U.S. DEPARTMENT OF ENERGY SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

JUNE 3, 2020

CITIES TOPOLOGY: CURBS AND PARKING

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National Renewable Energy Laboratory
DOE Vehicle Technologies Office
2020 Annual Merit Review

Project ID# eems074

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Argonne NATIONAL LABORATORY · BERKELEY LAB · INL Idaho National Laboratory · NREL · OAK RIDGE National Laboratory

OVERVIEW

Timeline

- Project start date: March 2019
- Project end date: March 2020
- Percent complete: 100%

Budget

- FY 2019: $275k
- FY 2020: $25K (Bridge funding)

Barriers

- Emerging mobility services barely (if at all) represented in transportation modeling
- Curb modeling/policy dominated by parking concerns until now.

Partners

- National Renewable Energy Laboratory
- Academia
- Industry (Transpo Group)
- Cities and other public organizations

RELEVANCE

- Given different mobility demands for curb space, research is needed to understand the potential consequences for urban development patterns (and hence energy use)
- Emerging modes such as Transport Network Companies (TNCs) (e.g., Uber, Lyft) impose a unique mix of demands on the road network and wider transportation system infrastructure
- Research needs to optimally allocate space for on-street parking and pickup/drop-off (PUDO) zones to minimize mobility impacts and energy use
- A need to update prevailing transportation models to account for increasing competition for curbside space.

Curb Topology
Optimized curb design and management for mobility – productivity – energy

MILESTONES

Date	Milestone	Status
FY 2019 Q2–Q3	Literature review and interviews	Complete
FY 2019 Q4	Optimization framework	Complete
FY 2020 Q1–Q2	Presentation at conferences (including the Transportation Research Board Annual Meeting) and publications in peer-reviewed journals	Complete

APPROACH

Literature Review (FY 2019 Q2)

- Review of studies on how academics and practitioners are modeling curb activity (including TNCs), as well as impacts on land use and urban infrastructure

Interviews (FY 2019 Q3)

- Interview experts with parking, curbside, land use, and emerging modes responsibility to understand the key requirements and priorities

Optimization Framework (FY 2019 Q4)

- Develop mathematical models to optimally allocate/manage curbside space

Publications and Microsimulation Setup (FY 2020 Q1–Q2)

- Publications in peer-reviewed journals
- Initial models implemented using SUMO (Simulation of Urban MObility) open-source traffic microsimulation software

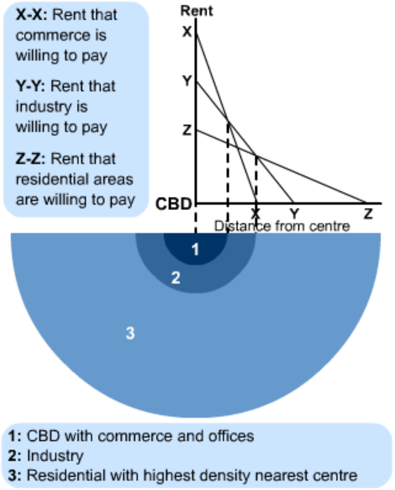
APPROACH

Newly Proposed Quantitative Framework

- Simulate the “market” for curbside space, inspired by and adapted from classical models of urban real estate (e.g., Bid-Rent theory)

- **Bid-Rent Theory** posits that urban land is used by the type of use that values it the most

- Develop a decision-support tool:
  - Test alternative geometry configurations
  - Test policy options and/or pricing strategies
  - Aim is to develop generic model forms



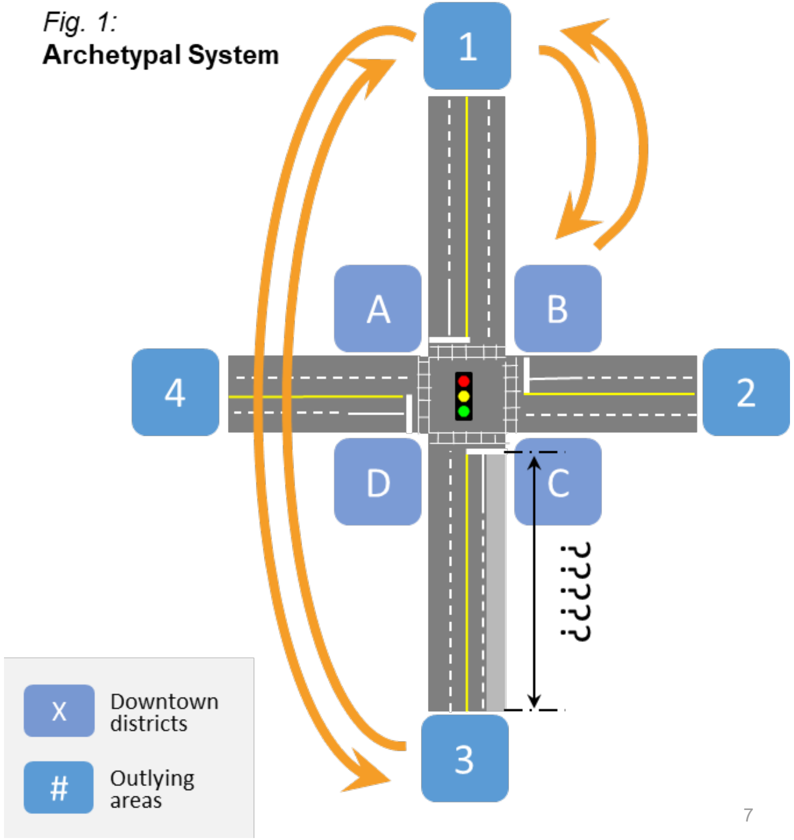
APPROACH

Newly Proposed Quantitative Framework

- Various modes of transport seek mobility ("through" movements) and/or accessibility (to local land uses), competing for scarce space within the public right-of-way.

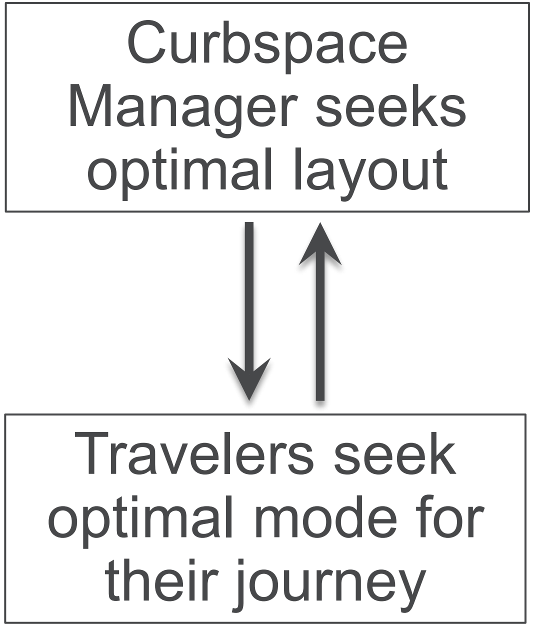
- Curb space can be flexibly allocated to a travel lane, on-street parking, bus lane, PUDO zone, commercial loading zone, or other mobility demands (e.g., sidewalk, scooter/bikeshare parking).

Fig. 1:
Archetypal System



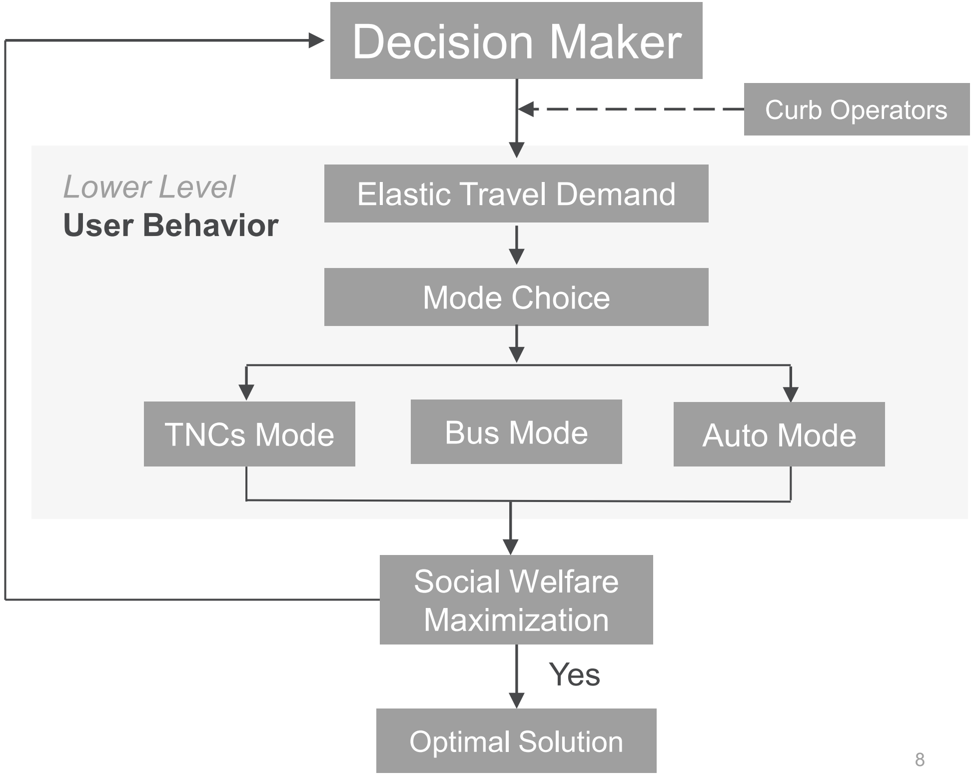
APPROACH

Bi-Level Interactive Decision-Making



Upper Level

Network Manager Space Allocation Decision



APPROACH

Sample Model Components

Objective Function:

$$Minimize \quad C_T + C_{PUDO} + C_P$$

Volume Delay Function for curbside lane used for "through" travel:

$$C_T = W \cdot v_T \cdot t_{T,0} \cdot \; 0.15 \cdot (\frac{v_T}{n_T})^4$$

"M/M/n" queuing model for PUDO Zone:

$$\rho = \frac{v_{PUDO}}{n_{PUDO} \cdot \mu_1} < 1$$

$$P_x = \frac{1}{\sum_{s=0}^{n_{PUDO}-1} \frac{1}{s!} (\frac{v_{PUDO}}{\mu_{PUDO}})^s + \frac{1}{n_{PUDO}!} \cdot \frac{1}{1-\rho} \cdot (\frac{v_{PUDO}}{\mu_{PUDO}})^{n_{PUDO}}}$$

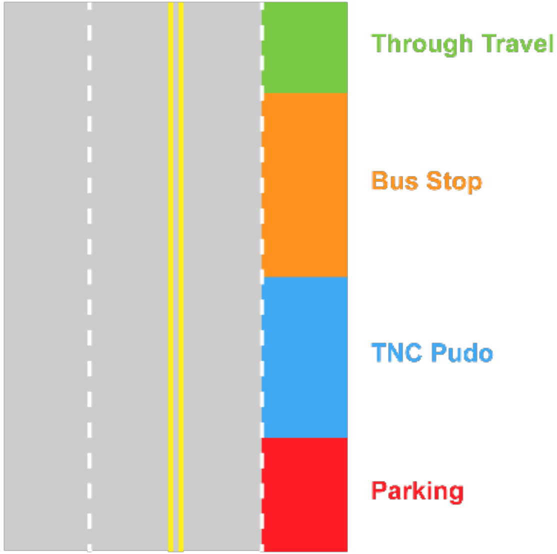
$$L_q = \frac{(n_{PUDO}\rho)^{n_{PUDO}}}{n_{PUDO}!(1-\rho)^2} P_x$$

$$T_{d,PUDO} = \frac{L_q}{v_{PUDO}}$$

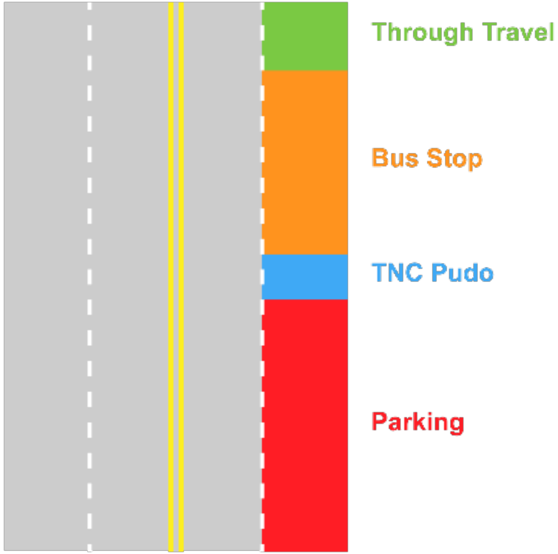
$$C_d, PUDO = W * T_{d,PUDO}$$

APPROACH

Which is Optimal?



Curbspace Distribution 1

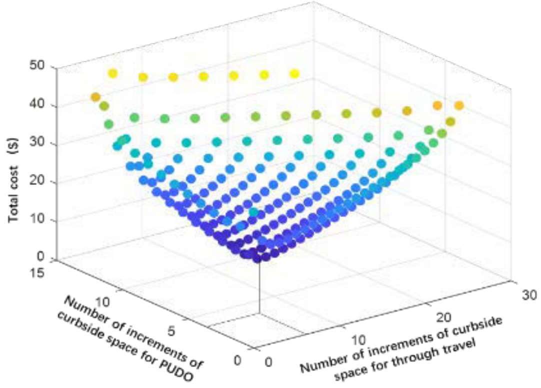


Curbspace Distribution 2

Curbspace Distribution 1 has more through travel, more TNC PUDO, and less parking than Curbspace Distribution 2

APPROACH

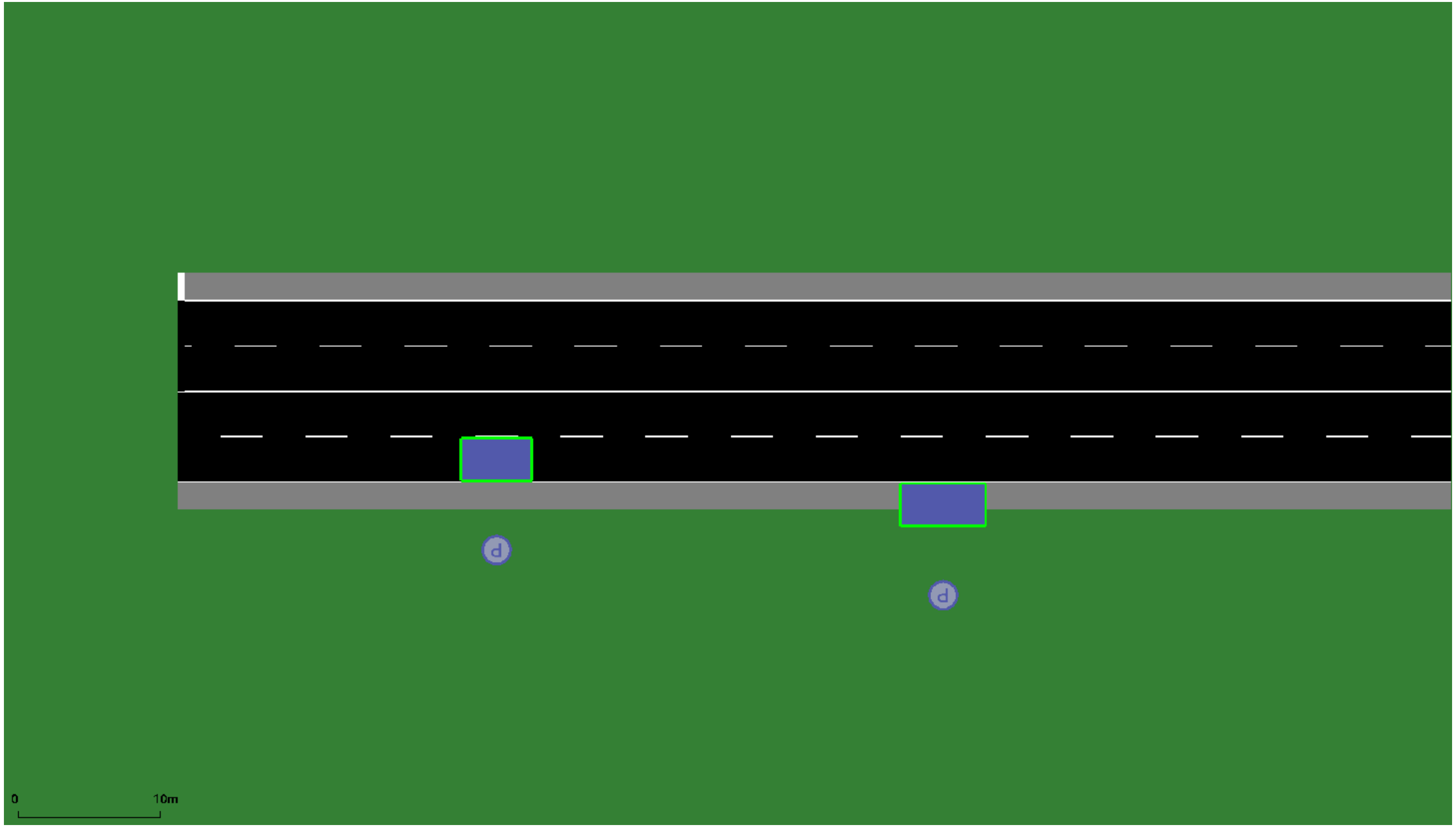
Optimization and Sensitivity Tests



PUDO dwell time (min)	Travel through demand (veh/h)	Parking duration (h)	Parking cost ($/h)	Optimal TRAFFIC LANE (ft)	BUS STOP (ft)	Optimal PUDO ZONE (ft)	Optimal STREET PARKING (ft)	BUS mode share	TNC mode share	PRIVATE CAR mode share
2.5	250	3	$4	100	50	200	650	34%	36%	31%
PUDO Dwell Time Halved				100	50	100	750	34%	36%	31%
Through Travel Demand Doubled				200	50	150	600	34%	36%	31%
TNC Per-Minute Fee Doubled				100	50	150	650	35%	34%	31%
Parking Fee Halved				100	50	150	700	22%	32%	46%

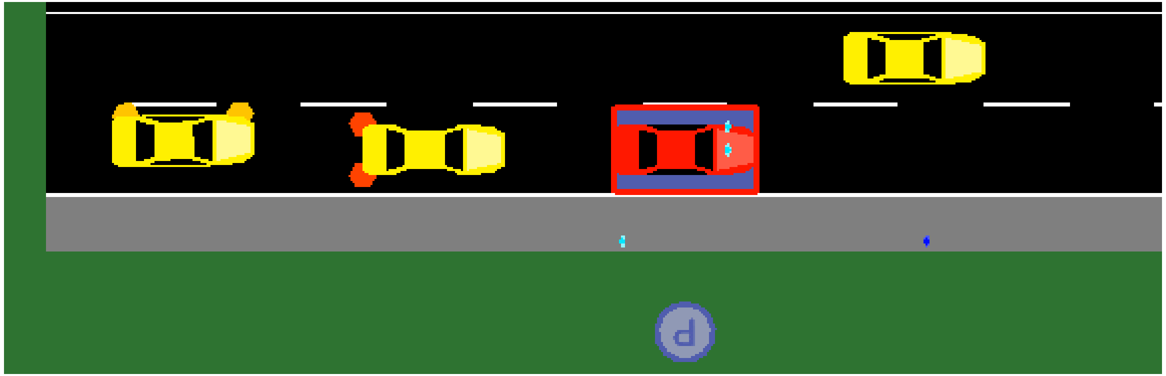
APPROACH

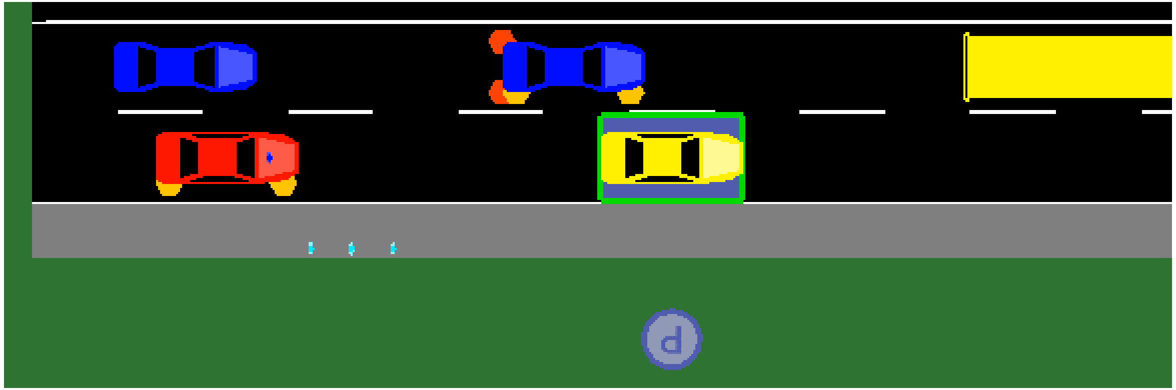
SUMO Microsimulation

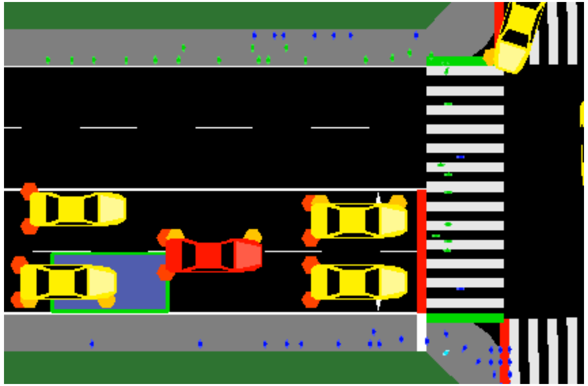


APPROACH

SUMO Microsimulation







TECHNICAL ACCOMPLISHMENTS AND PROGRESS

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Stakeholder Development

- Stakeholder engagement (expert interviews) lead to relevant publication
- Continue to develop these relationships (cities, airports, industry) for current and future collaboration.

Optimization Framework and Microsimulation Setup

- Mathematical models developed to optimally allocate/manage curbside space
- Initial models implemented using SUMO open-source traffic microsimulation software with a range of scenarios to analyze outputs of the proposed models.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Publications in peer-reviewed journals

- Butrina, P.; Le Vine, S.; Henao, A.; Sperling, J.; and Young, S. (2020). Municipal Adaptation to Changing Curbside Demands: Exploratory Findings from Semi-Structured Interviews with Ten U.S. Cities. *Transportation Policy*. https://doi.org/10.1016/j.tranpol.2020.03.005.
- Kong, Y.; Le Vine, S.; Henao, A.; and Young, S. (2020). A Framework for Optimal Allocation of Curbside Space. *Transportation* (submitted).

Presentations and Dissemination

- Driving Cars Conference, Princeton University, May 2019
- NREL/DOE Briefing Event, NREL office in Washington, D.C., May 2019
- University of Washington, Seattle, WA, June 2019
- NYS Association of MPOs, Syracuse, NY, July 2019
- NREL webinar, September 2019
- New York Institute of Technology/UTRC Region #2, November 2019
- Transportation Research Board Annual Meeting, Washington, D.C., January 2020
- ASCE International Conference on Transportation & Development, Seattle, WA, May 2020 (accepted)
- Institute of Transportation Engineers Annual Meeting, New Orleans, LA, August 2020 (accepted)

RESPONSES TO PREVIOUS YEAR REVIEWERS' COMMENTS

The following highlight the main comments from reviewers.

- Linkage between initial conceptual framework and existing transportation models (addressed)
- Stakeholder engagements with cities (addressed)
- The reviewers stated that the project is relevant to overall DOE objectives, especially with TNC growth. Better understanding of energy use (at the curb) requires more detail data such as vehicle type, length of stay at the curb, and number of passengers and goods.

COLLABORATION AND COORDINATION

- National Renewable Energy Laboratory (NREL)
- Academia (SUNY New Paltz, Southwest Jiaotong University)
  - Assistant professor
  - Doctoral student in traffic engineering, simulations
- Stakeholders
  - Industry: Transpo Group, Fehr & Peers, Coord, SharedStreets, video technology (artificial intelligence) start-ups, TNCs (Uber, Lyft)
  - Several cities and other public organizations

REMAINING CHALLENGES AND BARRIERS

- Scaling up from microscopic model (in which each linear foot of curb space is modeled) to larger level of analysis
- Incorporate traffic microsimulation to increase physical realism of volume-delay and queuing functions used in the proposed framework

PROPOSED FUTURE RESEARCH

- Incorporate larger, more realistic set of competing curbside uses such as urban freight (e-commerce) and micromobility
- Incorporate induced demand
- Make curbside dynamic
- Partner with cities and industry to test technologies for data collection and management
- Include other outcomes highly valued (e.g., safety, customer service, economic) by cities
- Test strategies for pricing the curbside, and explicitly model sensitivity to policies for off-street parking/loading

Any proposed future work is subject to change based on funding levels.

SUMMARY SLIDE

- Curbside activity has not traditionally been represented in transportation network modeling in high fidelity
- The experts interview study shows that cities managing curbside are adapting to growing curbside demand since prevailing practices are becoming increasingly untenable.
- Builds on "Curb Productivity Metric" introduced in 2018 (Fehr & Peers and Uber) to consider the overall function of infrastructure for different modes (not just parking) within the transportation system
- In this research, we are developing models that account for curbside activity at both the microscopic and macroscopic levels
- These new models will facilitate curbside allocation for mobility and energy optimization

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QUESTIONS?

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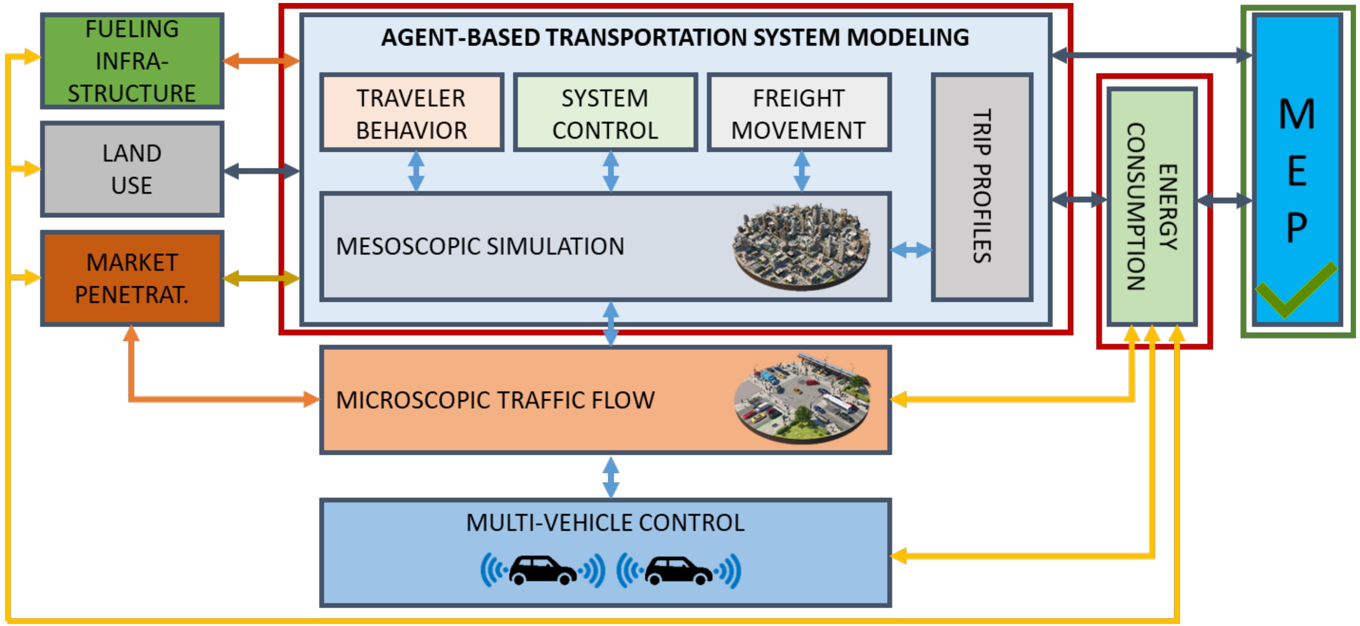
TECHNICAL BACKUP SLIDES

SMART WORKFLOW MODELING PROCESS



The work from "*Cities Topology: Curbs and Parking*" helps the SMART Workflow with land use and mesoscopic simulation to capturing the relationships between emerging technologies and land-use at the curb