PROJECT ID: EEMS043

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Mobility Behavioral Responses to Transportation Network Companies

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2018 ANNUAL MERIT REVIEW AND PEER EVALUATION MEETING
JUNE 20, 2018
WASHINGTON, D.C.

NREL/PR-5400-71358

Argonne NATIONAL LABORATORY

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ENERGY EFFICIENT MOBILITY SYSTEMS PROGRAM INVESTIGATES

MOBILITY ENERGY PRODUCTIVITY

THROUGH FIVE EEMS ACTIVITY AREAS

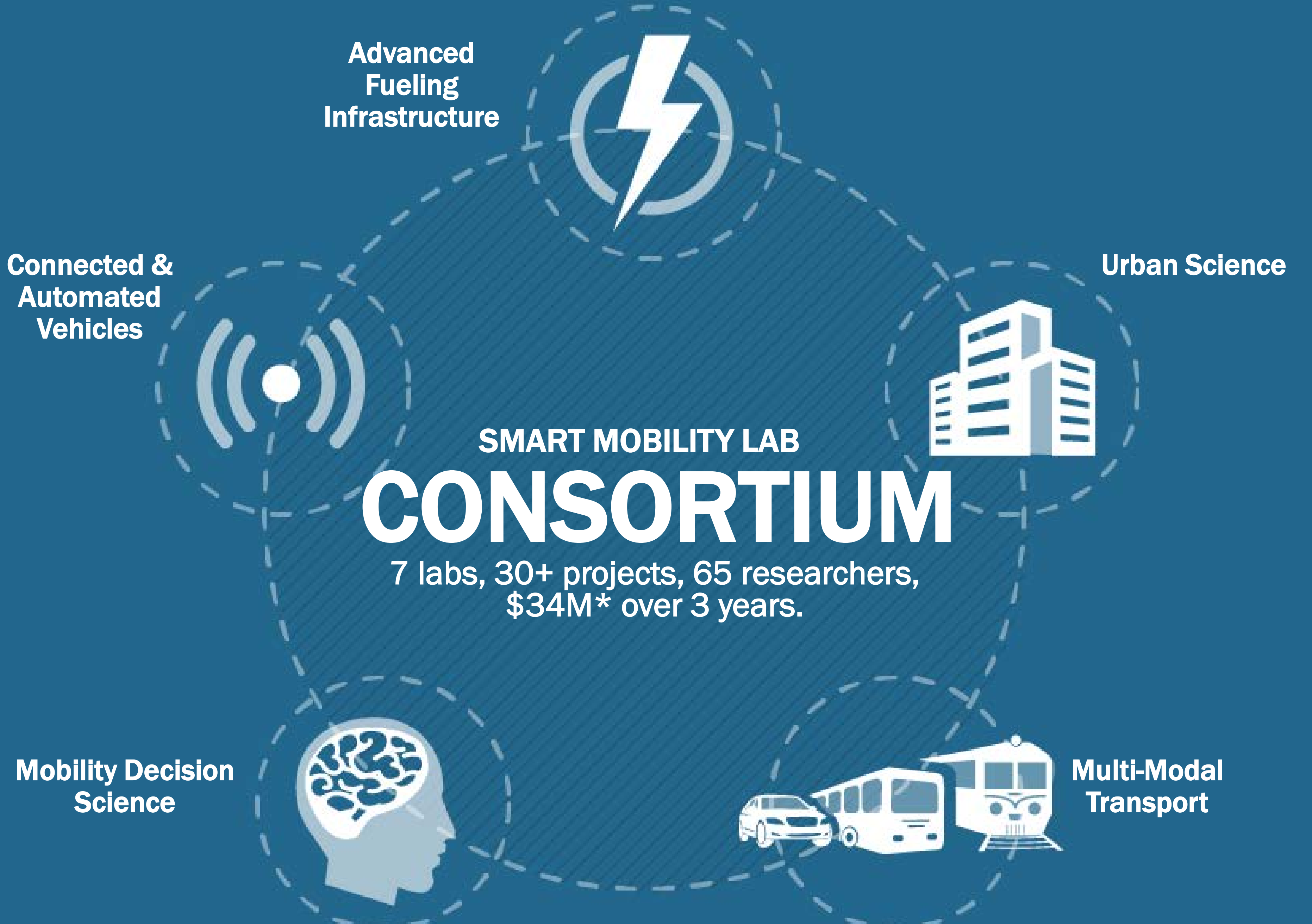
Advanced R&D Projects

Living Labs

Smart Mobility Lab Consortium

Core Evaluation & Simulation Tools

HPC4Mobility & Big Transportation Data Analytics



*Based on anticipated funding

OVERVIEW

Timeline

- Project start date: Aug 2017
- Project end date: Sept 2019
- Percent complete: 25%

Barriers

- Limited data on energy implications of transportation network companies (TNCs)
- TNCs are reluctant to share data with researchers

Budget

- Total project funding: $900K
- Funding for FY 2017: $300k
- Funding for FY 2018: $300K

Partners

- National Renewable Energy Lab (NREL)
- Lawrence Berkeley National Lab (LBNL)
- Carnegie Mellon University (CMU)

PROJECT RELEVANCE

Transportation Network Companies (TNCs) → Energy Impacts

Relevance: This research investigates how a disruptive force – Transportation Network Companies (TNCs) – is impacting energy consumption in transportation. It also helps better understand specific areas that encourage energy efficiency increases in mobility.

PROJECT RELEVANCE

Transportation Network Companies (TNCs) → Mobility Behavior Responses → Energy Impacts

Objective: Determine the impacts of TNCs on mobility behavior (both from supplier and consumer perspectives) and energy use.

- Vehicle ownership changes
- Deadheading
- Changes in vehicle type (fuel efficiency) and vehicle miles traveled (VMT) energy use
- Passenger modal shifts and sharing behaviors

APPROACH

- Investigate mobility behavior components of a TNC Energy Impacts Framework
- Understand data needs, including availability
- Research Question: What is the national impact of TNC availability on vehicle ownership?
  - Regression analysis using a difference-in-difference (DiD) econometric model with vehicle registration (Polk) data, TNC-entry dates, and census data (e.g., demographics, economics, travel modes, etc.)
- Research Question: What is the deadheading percentage of TNC miles?
  - Analyze 1.5 million rides from RideAustin (TNC in Austin, TX)
- Continue TNC data collection and analysis to better understand how changes in vehicle ownership, vehicle type, pooling services, and long-term behavioral changes induced by TNCs impact energy use
- Synergy with US 2.1.1: Airport Hub Data Collection

APPROACH

Date	Milestone	Status
FY18 Q1	Report on methodology and early analysis of 110 urban areas evaluating vehicle ownership in response to TNC penetration	Complete
FY18 Q3	Continue developing TNC energy impacts framework and identify additional mobility behavior components (including data)	On Track
FY18 Q4	Report/paper on energy aspects of TNCs, TNCs and vehicle registration analysis, and RideAustin study	On Track

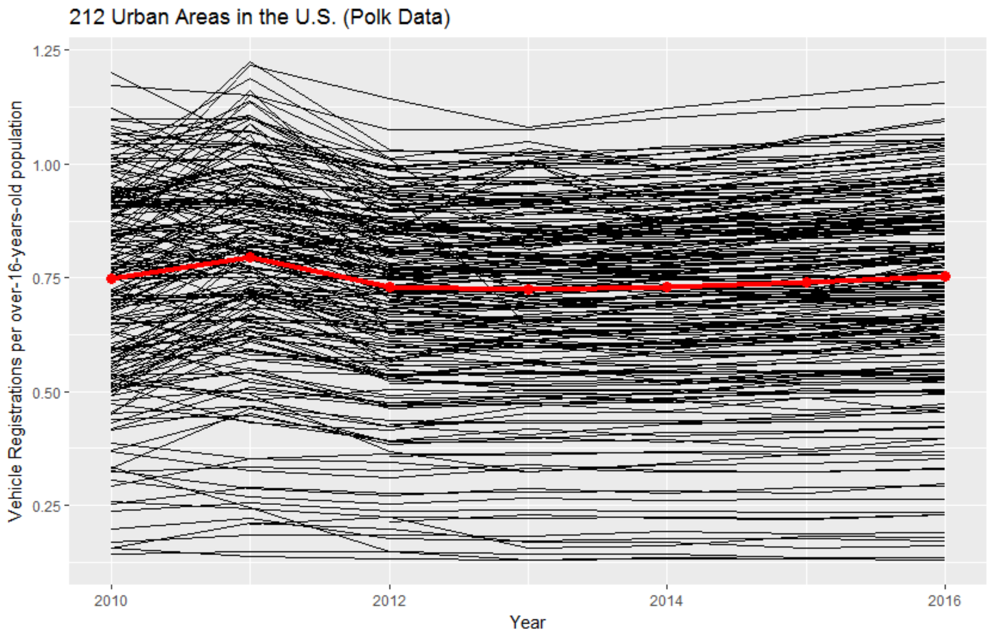
TECHNICAL ACCOMPLISHMENTS AND PROGRESS: TNC Energy Impacts

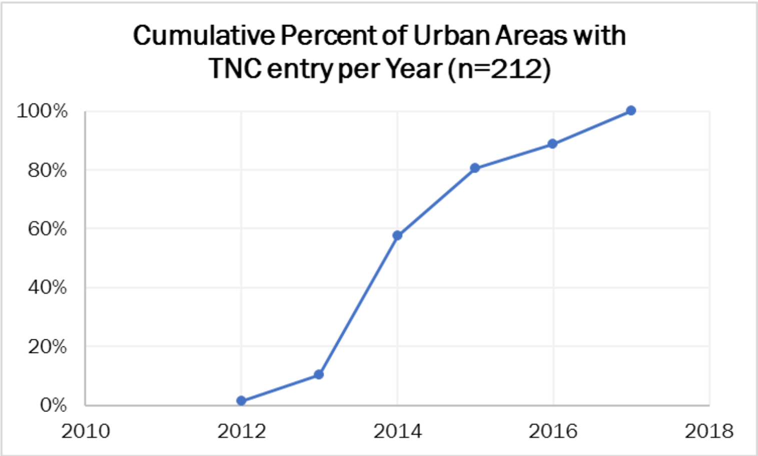
- Develop a TNC Energy Impacts Framework, identify mobility behavior components, and start filling research gaps

	TOPIC	SUB-TOPIC/RESEARCH QUESTIONS	POTENTIAL ENERGY IMPACTS	
Supplier (TNC)	Vehicle Fleets	Do TNC drivers use more fuel efficient/electric vehicles?	+	
		Is there an oversupply of vehicles?		−
	Deadheading	Deadheading percent of TNCs miles		−
		Deadheading variation per driver strategy		
		Deadheading variation per location		
Consumer (Passenger)	Mobility Behavior Changes	Vehicle ownership	+	
		Sharing: Vehicle occupancy and pooling	+	
		Mode replacement and modality style changes	+	−
		Induced travel		−
		Location	+	−
City	Infrastructure	Parking, density, multi-modal infrastructure	+	

TECHNICAL ACCOMPLISHMENTS AND PROGRESS: TNC Availability and Vehicle Ownership

- Data gathering, cleansing, and sharing
  - Polk registration data by ZIP code (2010 – 2016)
  - TNC entry dates by Urban Area (various sources)
  - Census demographic and travel data by Urban Area (2010 – 2016)
- Urban Area selection
  - Population and TNC entry dates
  - Vehicle registrations aggregated from ZIP code into Urban Areas





TECHNICAL ACCOMPLISHMENTS AND PROGRESS: TNC Availability and Vehicle Ownership

- Research Methodology
  - DiD econometric model
  - R code development
  - Identify variables to run in the regression model
  - Propensity score weighting in the DiD econometric model

$$y_{st} = \boldsymbol{\beta}'\mathbf{x}_{st} + \boldsymbol{\alpha}'\mathbf{z}_{st} + \gamma_s + \delta_t + \varepsilon_{st}$$

y_{st}: dependent variables (vehicle registration per over-16-years-old population) for urban area s and year t:

$\mathbf{x}_{st}$: treatment effects (i.e., TNC entry date)

$\mathbf{z}_{st}$: controls (population density, income, children, etc.)

γ_s: fixed effect for urban area s

δ_t: fixed effect for year t

ε_{st}: unobserved error

TNC Availability and Vehicle Ownership Preliminary Results (Binary Model)

Dependent Variable: Vehicle registration per over-16-years-old population

Treatment: TNC availability (TNC-entry <= 365 days = 0, TNC-entry > 365 days =1)

```
Call:
lm(formula = Polk_po16 ~ log_popden + log_inc + log_child + log_unem +
    factor(TNC_bin) + factor(DataYear) + factor(UA_code), data = UAData)

Residuals:
      Min        1Q    Median        3Q       Max
-0.245500 -0.014710 -0.000605  0.014423  0.215434

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)          3.0363070  0.3827234   7.933 4.74e-15 ***
log_popden          -0.4332427  0.0278314 -15.567  < 2e-16 ***
log_inc              0.0826809  0.0329860   2.507 0.012319 *
log_child            0.0829035  0.0252928   3.278 0.001075 **
log_unem            -0.0150855  0.0087094  -1.732 0.083508 .
factor(TNC_bin)1     0.0043792  0.0047337   0.925 0.355098
factor(DataYear)2011 0.0466189  0.0042435  10.986  < 2e-16 ***
factor(DataYear)2012 0.0156532  0.0051662   3.030 0.002497 **
factor(DataYear)2013 0.0137446  0.0056179   2.447 0.014561 *
factor(DataYear)2014 0.0161166  0.0064712   2.491 0.012886 *
factor(DataYear)2015 0.0260329  0.0077456   3.361 0.000800 ***
factor(DataYear)2016 0.0390620  0.0089219   4.378 1.30e-05 ***
```

No significant effect!

TNC Availability and Vehicle Ownership Preliminary Results (Binary Model 2)

Dependent Variable: Vehicle registration per over-16-years-old population

Treatment: TNC availability (TNC-entry <= 730 days = 0, TNC-entry > 730 days =2)

Interaction: Unemployment * TNC presence

```
Call:
lm(formula = Polk_po16 ~ log_popden + log_inc + log_child + factor(TNC_bin2) +
    factor(TNC_bin2) * log_unem + factor(DataYear) + factor(UA_code),
    data = UAData)

Residuals:
     Min       1Q   Median       3Q      Max
-0.24560 -0.01468 -0.00047  0.01443  0.21605

Coefficients:
                          Estimate Std. Error t value Pr(>|t|)
(Intercept)              3.0303312  0.3842887   7.886 6.84e-15 ***
log_popden              -0.4326121  0.0278415 -15.538  < 2e-16 ***
log_inc                  0.0827115  0.0331303   2.497 0.012670 *
log_child                0.0827631  0.0253072   3.270 0.001104 **
factor(TNC_bin2)2        0.0095157  0.0424589   0.224 0.822704
log_unem                -0.0154677  0.0088573  -1.746 0.081004 .
factor(DataYear)2011     0.0465933  0.0042472  10.970  < 2e-16 ***
factor(DataYear)2012     0.0155276  0.0051841   2.995 0.002797 **
factor(DataYear)2013     0.0136358  0.0056551   2.411 0.016043 *
factor(DataYear)2014     0.0162758  0.0065534   2.484 0.013139 *
factor(DataYear)2015     0.0278989  0.0075403   3.700 0.000225 ***
factor(DataYear)2016     0.0403860  0.0087401   4.621 4.22e-06 ***
factor(UA_code)2         0.2402503  0.0304955   7.878 7.23e-15 ***
factor(UA_code)3         0.1314242  0.0282469   4.653 3.63e-06 ***

factor(UA_code)297      -0.1521987  0.0331908  -4.586 4.99e-06 ***
factor(UA_code)298       0.2121547  0.0277316   7.650 4.02e-14 ***
factor(UA_code)299       0.3575760  0.0332998  10.738  < 2e-16 ***
factor(TNC_bin2)2:log_unem  0.0021551  0.0146665   0.147 0.883202
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04209 on 1236 degrees of freedom
Multiple R-squared:  0.9693,	Adjusted R-squared:  0.9638
F-statistic: 175.2 on 223 and 1236 DF,  p-value: < 2.2e-16
```

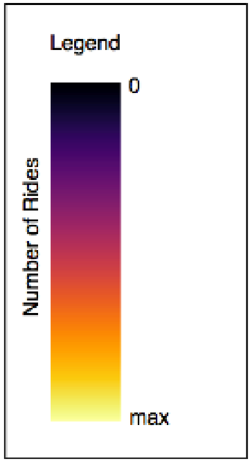
Effect on unemployment changes!

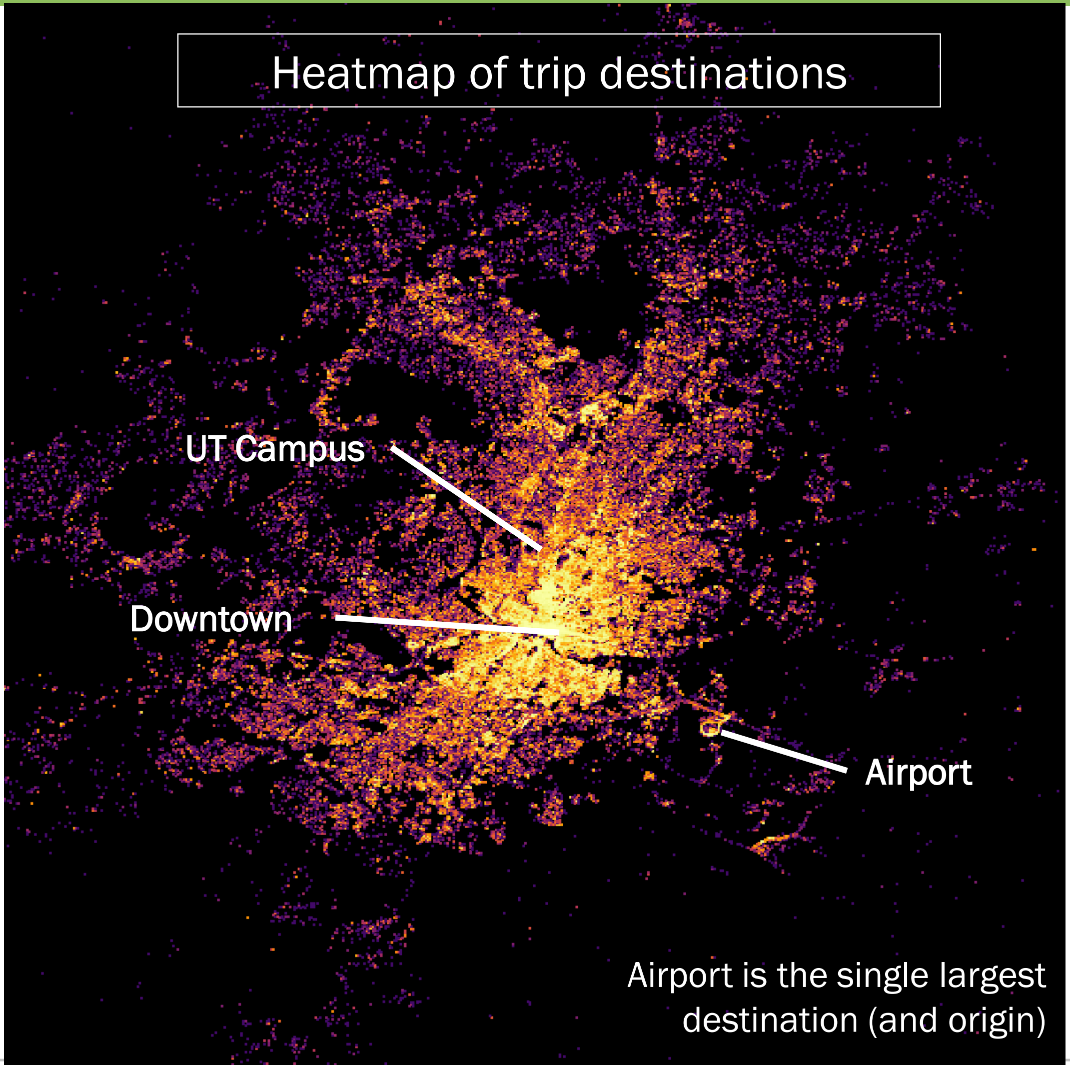
TNC Availability and Vehicle Registrations Preliminary Results

- Vehicle registrations, overall, do not change with TNC-availability
  – Decrease for general public
  – Increase for drivers

- Average "Vehicle Model Year" increase with TNC-availability
  – Thinking twice before you renew your car

TECHNICAL ACCOMPLISHMENTS AND PROGRESS: RideAustin – Preliminary Analysis



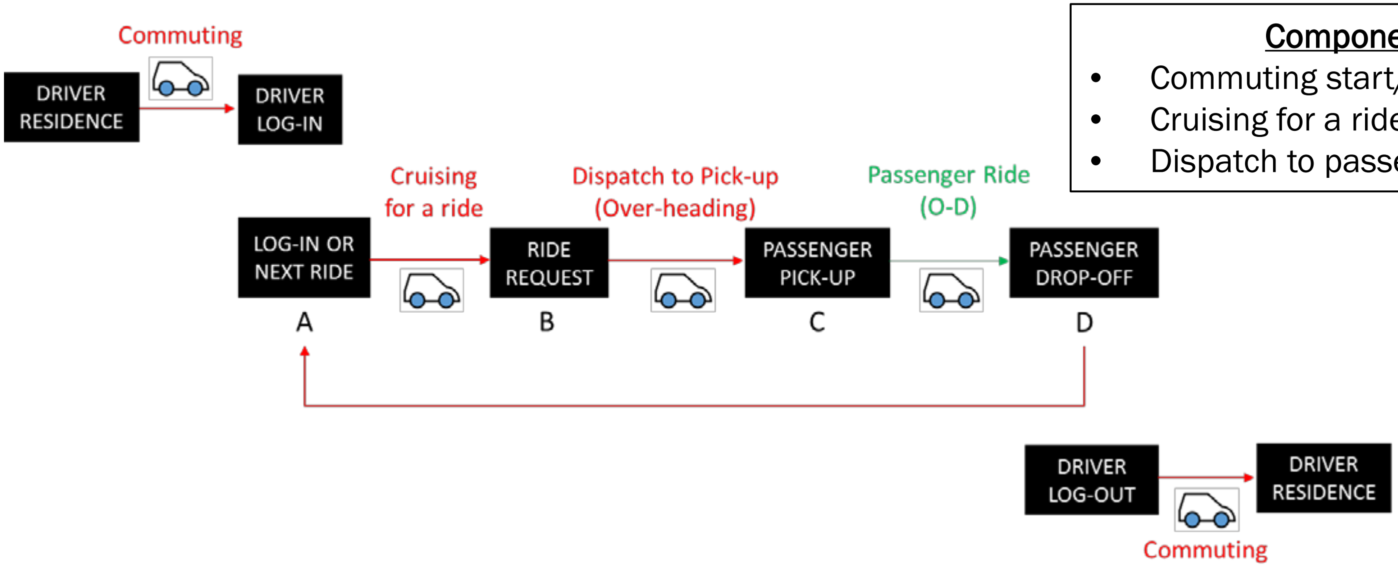


By the numbers

- Sample duration: 10 months
- Period: June 2016 to April 2017
- 4,961 unique drivers & vehicles
- 261,000 unique riders
- 1.49 million trips

Largest TNC data set currently available to researchers

RideAustin – Preliminary Analysis
Deadheading (i.e., empty miles, driving without a passenger)

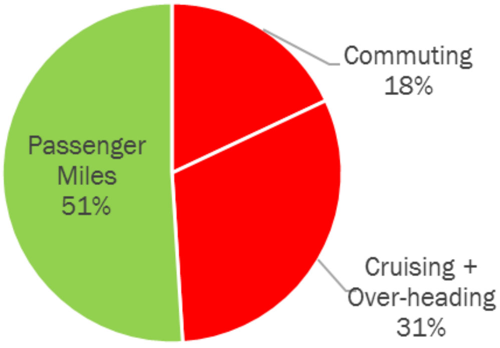


Components of deadheading

- Commuting start/end of driving shift
- Cruising for a ride request
- Dispatch to passenger pick-up (over-heading)

- Data set contains origin–destination (O-D) information for passenger trips and measured distance for passenger ride and from dispatch to pickup
- Distance computed using haversine equation with correction factor of 1.419, based on O-D info versus measured distance of passenger ride
- Inferred driver's "home" location as median position (x, y) of first pickup for every driving day to estimate commute distance to/from "home"
- Preliminary conservative results (using conservative assumptions) consistent with other research

TNC Driving Miles Distribution

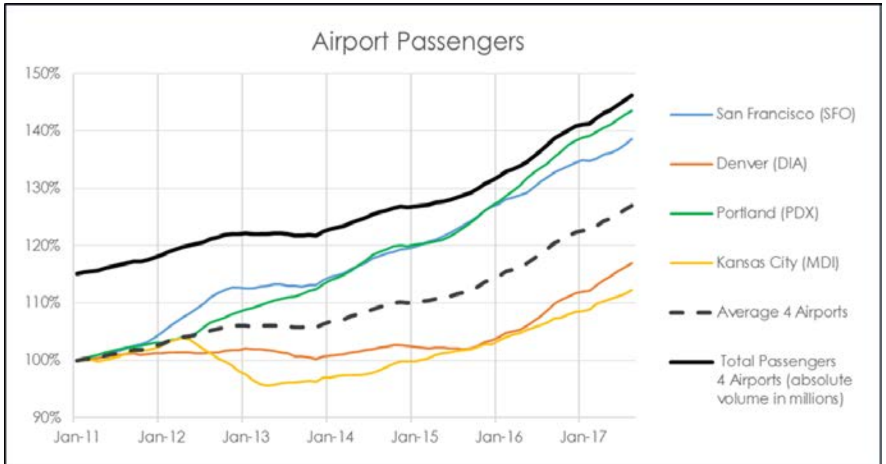


Deadheading = 49%

Synergy with US 2.1.1: Airport Hub Data Collection

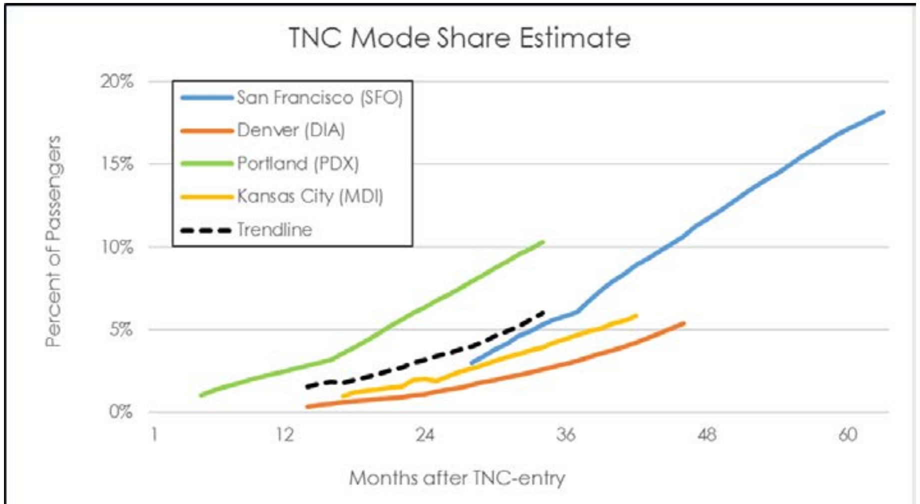
TNC use and impacts:

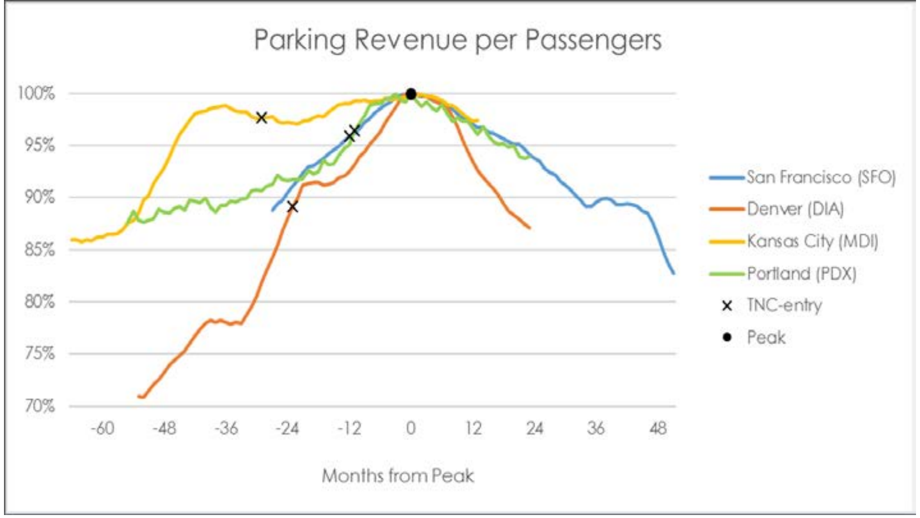
- Airports
- Data from public information request
- TNC mode share estimates
- Mode shift (e.g. parking, car-use)



Notes:

- Total airport passengers (enplaned + deplaned)
- All airports indexed to Jan 2011 as baseline (100%)
- Twelve-month running average, each month
- Airports have mass transit service (except for Kansas City)





RESPONSES TO PREVIOUS YEAR REVIEWERS' COMMENTS

- Project was not reviewed last year

COLLABORATION AND COORDINATION

NREL	National Renewable Energy Laboratory (NREL) • Data gathering, cleansing, analysis • Experience with TNC data collection and analysis
Berkeley Lab	Berkeley Lab • Data gathering, cleansing, analysis • Experience with TNC and regression analysis
Carnegie Mellon University	Carnegie Mellon University (CMU) • Data gathering, cleansing, analysis • Doctoral student – TNC research
Industry Collaboration	Research team requested entry dates to TNCs: • Uber provided a list of UberX entry at some cities • Lyft (in-development) • Other research collaborations (in-development)

CHALLENGES AND BARRIERS

- Data availability and sharing
  - Polk data
  - TNC entry dates
  - Additional TNC data related to mobility behavior changes

PROPOSED FUTURE RESEARCH

- Expand regression model to include analysis of TNC entry on direct energy use (vehicle type, engine size, fuel economy, electric vehicles, newer vehicles)
- Analyze effect of TNC entry on vehicle ownership by ZIP code
- Additional analysis of deadheading variation
- Identify additional TNC data gaps and continue data collection and analysis to better understand how mobility behavior changes induced by TNCs impact energy use
- Develop a TNC energy conversion factor based on the mobility behavior responses (e.g., vehicle ownership, deadheading, vehicle occupancy, modality style changes, mode replacement) using the TNC Energy Framework

[Note: Any proposed future work is subject to change based on funding levels]

SUMMARY

- There are limited data sources and research to understand the energy implications of TNC ride-hailing services.
- This task is gathering data and conducting analysis related to TNCs from a variety of sources.
- Results will start to fill a gap in the energy implications induced by the mobility behavior responses to TNCs.
- Effect analysis of TNC date of entry on vehicle registrations may indicate extent to which travelers value existing vehicles, and how makeup of on-road fleet is changing due to TNCs.
- Preliminary analysis of RideAustin data suggests that nearly half of all TNC miles traveled are without a rider.
- Results can be used as inputs to BEAM and POLARIS to forecast system energy use under different TNC scenarios.

THANK YOU!
QUESTIONS?

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