Optimal Dynamic Curbside Zoning

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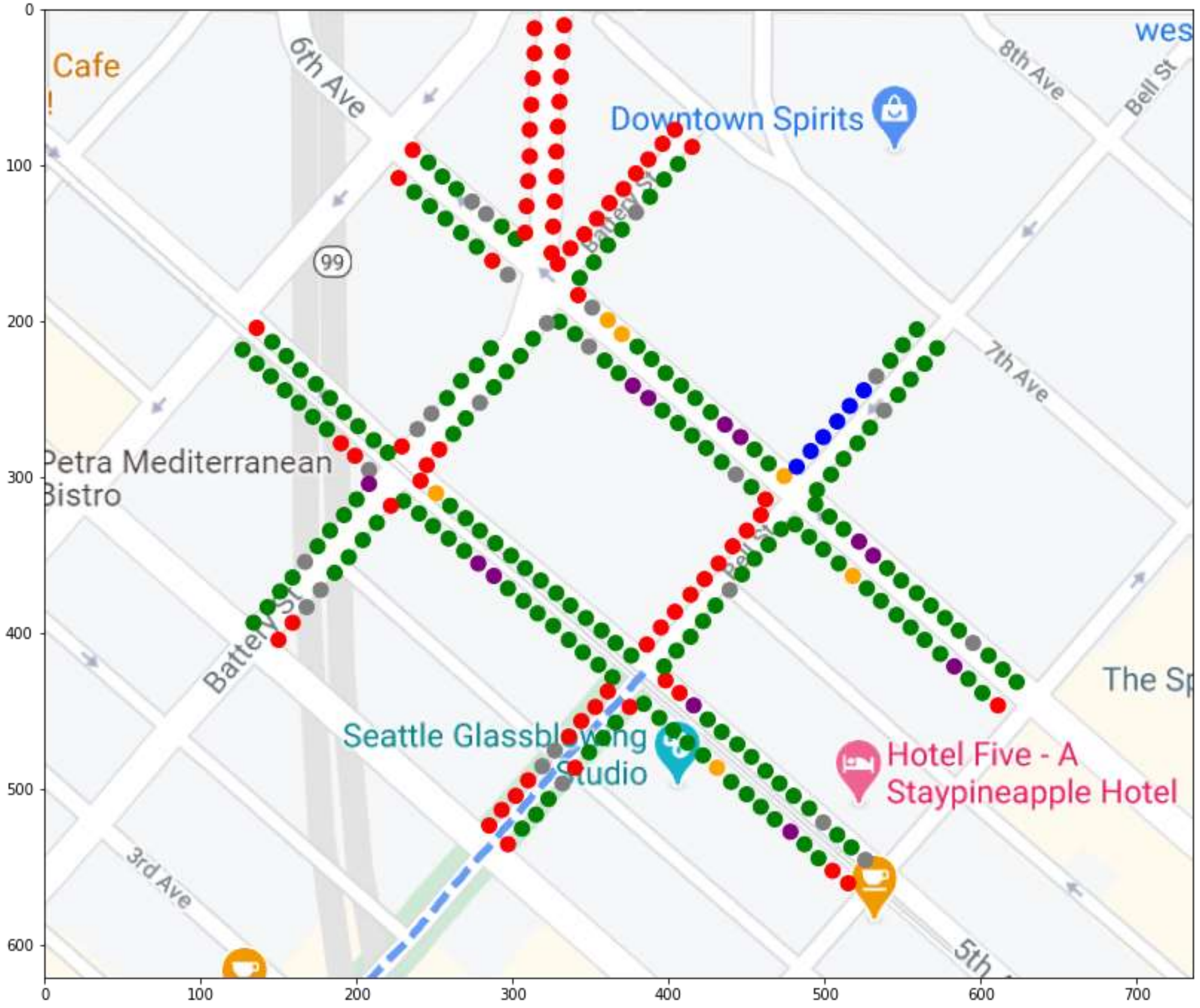
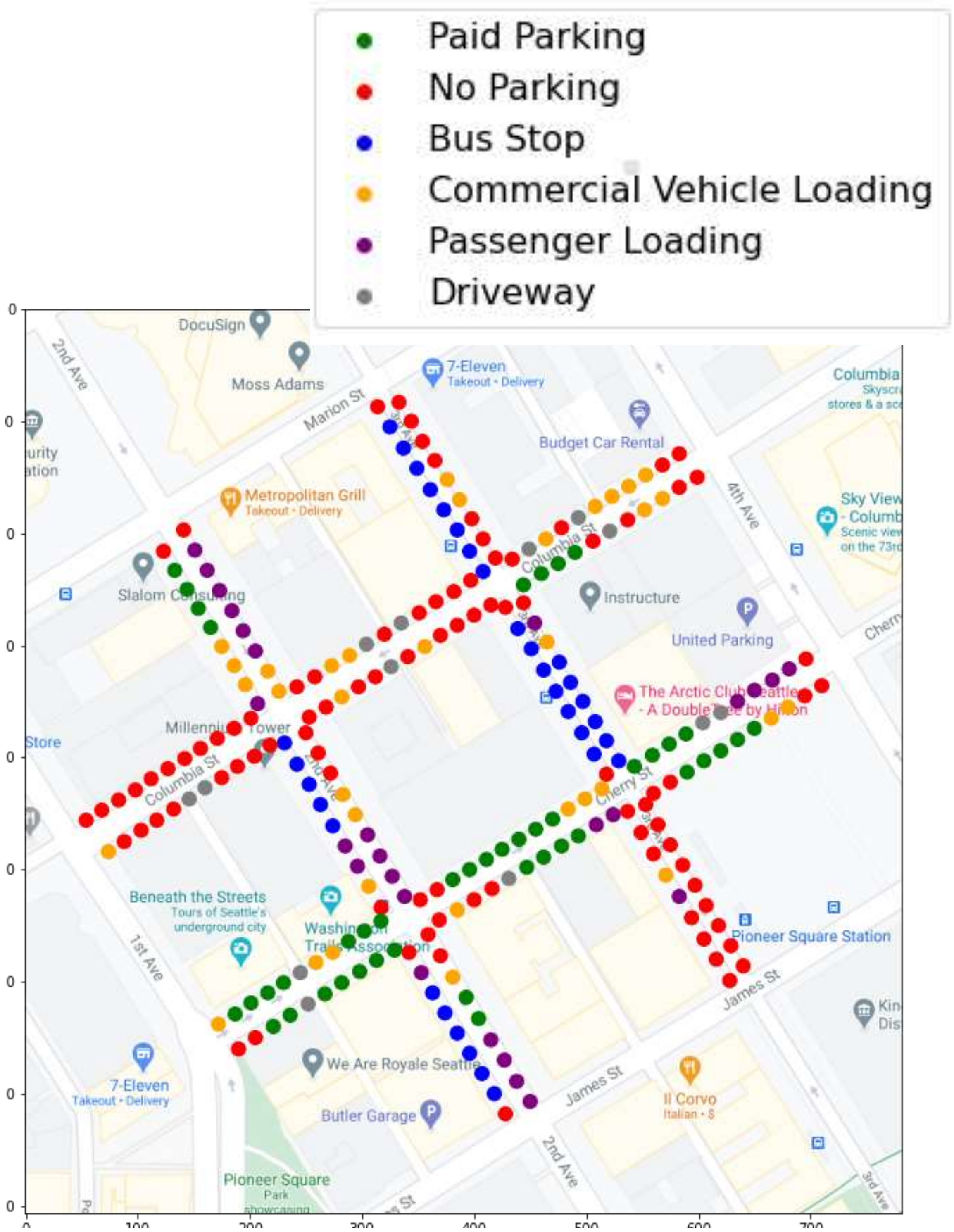
Overview

- What is the curb zoning problem?
- How do we value curb space?
- Centralized dynamic curb zoning via ADP
- Decentralized curb zoning via auctioning
- Related work

Static Curb Zoning





Dynamic Curb Zoning

- Curb zone use changes over time as function of demand pressures
  - Rush hour traffic
  - Stadium events
  - Street festivals/parades/markets
- With a more connected city, can the interfacing layer between the transportation system and destination/point of departure be more responsive to changing demand?

Curb Space Valuation

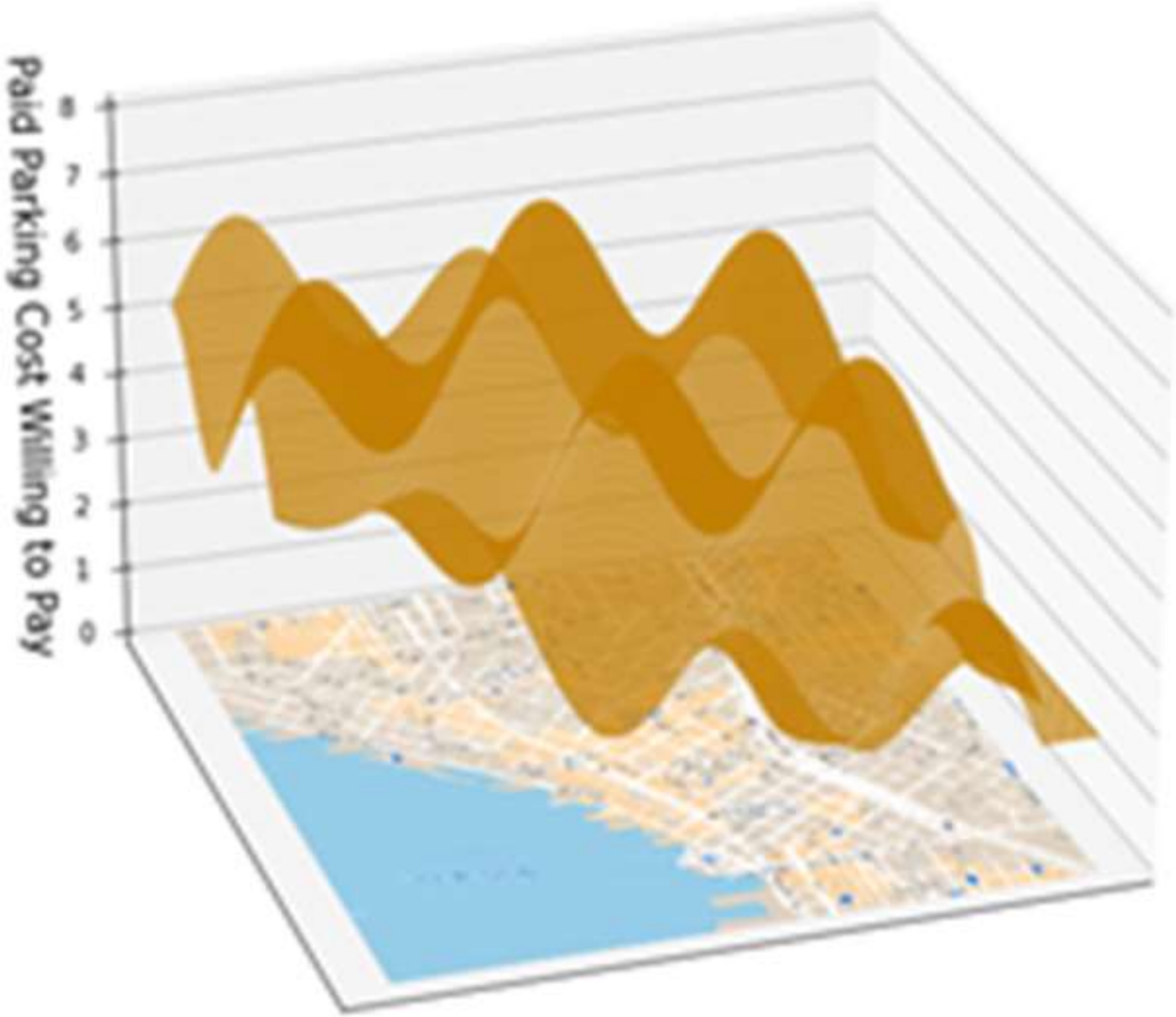
To optimize zoning, an objective function is required, mapping zone type to some value

- Curb owner revenue
- Cost of emissions
- Goods/people moved
- Accessibility

- Cost of congestion
- Value of time cost due to distance from desired destination

Dowling, Henao, et al. “Turning curb data into curb policy via a bid-rent framework” TRB Jan 2022 (to appear)

Curb Space Valuation



Problem Formulation

Curb valuation/objective **Distance regularizer**

$$\text{maximize} \quad \sum_{j=1}^{N} \sum_{t=1}^{T} \boxed{F_t(u_{t,c_j}, c_j)} + \boxed{\rho \sum_{i=1}^{M} \sum_{t=1}^{T} w_{t,i}}$$

$$\text{subject to} \quad \boxed{\sum_{t=1}^{T-1} \frac{1}{2} ||u_{t+1,c_j} - u_{t,c_j}||_1 \leq b \ \forall j}$$

Switching constraint

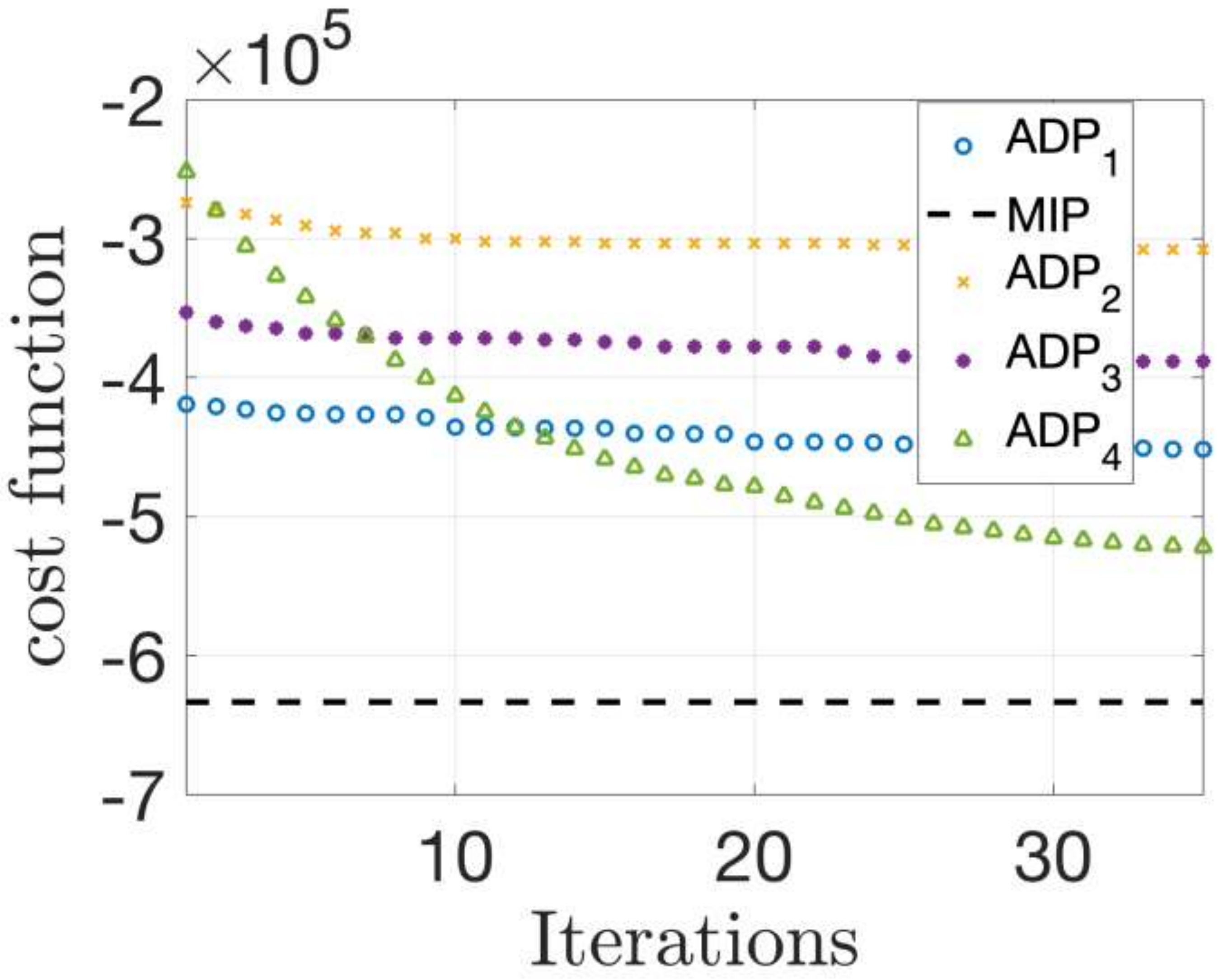
$$\boxed{\begin{aligned} &\sum_{j=1}^{N} 1\left[u_j = u_{type}\right] \leq \bar{u}_{type} \forall t \\ &\sum_{j=1}^{N} 1\left[u_j = u_{type}\right] \geq \bar{u}_{type} \forall t \end{aligned}}$$

Cardinality constraints

$$w_{t,i} \leq u_t^{(i)\top} A_{\mathrm{m}} u_t^{(i)} \qquad \forall t \in \mathcal{T}, i \in \mathcal{M}$$

Approximation Dynamic Programming

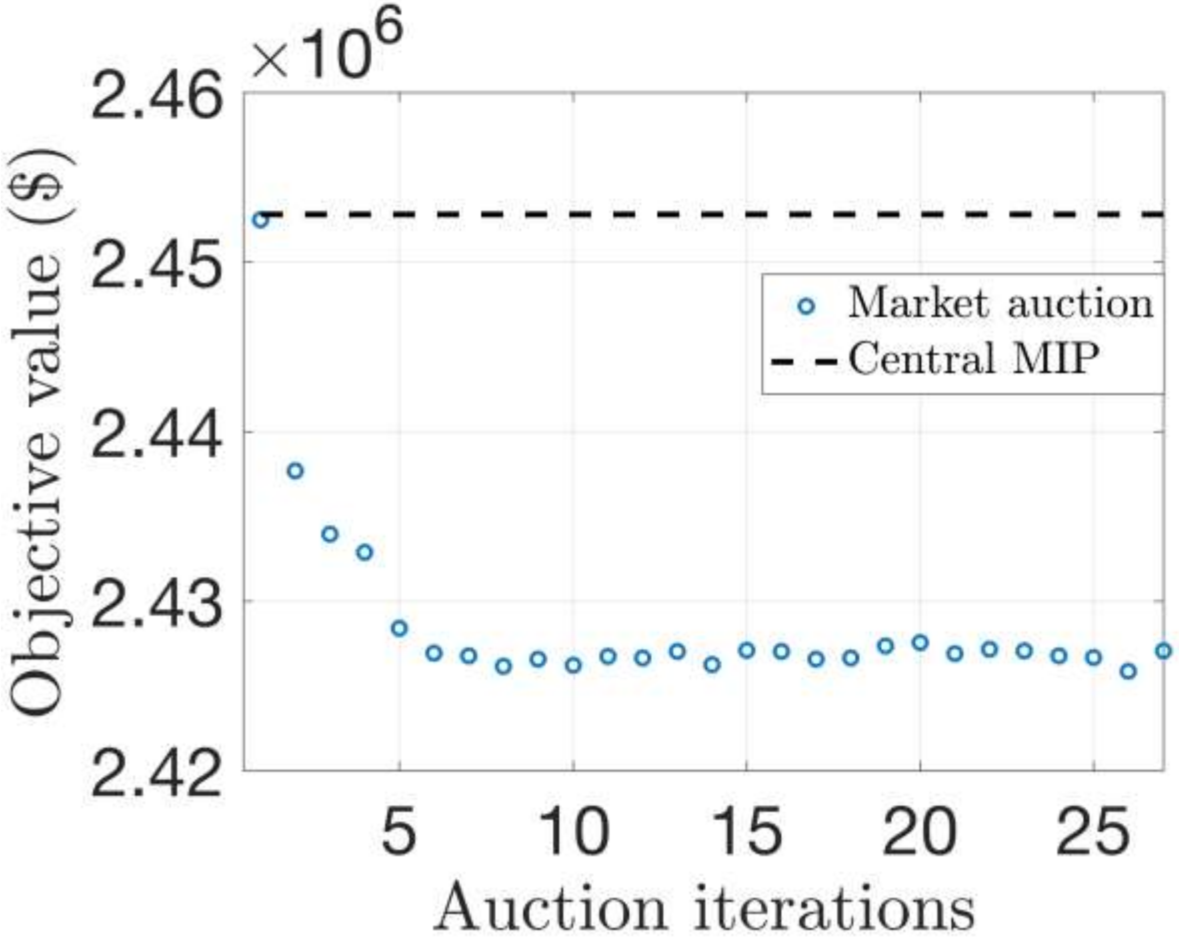
- Can be solved as a mixed integer program for all time steps, complex for modest number of spaces/time steps
- Solve using approximate dynamic programming (sample random solution paths over time horizon, pick best)
- Objective functions are continuous functions of latitude/longitude, if Lipschitz, can assume neighborhood of single curb space has same solution, speeds up ADP converge considerably

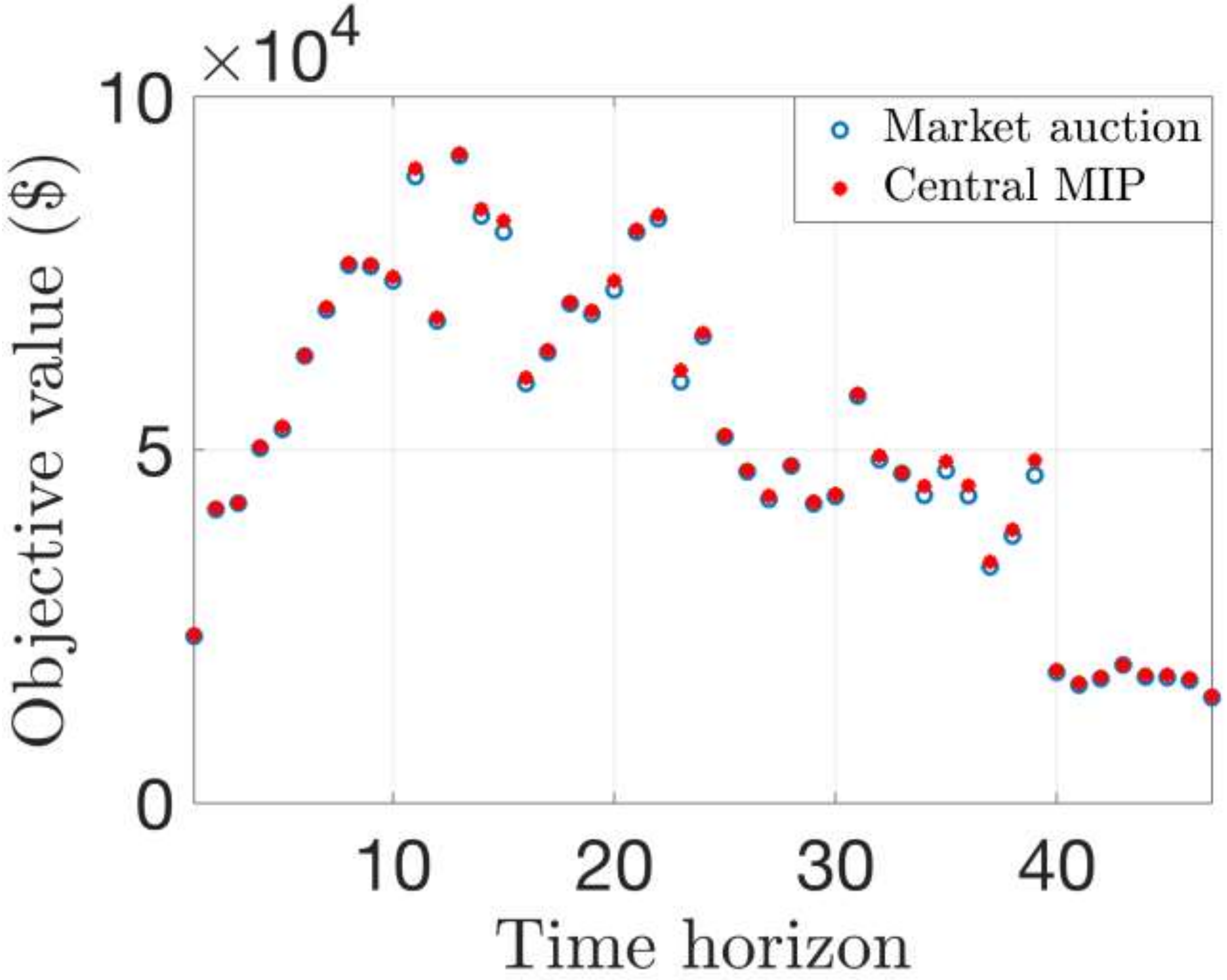


Decentralized Solutions

The MIP solution is “centralized”, market operator has complete control of resultant space zoning

Also implementing auction methods, e.g. a Dutch auction





Forthcoming Work

- Better approximations of curb valuation (internalities vs externalities, surpluses vs costs)
- Direct comparison of “centralized” MIP/ADP solution, and “decentralized” auction methods, both subject to identical policy constraints to compute a price of anarchy
- Accounting for demand-response effects: valuation of the curb changes as a function of changing control signal over short and long time periods

Thank you

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