Project ID # EEMS007
Urban Science

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

Mobility Data and Models Informing Smart Cities

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2019 ANNUAL MERIT REVIEW
JUNE 2019

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

OVERVIEW

Timeline

- Project start date: 10/01/2016
- Project end date: 9/30/2019
- Percent complete: 80%

Budget

- Total project funding

- DOE share: $1.655M Fiscal Year (FY) 17–FY 19

- Funding for FY 2017: $220k
- Funding for FY 2018: $220k

Barriers

- Lack integrated data: new modes+ behaviors
- Ever-increasing mobility options within cities, yet lack evaluation frameworks on multiple co-benefits, risks, unintended consequences

Partners

- DOE Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Lab Consortium
- U.S. Department of Transportation (DOT) Smart City Challenge Finalists
- Respective university researchers in these cities (e.g., Carnegie Mellon University)
- Key City Data/Modeling/GeoViz Communities
- Smart Cities, Metropolitan Planning Organizations (MPOs), DOTs, Utilities, Transit, Mobility as a Service (MaaS) Providers and Data Integration, Viz, and Modeling Platforms

Urban Science Informing Advanced Mobility, Energy Productivity, Smart Cities

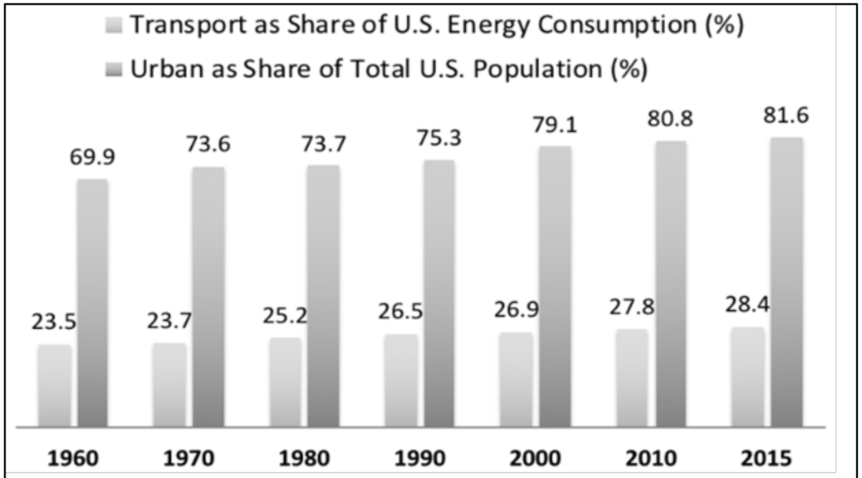
RELEVANCE: Interactions of Emerging Technology, Changing Urban Environments, and Travel Behavior on Mobility and Energy Impacts

Research Question: what are the key changes for, and impacts of mobility trends on, urban travelers?

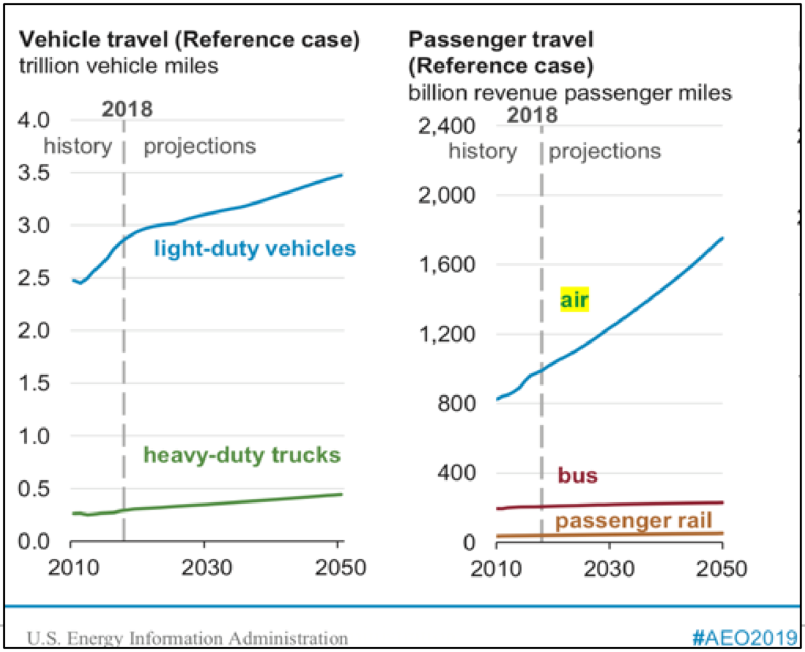
– Air travel and airports are the leading, measurable front of urban communities quickly adapting to Mobility as a Service options, of which ride-hailing is predominant

– Insights on mode/vehicle choices, travel behavior and transaction data at airports, in particular transportation network companies (TNCs), provides observability into urban mobility transitions

– In competing for talent, employer-provided mobility (EPM) emerging in diverse urban areas, reshaping commuting patterns



[Sources: Adapted from US DOT/Census]



RELEVANCE: Task Objectives

The overall goal of this task:

- Identifying and quantifying impacts of emerging mobility behaviors associated with MaaS and other new mobility choices in urban areas

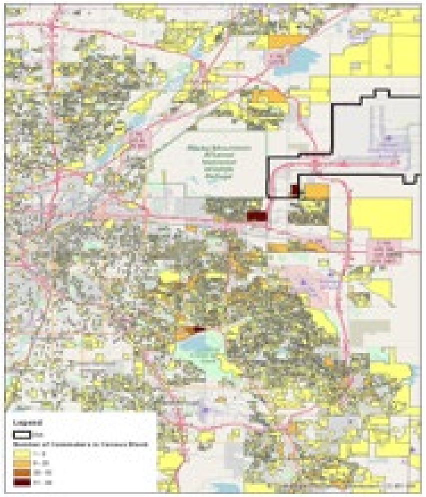
Key objectives include:

- Acquire data on quickly evolving MaaS in order to monitor rapidly shifting urban mobility patterns
- Develop a first airport sub-model for access/egress, curbs, & vehicles related to TNC use versus traditional modes
- Estimate potential of EPM on energy impacts (using MEP metric developed in parallel Urban Science efforts)

Origin-destination data: 48,600 employees

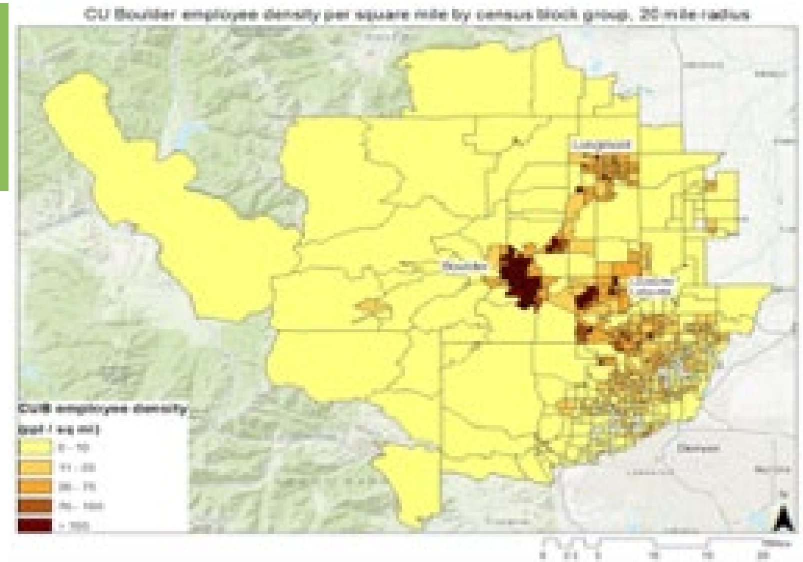
- Daily round trip employee vehicle miles travelled : ~1,501,930
  - Annual VMT: 391,574,607 miles (~31 VMT/person/day)
  - Annual fuel use: 6.17 billion gallons
  - Greenhouse gas (GHG) emissions: 215.4 thousand mt-CO_2e
- "What if" scenario-modeling:
  - 50% use employer shuttles offered if home <5 miles
  - 30% mode switch, due to new first/last mile services to transit
  - 5% to 10% use 'pooling' for high-density employee origins

~ 3% to 8% of transport energy use/scope 3 GHG reductions

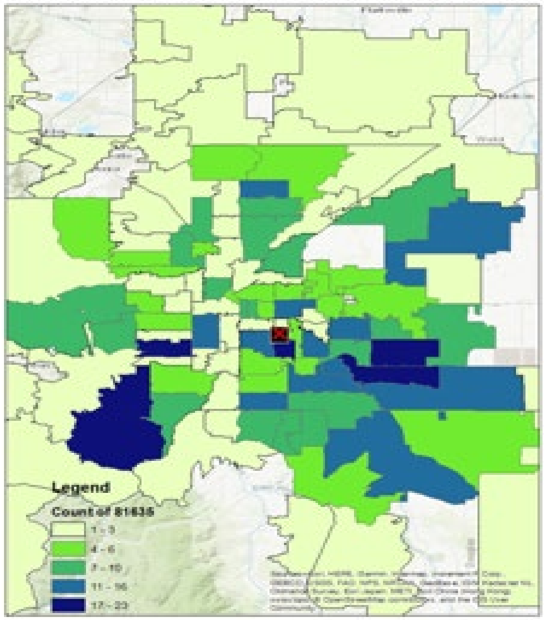


MILESTONES: FY 2019

- First Quarter (Q1) – Acquire EPM origin/ destination employment data for case studies ; develop framework to evaluate EPM potential
- Q2 – Develop first airport TNC mode choice model and initial EPM regional case study
- Q3 – Generalize airport TNC mode choice model
- Q4 – Refine and bound regional EPM study
- FINAL – Shifting Urban Mobility Behavior report (as part of the Urban Science Capstone Report)



Number of commuters to CDOT headquarters by zip code



<u>Key finding</u>:

New mobility choice impacts, as percent mode replacement:

- ***~30% or 30 trips replacing transit, ~35% or 35 trips replacing parking at airport per 100 new TNC transactions (case of Denver and Seattle)***

APPROACH

Cross-Scale Actors & Institutions	Data Inventory	Smart City Performance Metrics (MEP)	Mapping Data & Models	City-Based Lit. Review & Reports

- From engaging cities, identifying data/gaps, and model maturity to inform SMART Mobility, to:
  - Enabling urban data integration, visualization, analysis, modeling via MaaS data (TNC, shared electric vehicle [EV] bikes, scooters, automated electric shuttles) to mobility energy data analysis (e.g. at major employment hubs to key destinations - airports, downtowns, campuses, and employment centers).
- Focus on two major trip generators, where emerging mobility options have key impacts:
  - **Airports as gateways to cities**: access to airports shifting to MaaS options, primarily TNC vehicles, at expense of access / parking by private vehicles (**informing data needs for future urban mobility models**)
  - From employment hubs to large employers generating trips at peak demand, analysis efforts to enhance **efficient commuting** via EPM strategies led by employers, chambers of commerce, and municipalities.

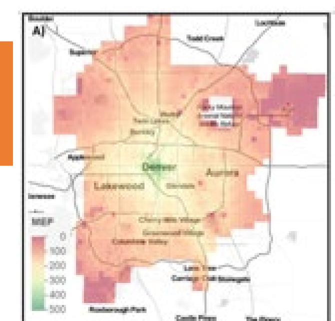
Smart City Curation of Data and Model Capacity

Employer Provided Mobility: explores EPM role to attract/ retain best and brightest?

Urban Typology: Explores how behavior / outcomes vary across multiple factors

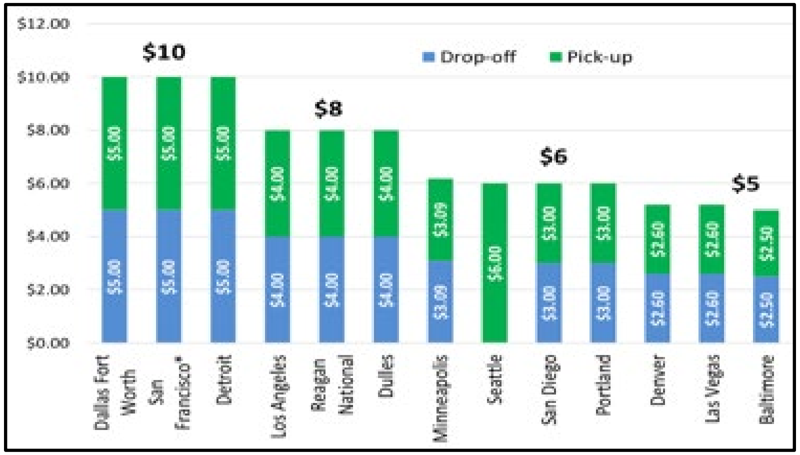
Quantifying Changes in Urban Mobility Behaviors: starting with airports, downtowns, and campuses

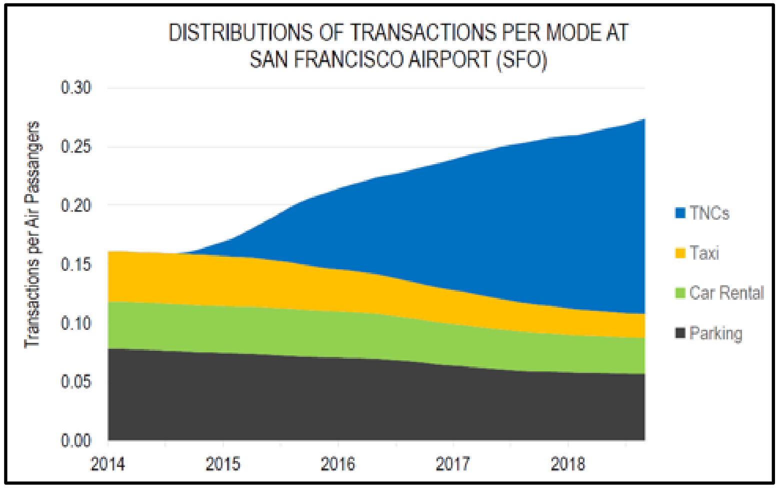
Mobility Energy Productivity Metric as Time, Cost, Energy-Efficient Access to Opportunities



APPROACH: AIRPORT TO CITY MODE CHOICE MODELING ENABLED BY AIRPORT REVENUE RECORDS AND TNC TRANSACTION DATA

- **Key research questions:**
  - *How does ride-hailing affect mode share of ground transportation trips to/from airports?*
  - *Does the cost and travel time utility of prior modes change with MaaS choice adoption?*
- **To address the research questions, efforts included:**
  - Identifying data sources for impacts at major employment hubs and destinations (airports, downtowns, campuses, and employment centers)
  - Developing airport mode choice behavioral model for representative airports via public records requests - data cleaning, processing, integration
  - TNC, curbs, on-demand transit data collection to shared EV bikes, scooters, and AES for agile data analysis to 'useable' models across urban settings
  - Exploring co-benefits, risks, synergies, & tradeoffs





U.S. DEPARTMENT OF ENERGY SMARTMOBILITY

Argonne INL NREL

APPROACH: EMPLOYER-PROVIDED MOBILITY

- **Key research questions:**
  - What is the potential energy impact of EPM benefits programs, to new mobility choices, that could be further designed to increase shared-EV(?) commuting options?
  - How can de-identified employee residence data inform development of EPM deployment strategies?
- **Methods:**
  - Collect employee origin data with HRs
  - Map US Census Bureau LEHD datasets
  - Extrapolate comparative case study impacts of EPM to broader representative urban areas (for example: Columbus, Denver) to estimate potential impact of EPM in terms of new synergies, co-benefits, and risks at regional scales

EPM Study Rationale:

Employer Benefits

- Attract talent, better retention
- Access to employees from doorstep
- More productivity
- Decreased parking
- Harnessing new mobility services

Employee Benefits

- More productivity
- Less stress
- New utility/economics/incentives

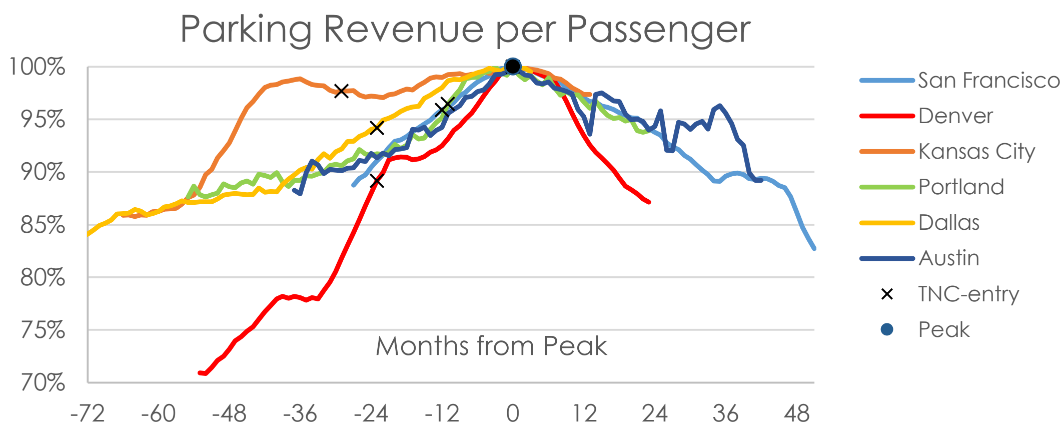
Societal Benefits:

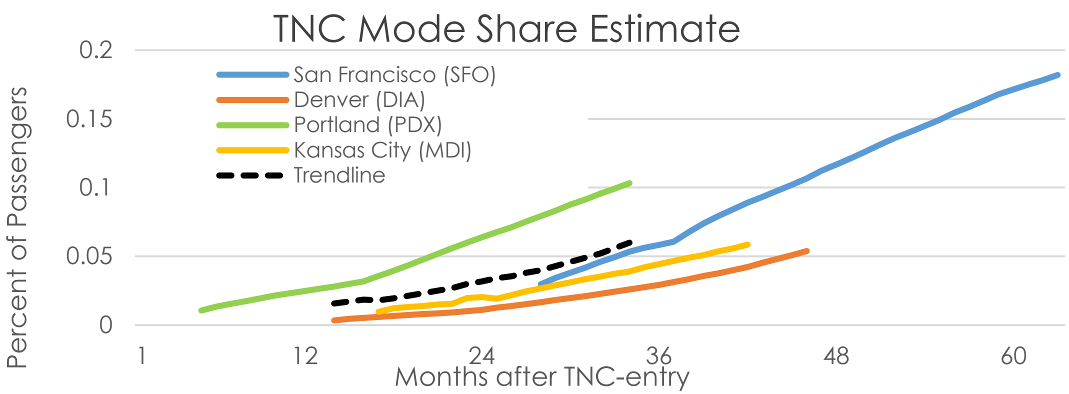
- Reduced congestion, VMT, energy inefficiencies, emissions
- Pathways to electrification in fleets
- Employers in transit/mobility discourse

TECHNICAL ACCOMPLISHMENTS: Publications on observable areas of urban mobility behavior shifts and rapid travel demand growth

Why Important:

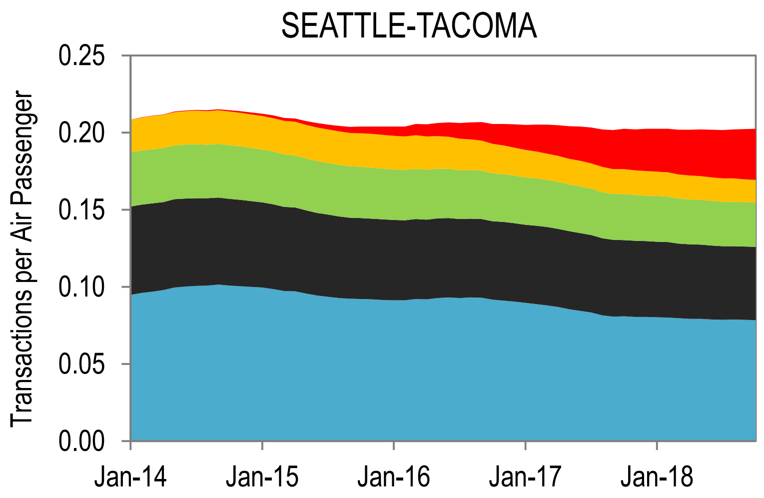
- From 2015 to 2035, global air travel expected to double (~18.7 years for select US airports)
- Energy related to air travel expected to increase
- Changes in ground transportation revenues
- Tens of billions in urban airport infrastructure investments are expected (obsolete or strategic?)

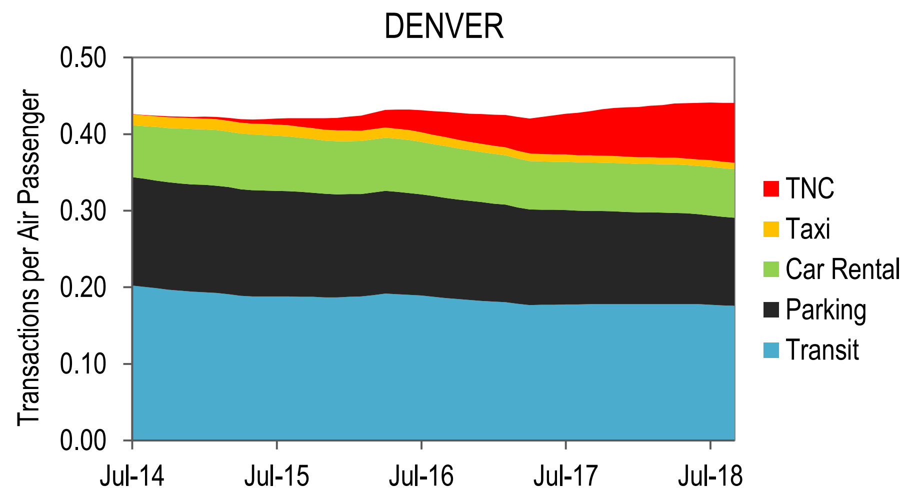




Henao, A., Sperling, J., Garikapati, V., Hou Y., & Young, S. (2018). "Airport Analyses Informing New Mobility Shifts: Opportunities to Adapt Energy-Efficient Mobility Services and Infrastructure" Golden, CO: National Renewable Energy Laboratory. NREL/CP-5400-71036. https://www.nrel.gov/docs/fy18osti/71036.pdf

TECHNICAL ACCOMPLISHMENTS AND PROGRESS



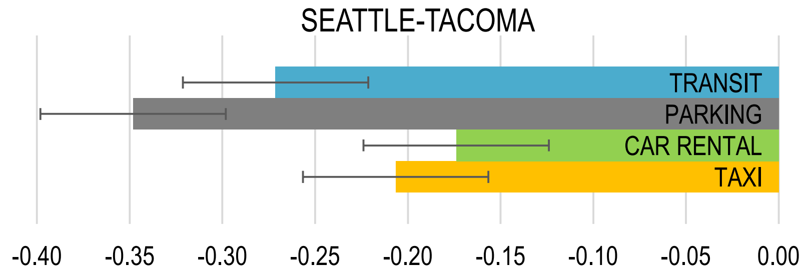


- For this study we gathered monthly transactions from January 2010 to December 2018 with the following data via public requests:
  - Airport passengers (enplaned and deplaned) collected by airports
  - Ground transportation transactions for parking, car rental, taxis, to TNCs (collected by airports)
  - Transit transactions collected by the corresponding public transportation authority (Sound Transit for Seattle-Tacoma and the Regional Transit District for Denver)

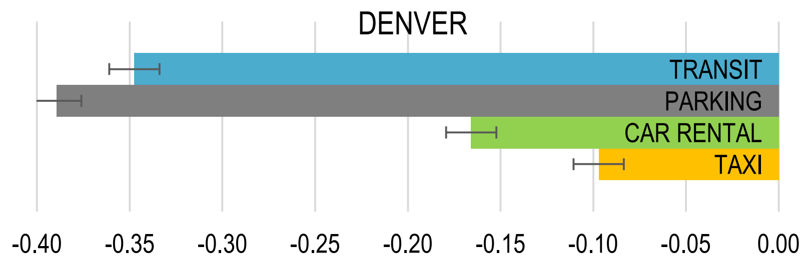
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Change in mode share (transit, parking, car rental, taxi) per TNC addition

mode (sea-tac)	Estimate	Pr(>|t|)	95% CI
tnc (transit)	-0.2714	< 2e-16 ***	(-0.3226 -0.2201)
tnc (parking)	-0.3483	< 2e-16 ***	(-0.3994 -0.2970)
tnc (car rental)	-0.1739	9E-11 ***	(-0.2251 -0.1226)
tnc (taxi)	-0.2065	3E-14 ***	(-0.2578 -0.1553)

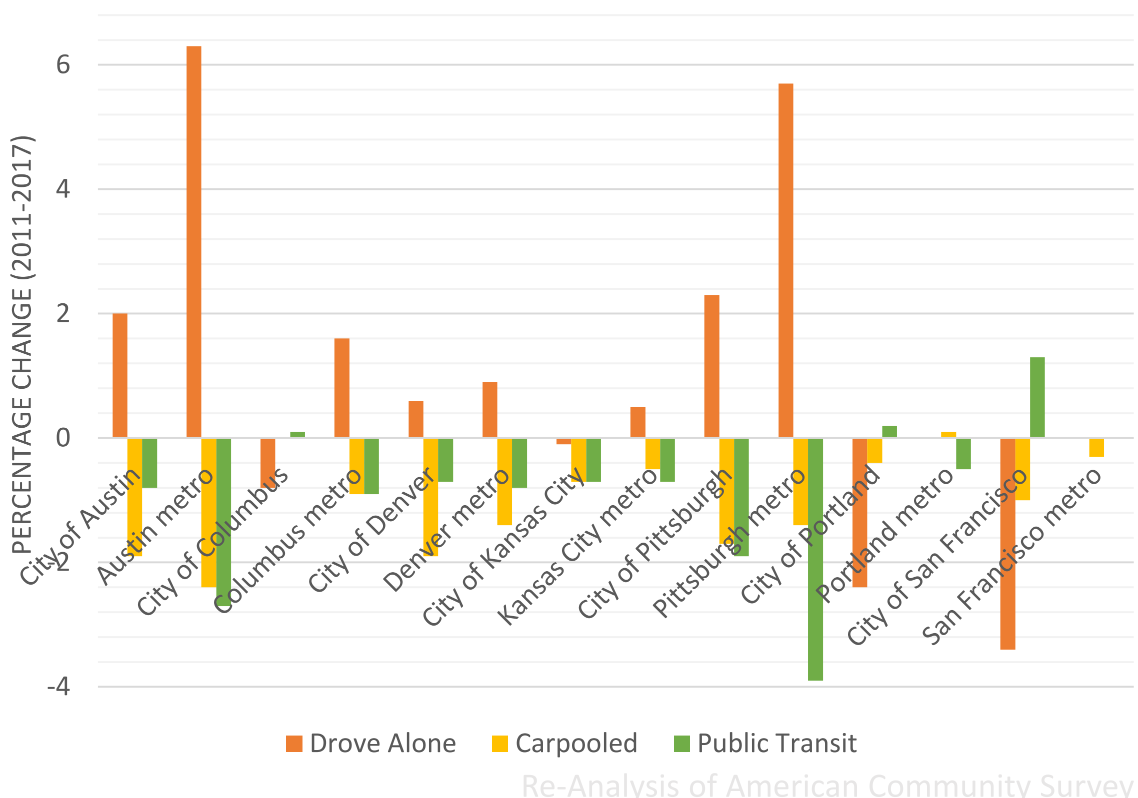


mode (den)	Estimate	Pr(>|t|)	95% CI
tnc (transit)	-0.3475	< 2e-16 ***	(-0.3610 -0.3340)
tnc (parking)	-0.3896	< 2e-16 ***	(-0.4031 -0.3761)
tnc (car rental)	-0.1658	< 2e-16 ***	(-0.1793 -0.1523)
tnc (taxi)	-0.0971	< 2e-16 ***	(-0.1106 -0.0836)

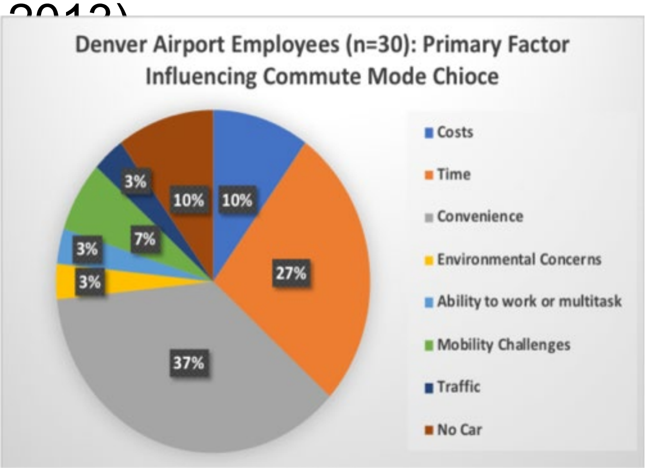


- Mode replacement findings, based on # of transactions per mode after ride-hailing introduction:
  - Seattle (SEA-TAC) airport: for every 100 new TNC transactions for ground transportation, ~ 27% replaced transit, 35% replaced parking, 17% replaced car rentals, and 21% replaced taxis
  - Similarly, at Denver International (DEN), ride-hailing transactions replaced transit, parking, car rental and taxis at a rate of 34.7%, 39.0%, 16.6%, and 9.7%, respectively.

EPM TECHNICAL ACCOMPLISHMENTS AND PROGRESS: Baseline Commuting Data and Trends for Smart City Finalists



Commuting to work constitutes approximately **28%** of all person VMT, and **39%** of all transit person miles of travel (Commuting in America, 2013)

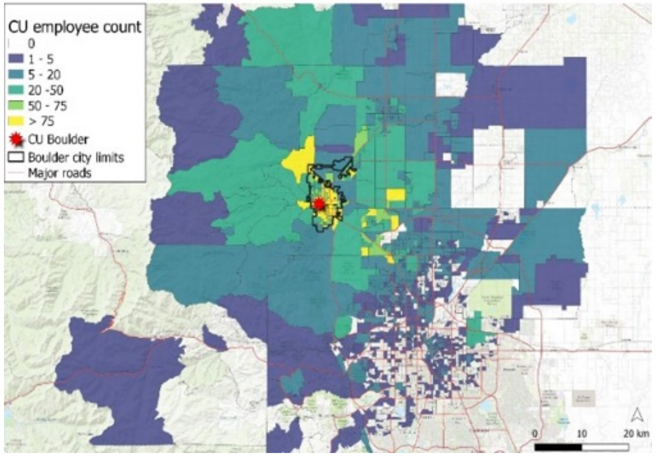


Changes in commute mode choice in several U.S. DOT Smart City finalists between 2011 and 2017 show increases in SOV commuting and decreases in shared modes – motivation for EPM?

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

- **Case studies with aggregated geolocation data of employee residence for sample employers:**
  - University of Colorado (CU) Boulder (15,567 employees)
  - NREL (1,528 employees)
  - Colorado Department of Transportation (CDOT) Headquarters (663 employees)

CU Boulder employees by census block group



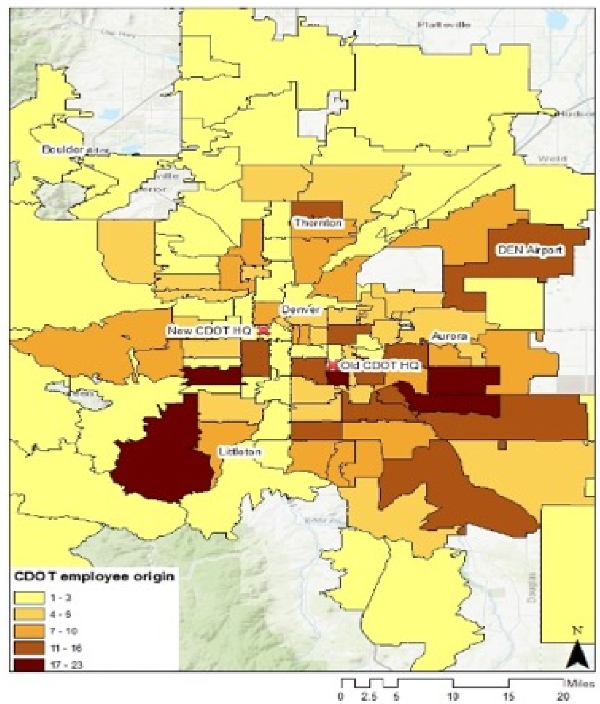
Different size employers, providing an informative overview of EPM possibilities in a local context and for diverse use cases across a university, national lab, CDOT, and airports as major employment hubs state-wide

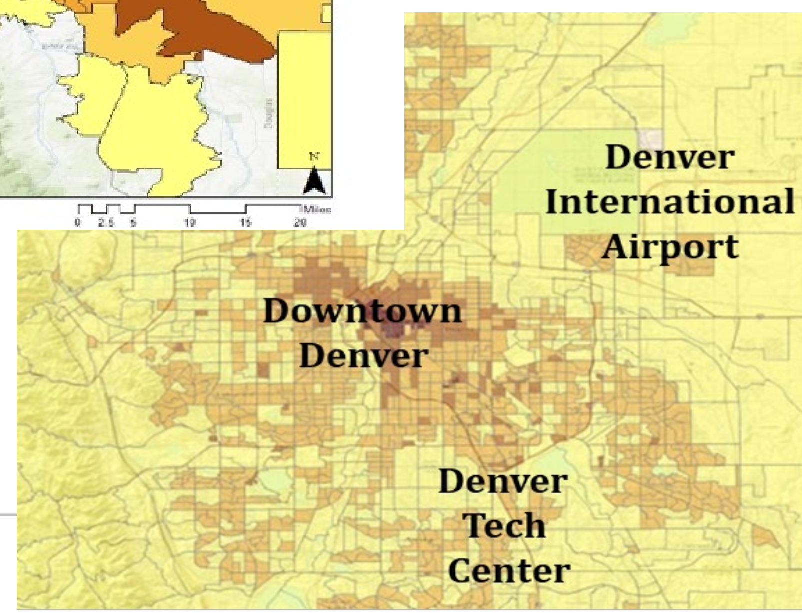
	Mode	Miles driven	Gallons of gasoline	Direct costs ($2.25/gallon or avg. of local & regional bus fare: $7.86 round trip)	Total costs (operating costs for private vehicles - $.58/mile)	Tons of CO2
CU - outside of Boulder (daily data)	Car - SOV	136,879	5,475	$12,319 (personal expense)	$79,390	48.7
	Car - carpool	10,755	430	$968 (personal expense)	$6,238	3.8
	Bus	2,477	248	$12,274 (employer-paid)	-	2.2
CU - inside of Boulder (daily data)	Car - SOV	4,760	190	$428 (personal expense)	$2,761	1.7
	Car - carpool	144	6	$13 (personal expense)	$84	0.1
	Bus	202	20	$6,223 (employer-paid)	-	0.2
Totals (daily)		155,218	6,369	$32,226	$88,472	56.6
Totals (annual)		34,768,726	1,426,752	$7,218,641	$19,817,829	12,679.5

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

- An objective of this task is to extrapolate the potential impact of EPM at a regional scale
- Longitudinal employer-household dynamics (LEHD) data, a resource that encapsulates location of residence and employment (origin and destination data) for a vast swath of the U.S. population
- Current efforts are exploring regional commuter characteristics and surveys in downtown Denver and scenarios for new energy-efficient commuting mobility choices

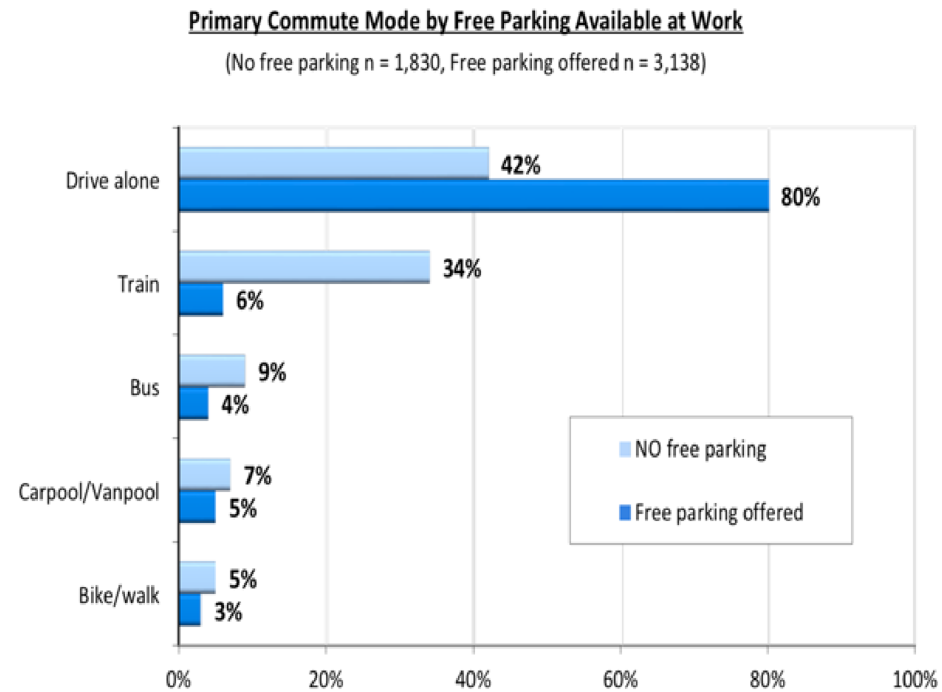
Number of commuters to CDOT headquarters by zip code





TECHNICAL ACCOMPLISHMENTS AND PROGRESS

- Summary of Findings: EPM Case Studies
  - New database and geolocation tool: employers can extract usable de-identified data
  - Aggregated employee residence location at U.S. Census Block group level to identify clusters of employee residences
  - LEHD dataset allows broader regional modeling/estimation of EPM implementation
  - Potential impact of EPM as low to high adoption, and likely EPM adoption scenarios based on case studies of participation rates



<u>EPM Motivation in DC Metro Area:</u> Forty-three percent of Washington, DC area metro (2016 State of the Commute) survey respondents have changed jobs or residence due to their commutes, and 63% made commuting the only factor considered in their decision to accept a job.

RESPONSES TO PREVIOUS YEAR'S REVIEWERS' COMMENTS

- Comments from the previous year's reviewers included concerns about ensuring that specific research questions and data sources to address those questions were more well refined. These comments, along with outcomes from engagement with cities and agencies and coordination with VTO managers were used to help inform a reframing of this task to concentrate research focal points.
- For FY 2019, key research objectives were restructured with goals to concentrate on high-value mobility activities and to best leverage data sources:
  - Airports exhibit concentrated scenarios of emerging MaaS use - also locations for which observability into travel behavior is supported by public data records.
  - Large employers induce commuting behavior and have recruitment, economic, and public relations reasons to offer efficient commuting options to employees.
  - Employers and U.S. Census maintain unique origin-destination data, including employee residence locations, that inform EPM strategies, and possible new solutions, to improve energy-efficient commute options.

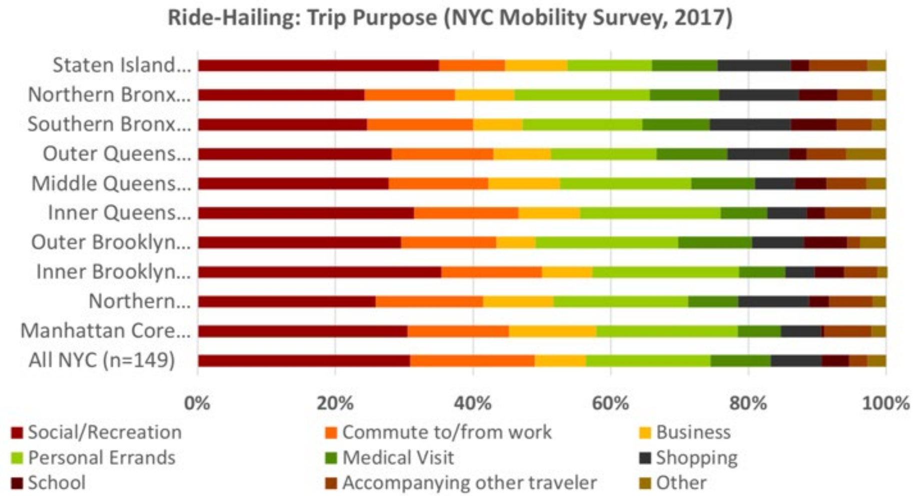
COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

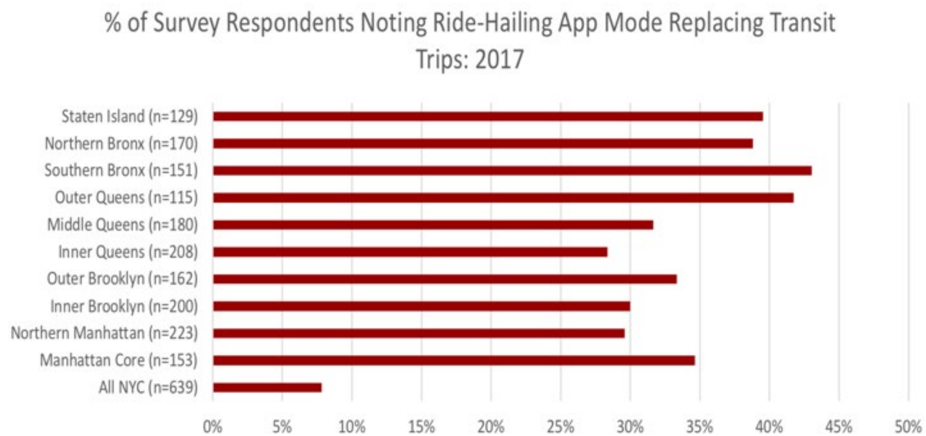
- Airport Mode Choice segment of the task has partners that provide data for developing mode choice model:
  - Denver International Airport, Seattle-Tacoma Airport, etc.
- EPM: multiple collaborators, some with complementary research efforts and others that provide data:
  - Luum, LLC, Seattle, Washington
  - ACES Northwest, Belleview, WA
  - Denver South TMA, Englewood, CO
  - Downtown Denver Partnership
  - Universities
  - Ford Greenfield Labs, Palo Alto, CA
  - Columbus Partnership
  - CDOT
  - Google, Inc., Boulder, CO
  - City of Buffalo, NY
  - Mobility Choice Blueprint

Source: www.mobilitychoiceblueprintstudy.com

REMAINING CHALLENGES AND BARRIERS

- **Data access:** engagement with collaborative partners and development of data-sharing tools have borne progress:
  - **Airports:** are beginning to acknowledge reduced parking and increased TNC use are an emerging norm;
  - **Cities: amenable to sharing data** to restructure their strategic plans and inform infrastructure investments moving forward
  - **Employers:** recognizing need to maintain access to the emerging (younger) talent pool less vested in vehicle ownership/driving than previous generations. **Securely sharing sensitive data** of employee residence to enable appropriate analysis of EPM solutions.
  - **States: understanding travel behaviors and rural to urban technology adoption** of new mobility services; plans to integrate data, survey of EPM/other technology early adopters to characterize benefits, scalability, and unintended consequences;
  - Generalization of TNC/MaaS mode choices for urban models to extrapolate regional / national level understanding of impacts.





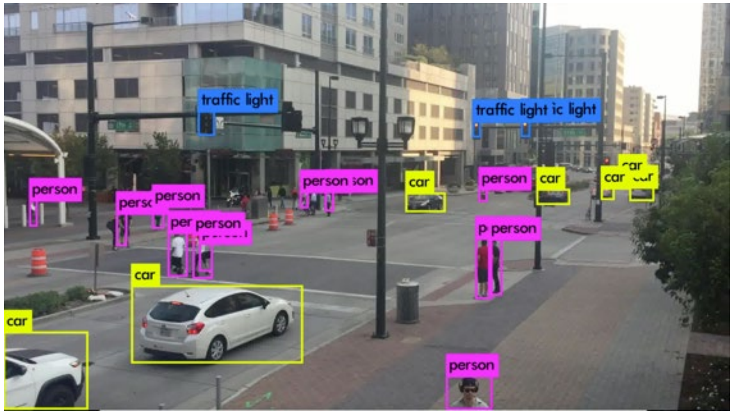
PROPOSED FUTURE RESEARCH

- **Airport to City Behavior/MaaS Mode Choice Data:**
  – Harnessing new computer vision capabilities?

  Future research question:
    - Can new data, observability, enhance a general model for airport access/egress modes and what curb/parking strategies may be applicable across a range of airports?
    - What lessons can be transferred between urban areas for upgraded data and model environments that are 'useful'/'useable' ?

  – Investigating additional airports and cities is necessary to address these questions, and is in the works for completion by the end of FY 2019.

  – Future implementation of methods developed in examination of airports can enable investigation of other special trip generation locations, such as central business districts, business parks, universities, downtowns, and other areas of concentrated human presence.



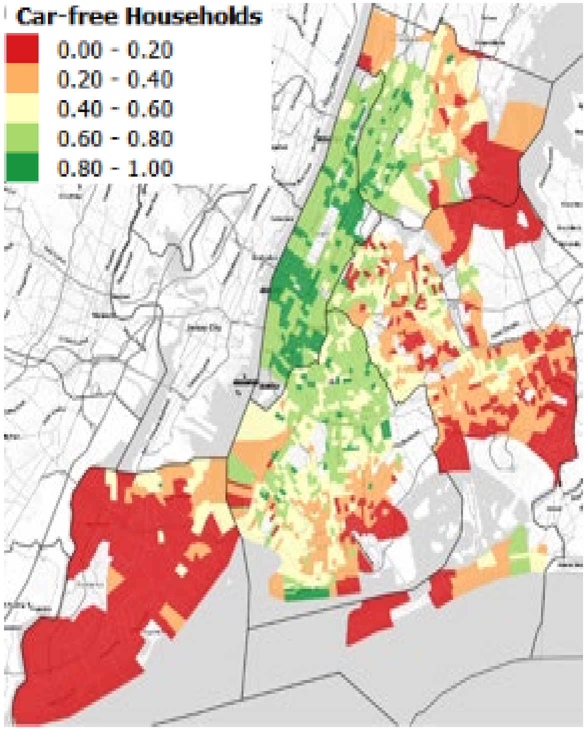
- Develop **a deep learning based computer vision system for energy and mobility analysis** through occupancy detection, counting TNC vehicles, curbside volumes, estimation of delay, and calculation of energy consumption and GHG emissions.
- **Test system on sample video data** collected at airport and city curbs.

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

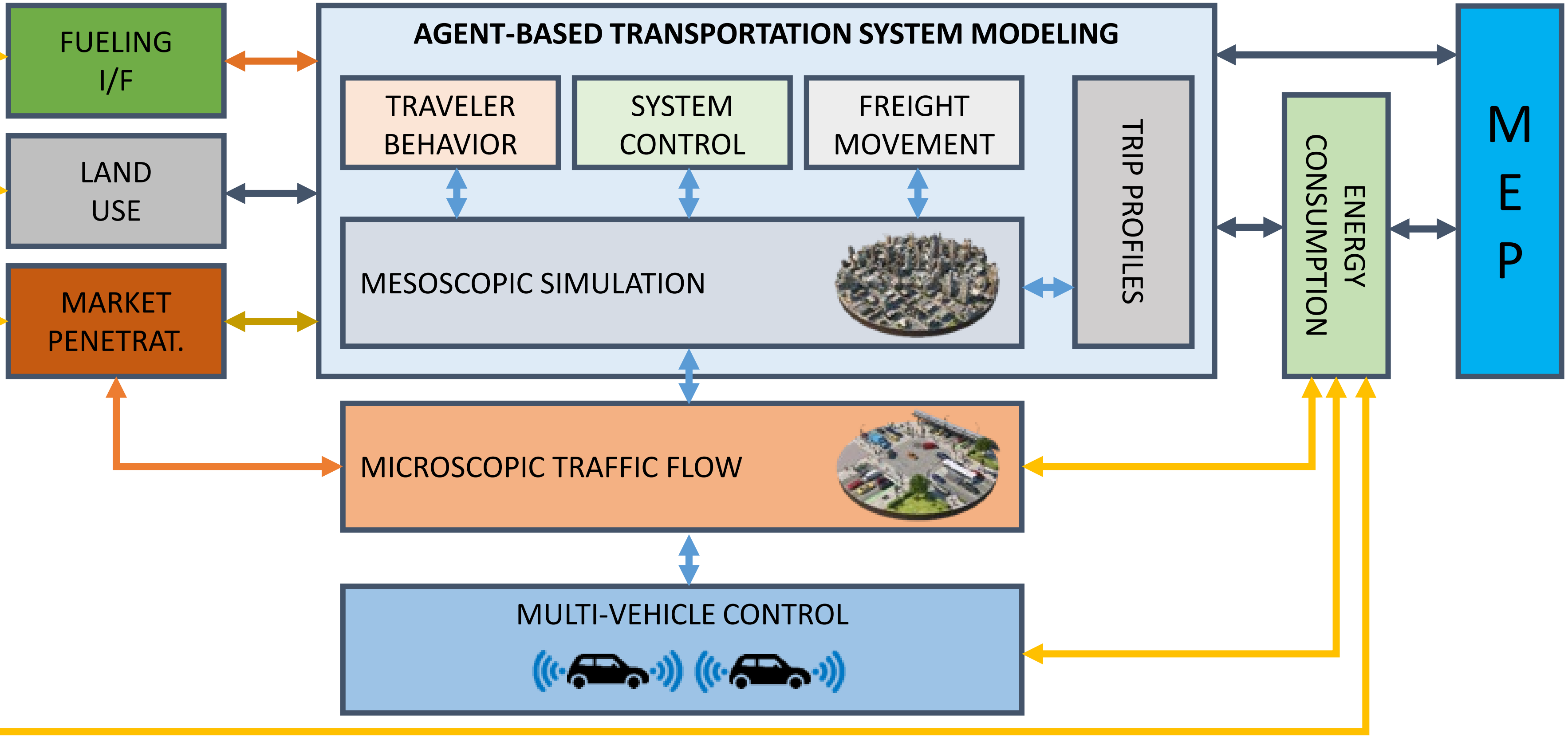
SUMMARY - Affordability, “Anxiety” (or Reliability), to Energy Productivity of Mobility: Expanding Choices, Opportunities and Re-Defining “Freedom”

Future Research Questions: Aligning EPM, MEP and Typology:

- *What factors are shaping employer-mobility services, shifts in MEP, auto-ownership, VMT, mode choice, SOV vs. higher-occupancy travel and spatial differences among types of populations (age, gender, income) and rural to urban settlements on adoption/impacts of new services?*
- *How best to address trends heading in wrong direction, i.e.:*
  - “car ownership is rising steadily in Southern California. Between 2000 and 2015, every new SoCal resident added 0.95 car on average to the region. From 1990 to 2000, each resident added 0.25 car.
  - Notably, car ownership in Los Angeles is rising the most among people with low incomes and recent immigrants from Latin America, according to a study from the Southern California Association of Governments (SCAG). The reasons are unknown.
  - Still, 21% of low-income households do not own cars, compared to only 4% of high-income households.”



END-TO-END MODELING WORKFLOW



QUESTIONS? Joshua.Sperling@nrel.gov

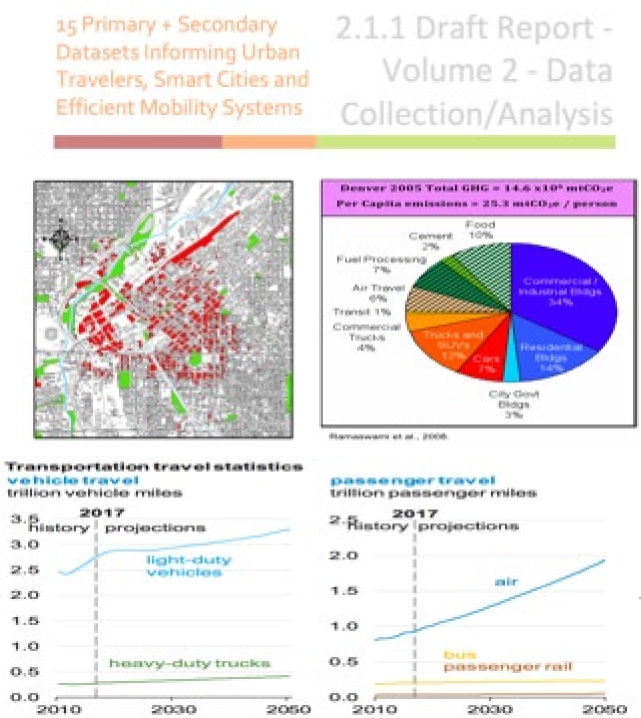
TECHNICAL BACK-UP SLIDES

RELEVANCE: 'A Race to the Top' - What are Energy Efficient Mobility Systems' Interactions of Emerging Technology + Urban Infrastructure + Travel Behavior?

→ **Integrated mobility transitions and transformations** at different speeds, in diverse settlements:

- **How** much will urban (to rural) mobility change in next 3, 10, 30 years (**quantifying** mobility/energy impacts)?
- **Why** and **where** will cities/districts individually and collectively shape energy-efficient mobility and mobility energy productivity in the age of shared, electric, automated, and connected vehicles?
- **When** are transitions/rates of change accelerated or non-existent (as 'innovation hot-spots and deserts')?

- All cities are invested in improving **quality of life**, **economic productivity**, **environment**, and **equity**



Mobility: evolving to increased use of shared, electric, on demand, connected, automated vehicles with greater affordability, reliability, yet with new cyber-concerns.

Energy: evolving to increased use of renewables, efficiency, electric vehicles on the grid, personalized, and with greater affordability / cyber-concerns.

These megatrends and features are interrelated and critical to exploring the infrastructure, energy, mobility, and finance nexus for shaping smart/resilient cities & systems modernization

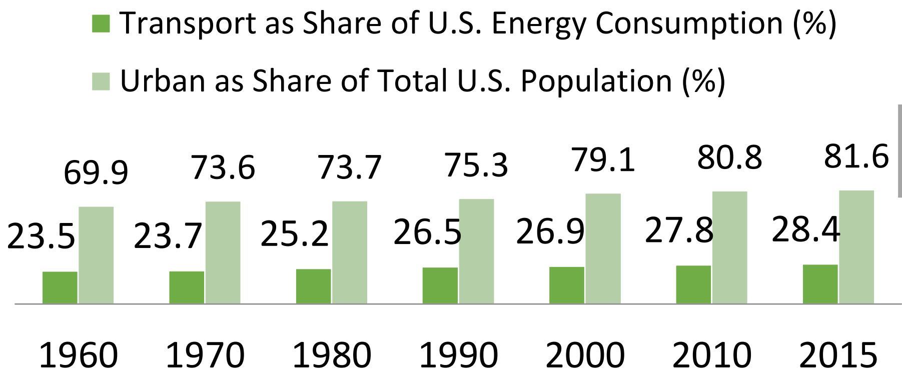
Infrastructure: airport facilities evolving to accommodate double the air passengers by 2036 with sustainability and cyber-resiliency upgrades.

Finance: profits, revenues, and finance mechanisms evolving to rapidly changing conditions, e.g. increased TNC service fees, less parking and car rentals.

RELEVANCE – Alternative Urban Futures: Nightmare? Utopia?

- **Rationale:** Transportation may soon reach over 30% of U.S. energy consumption, with urban >80% of U.S. population
- **Objective:** Engage stakeholders to curate urban data/models and accelerate research and innovation at the nexus of mobility and energy
- **Methods:** Co-designed research and & analytical approaches/questions to shaping mobility ecosystems with smart city stakeholders:

  >Top-Down; Bottom-Up; Inside-Out; Outside-In



Multi-Criteria Performance (Adapted from Isaac, 2016)	(-)	(+)
Energy/Vehicle Miles Traveled	↑	↑↓
Urban Sprawl/Congestion	↑	↓
Parking Requirements	No change	↓
Low-Income Mobility	↓	↑
Safety	↑	↑
Roadway Maintenance	↓	↓
City Revenues (e.g., parking)	↓	↑

[Sources: Adapted from *Driving Towards Driverless: A Guide For Government Agencies*, Isaac, 2016; US DOT/Census]

RELEVANCE – Supporting Maximum Mobility, Minimum Energy...Urban Futures

Technology convergence *could* revolutionize transportation, dramatically improve safety and mobility while reducing costs and environmental impacts (e.g., via electrification)

Will Zahovi and Marchetti's constant for cities hold true? Imagine 9 out of 10 cars and parking spaces disappearing from city centers **vs.** auto-oriented sprawl for hundreds of miles...

- Connected Vehicles
- Vehicle Automation
- Internet of Things
- Machine Learning
- Big Data
- Mobility on Demand

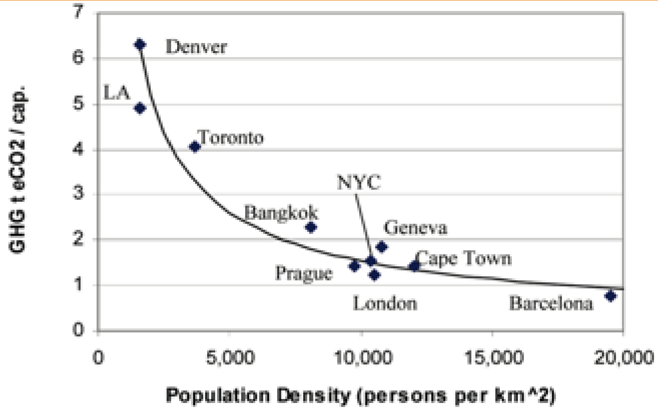


FIGURE 3. GHG emissions from ground transportation fuels are inversely related to population density.

U.S. Petroleum, million barrels/day (EIA, 2016)

Gross Import	Export	Net Imports
10.06	5.19	4.87

Impacts of Integrated Mobility for Smarter Cities?

Risks and Benefits:

- Order of magnitude energy savings/ increases and safety upgrades/risks
- Increasingly vulnerable or resilient transport energy system (e.g. cyber)
- Reduced or increased congestion?
- Improved access to jobs and services or increased accessibility anxiety?
- Reduced costs for gov't and users vs. big $ for infrastructure modernization
- Access & mobility synergies/tradeoffs

Does increasingly automated, connected, electric, and shared (ACES) mobility lead to energy efficiency gains? Quantitative impacts on urban travel, infrastructure, and energy consumption/supply/demand?