions: Quantity, Efficiency, Locations, Pricing
- Lanes (e.g., more costly, save delays, promote EVs)
- Stations (e.g., less costly, more delays)

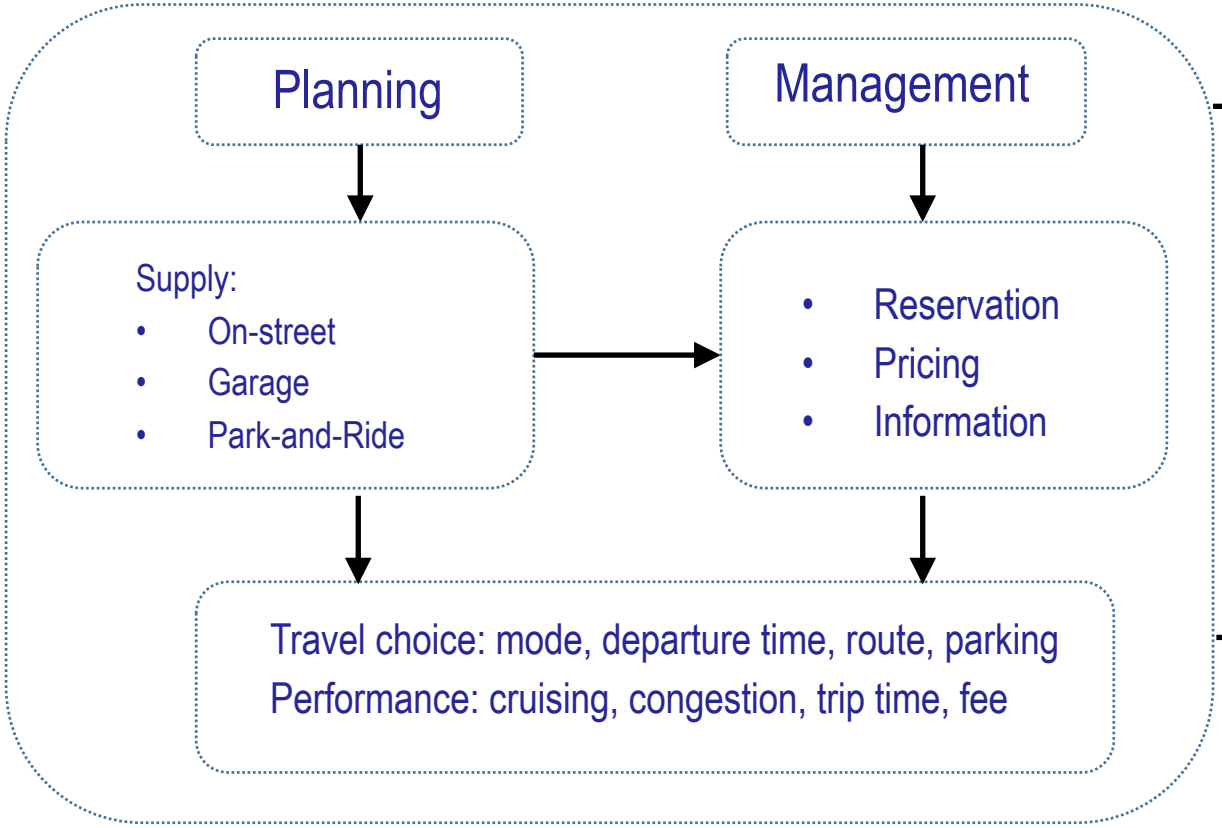
- ➢ **Different objectives**:
- System planner (minimize social cost, e.g., travel time, emissions, oil consumption; maintain break-even)
- Private Operators (maximize profits subject to regulation)

South Korea & UK

- ➢ Elastic Demand of EVs and charging facilities
- ➢ Traffic assignment: consider charging options
- ➢ Heterogeneous population

Parking Modeling and Simulation

❑ Parking is an important part of urban transportation systems



Modeling

- Reservation: Yang et al. (2013), Liu et al. (2014b,c; 2016)
- Park-and-ride: Liu et al. (2014a), Liu and Geroliminis (2016b)
- Pricing: Liu and Geroliminis (2016a,b)

Simulation

Liu, W., Lamotte, R., Waraich, R., Geroliminis, N. (2016) Evaluating Parking Information Provision and Optimizing Parking Pricing in an Agent-based Environment.

Liu, W., Geroliminis, N. (2016b) Dynamics of Dynamics for Multi-modal Networks with Park-and-ride and Adaptive Pricing. Transportation Research Part B.

Liu, W., Geroliminis, N. (2016a) Modeling the Morning Commute for Urban Networks with Cruising-for-parking: an MFD Approach. Transportation Research Part B.

Liu, W., Zhang, F., Yang, H. (2016) Managing Morning Commute with Parking Space Constraints in the Case of Bi-modal Many-to-One Network. Transportmetrica A.

Liu, W., Yang, H., Yin, Y., Zhang, F. (2014c) A Novel Permit Scheme for Managing Parking Competition and Bottleneck Congestion. Transportation Research Part C.

Liu, W., Yang, H., Yin, Y. (2014b) Expirable Parking Reservations for Managing Morning Commute with Parking Space Constraints. Transportation Research Part C.

Liu, W., Yang, H., Yin, Y. (2014a) Traffic Rationing and Pricing in a Linear Monocentric City. Journal of Advanced Transportation.

Yang, H., Liu, W., Wang, X., Zhang, X. (2013) On the Morning Commute Problem with Bottleneck Congestion and Parking Space Constraints. Transportation Research Part B.

Parking Modeling and Simulation

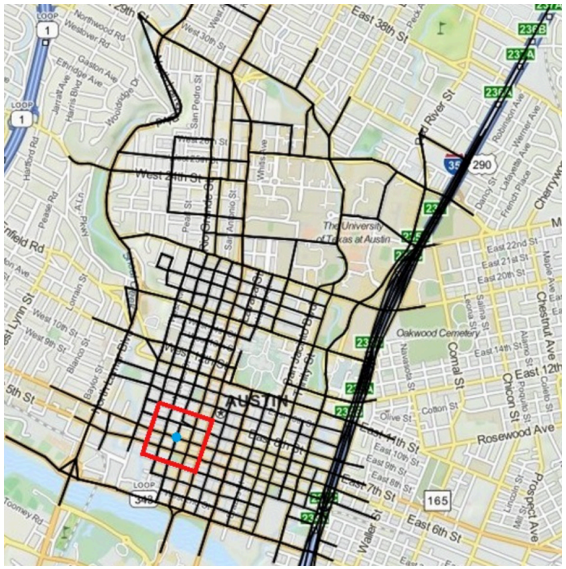
❑ Parking is an important part of urban transportation systems

To examine and manage cruising for curbside parking of travelers in the city center

- **Information provision:**
  - Belief-updating: prior knowledge/belief about the zonal parking availability over the network, and update their knowledge/belief over time and space based on their observations
  - Area full-knowledge: real-time information regarding zonal parking availability is provided to users
- **Parking pricing:**
  - Static pricing (under belief-updating)
  - time-dependent parking pricing (under belief-updating)
- **Reservation:**
  - Centralized reservation system
  - Decentralized system based on V2I

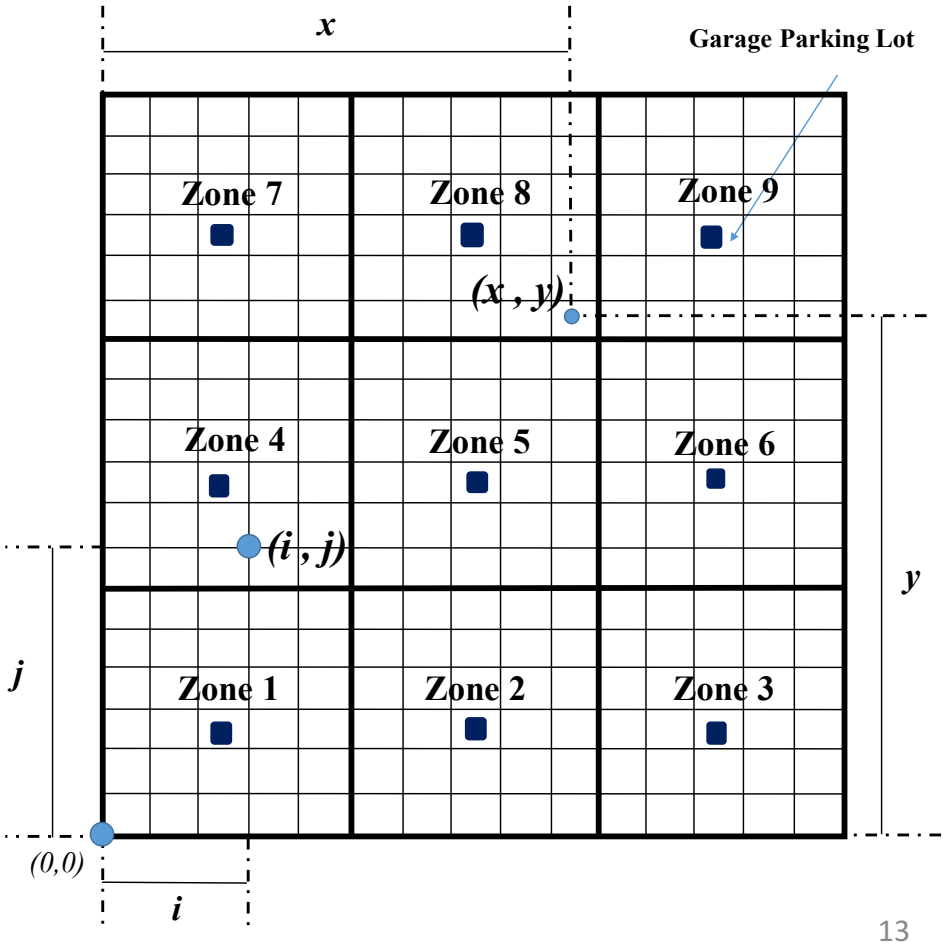
Parking Modeling and Simulation

- **Parking is an important part of urban transportation systems**



Grid network example:
Downtown Austin

Parking Network in City center



Parking Modeling and Simulation

- **Parking is an important part of urban transportation systems**

Utility-based Individual Decision Making:

$$u_{i,n}^{j} = \rho_m \times mt_{i,n}^{j} + \rho_c \times ct_{i,n}^{j} + \rho_w \times wt_{i,n}^{j} + \rho_l \times lateness_{i,n}^{j} + \rho_f \times pf_{i,n}^{j}$$

where $u_{i,n}^{j}$ is the disutility estimate (expected) of traveler i for parking his or her car at type j parking at zone n.

Concern:

- Driving Time cost
- Walking Time cost
- Parking fee cost
- Lateness cost

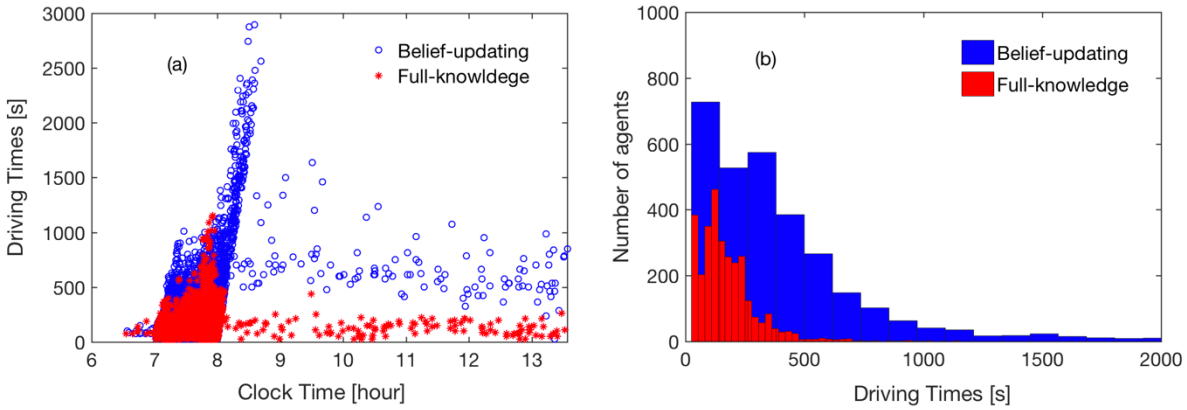
Estimate affects choice ↓ ↑ Choice affects actual cost

Decision:

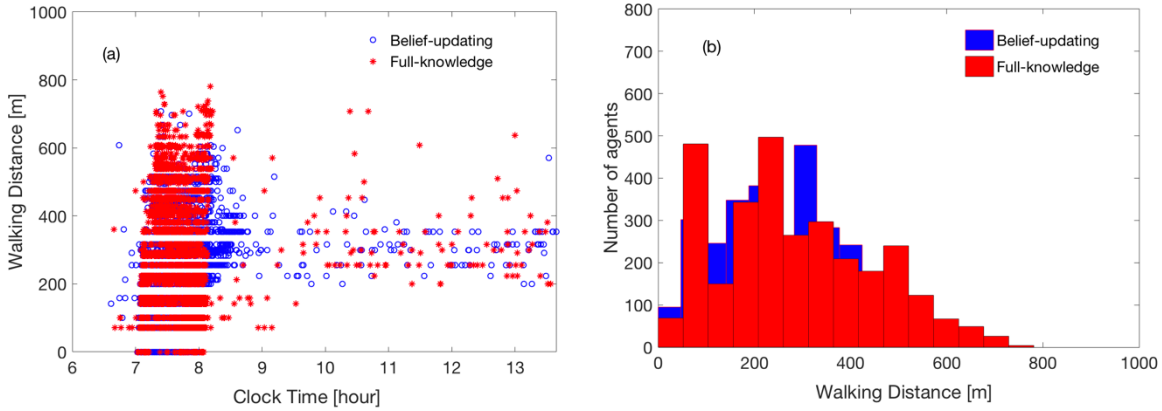
- Change parking type: on-street vs. garage
- Change parking zone: destination zone or surrounding areas

Parking Modeling and Simulation

❑ Belief-updating vs. Full-knowledge

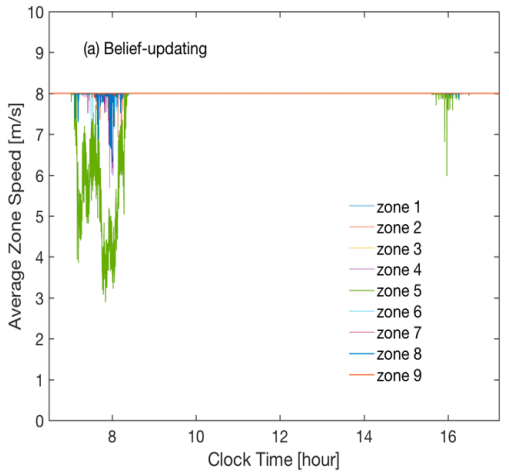


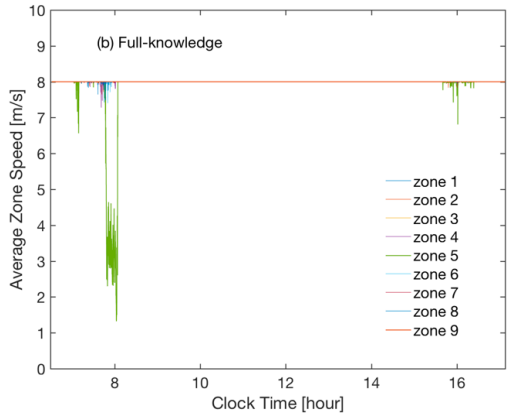
Driving time of travelers: (a) arrival time based; (b) histogram



Walking distance of travelers: (a) arrival time based; (b) histogram

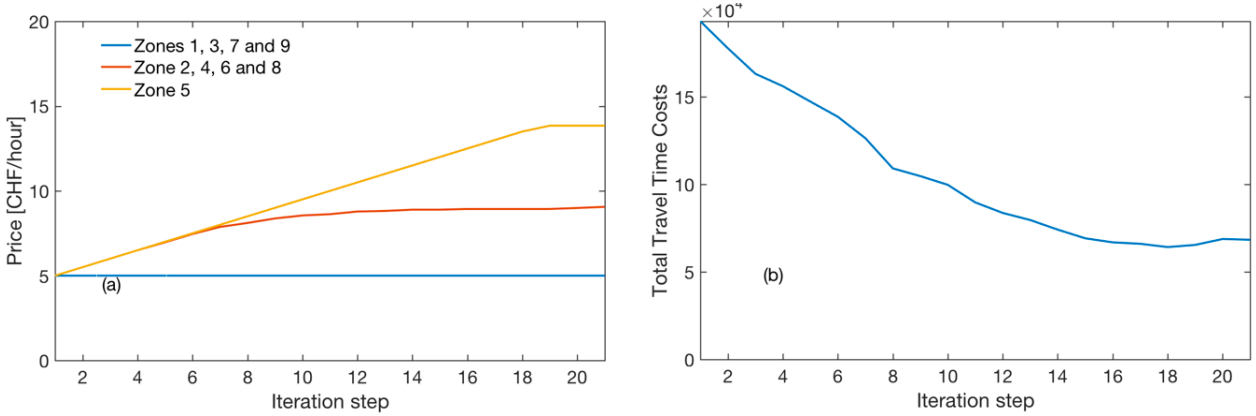
Parking occupancy for typical zones: (a) garage parking; (b) on-street parking





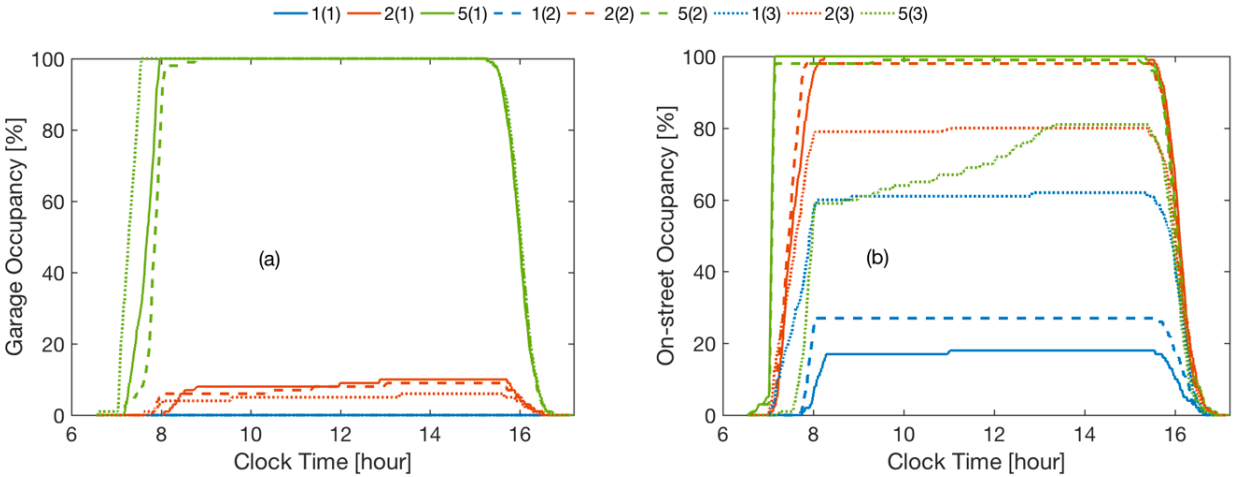
Parking Modeling and Simulation

- **Belief-updating vs. Full-knowledge vs. Pricing**



Prices and travel time disutility over iterations (simulation-based optimization)

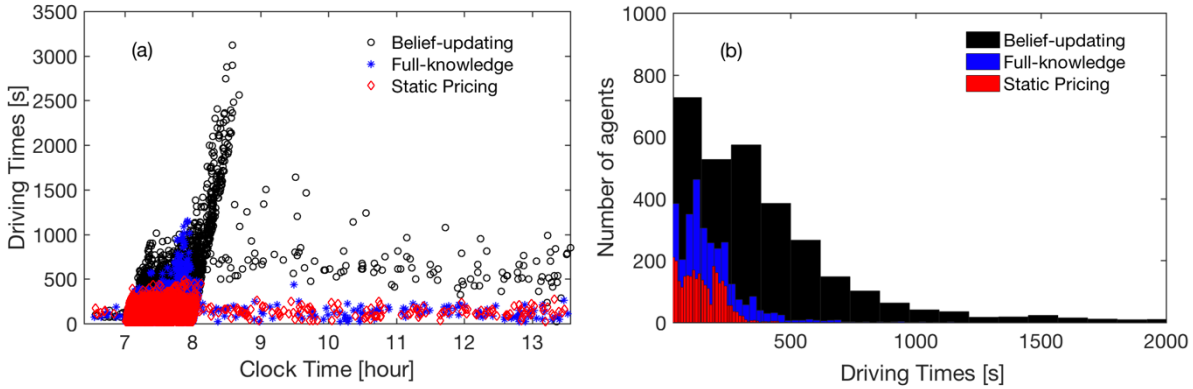
$$price_h^{\eta+1} = price_h^{\eta} + \max\{0, \max\{occupancy_h^{\eta}\} - occupancy_{cri}\} \times price_{coe}.$$



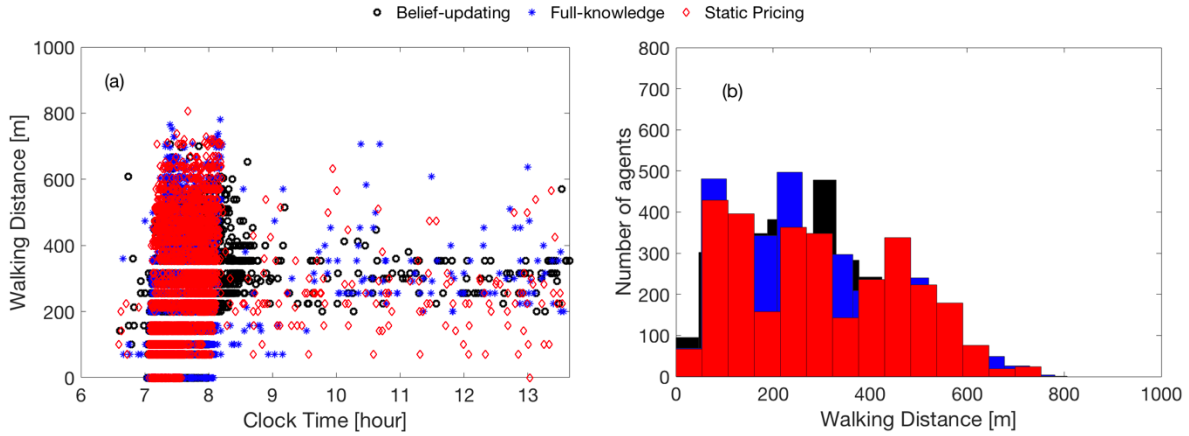
Parking occupancy for typical zones: (a) garage parking; (b) on-street parking

Parking Modeling and Simulation

❑ Belief-updating vs. Full-knowledge vs. Pricing



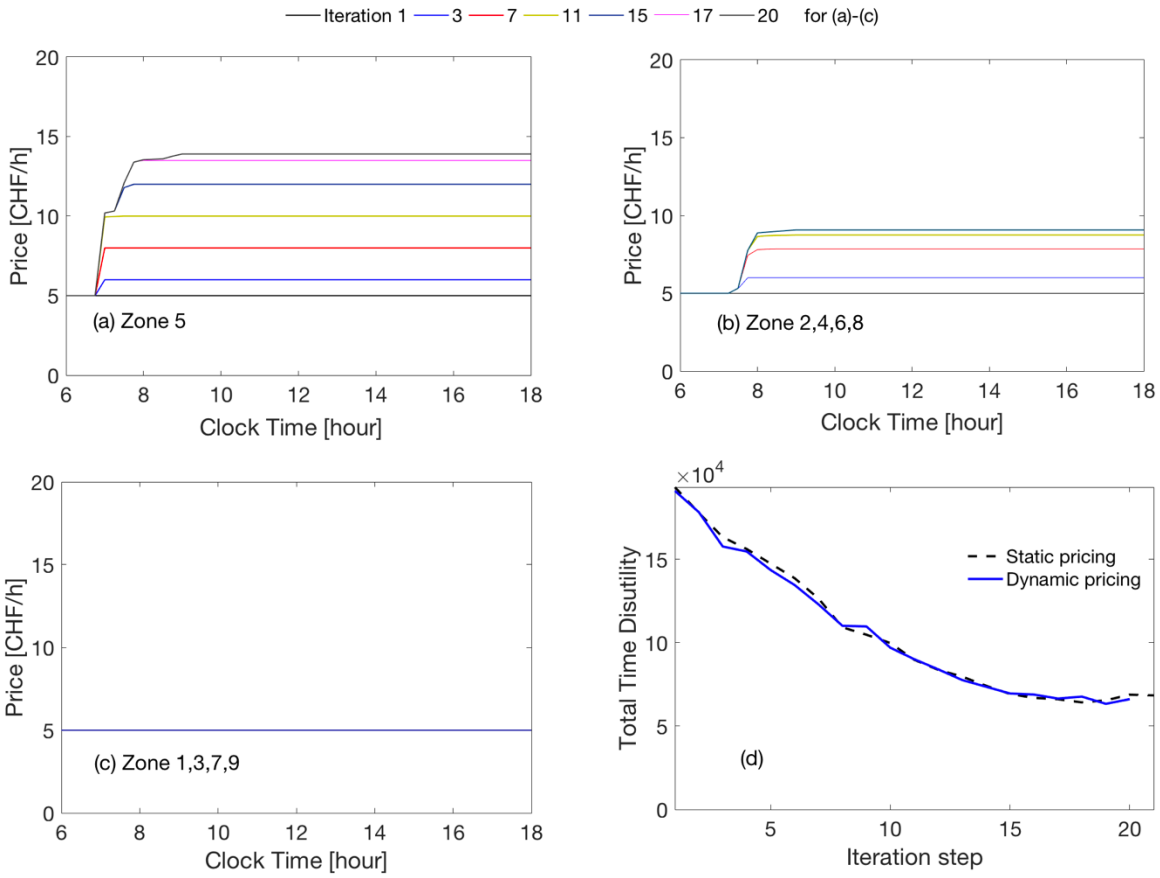
Driving time of travelers: (a) arrival time based; (b) histogram



Walking distance of travelers: (a) arrival time based; (b) histogram

Parking Modeling and Simulation

❑ Dynamic Pricing



Time-dependent pricing at different iterations: (a) price for zone 5; (b) price for zone 2, 4, 6, 8; (c) price for zone 1, 3, 7, 9; (d) travel time disutility

Parking Modeling and Simulation

❑ Reservation System

- Centralized reservation system
- Decentralized system based on V2I
  - Performance depends on penetration
  - Different effects on equipped and non-equipped users

Summary

- Examine behaviors of cruising for curbside parking of travelers in the city center
- Test and compare performances of all the following;
  - Information provision
  - Parking pricing
  - Reservation
- To propose optimization strategy for very detailed simulation

Thank you!

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