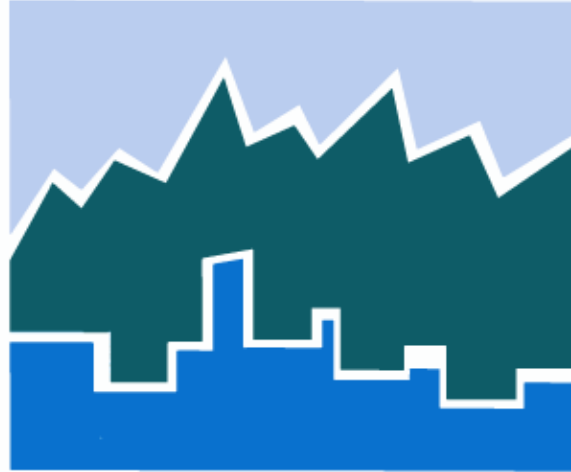# National Household Travel Survey

Compendium of Uses

January 2019 –May 2019

Foreword

This compendium contains various uses and applications of the National Household Travel Survey (NHTS) data used in transportation planning and research from January to May 2019. Published journal articles and reports that cite the use of NHTS data were selected using the Transportation Research Board's (TRB's) Annual Meeting Online Portal, Google Scholar, and Google Alerts. Notification emails were sent by Google when new search results matched predetermined search terms pertaining to NHTS data. The keyword and search engine terms used in both online sources were "National Household Travel Survey" and "NHTS".

The articles and reports in this compendium cover a diverse range of topics in the areas of transportation, health, safety, environment, and engineering and were published in various journals including, but not limited to, the *American Journal of Public Health*, the *International Journal of Behavioral Nutrition and Physical Activity*, and the *National Center for Transit Research*. Several papers were also submitted by researchers and graduate students for presentation and publication to TRB's 98th Annual Meeting and can be found in the 2019 *TRB Annual Meeting Compendium of Papers*.

These selected articles and reports were grouped into 11 categories that were created based on the subject areas and index terms identified in each abstract as well as category titles used in previous NHTS compendium databases. The categories are as follows:

1. Bicycle and pedestrian studies.
2. Energy consumption.
3. Environment.
4. Health.
5. Policy and mobility.
6. Special population groups.
7. Survey, data synthesis, and other applications.
8. Traffic safety.
9. Transit planning.
10. Travel behavior.
11. Trend analysis and market segmentation.

This compendium includes a short description of each article and report along with the title, author(s), abstract, subject areas, and availability.

Please note that this 2019 (interim) compendium consists of 137 research articles and reports. It is updated on an ongoing basis, with newly published papers that cite NHTS data. For information about adding a research paper to the NHTS compendium, please contact Daniel Jenkins at Daniel.Jenkins@dot.gov.

Search and documentation support was provided by Apara Banerjee (MacroSys), who also categorized the paper abstracts.

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Chapter 1. Bicycle and Pedestrian Studies

1.1. Title: Examining Urban and Rural Bicycling in the United States: Early Findings from the 2017 National Household Travel Survey

Author(s): Tribby, C.P. and Tharp, D.S.

Abstract: Introduction: Bicycling has personal and population health benefits. While bicycle research has focused primarily on the urban context, the rural context is equally important. There are documented disparities in health behaviors and health outcomes in rural areas compared to urban areas. It is unknown whether bicycling is one of these health behavior disparities.

Method: This study addresses two questions: 1) what is the prevalence of bicycling behaviors by urbanicity (urban/rural and population density category), and 2) what are the characteristics that best categorize individuals as cyclists versus non-cyclists, overall and for rural populations. We used the 2017 National Household Travel Survey, a nationally representative sample of the US non-institutionalized population (age ≥ 5 years). Bicycling was defined as any bicycling, bicycling for exercise, bicycle commuting, and bike share program use. Analyses used complex survey procedures to estimate unadjusted and adjusted prevalence; and, random forest to rank characteristics that best categorize respondents as bicyclists.

Results: The unadjusted prevalence of any reported bicycling was higher in high-density urban areas ($\geq 10,000$ persons per square mile (ppsm)), 14.7% (95% CI: 13.4%–16.0%), than very low-density rural areas (<500 ppsm), 11.8% (10.4%–13.2%). However, when adjusting for covariates, the prevalence was comparable: high-density urban: 14.4% (12.9%–16.0%); very low-density rural: 12.2% (10.8%–13.7%). Unadjusted prevalence of bicycling for exercise were also similar (high-density urban: 8.2% (7.0%–9.3%); very low-density rural: 7.0% (6.1%–7.9%)). We also found that characteristics that best categorize bicyclists from the overall sample were different from the rural only sample.

Conclusions: This research suggests that bicycling prevalence overall and for exercise are similar between urban and rural areas across population densities. It also suggests that characteristics that were important for rural bicyclists were different from urban bicyclists. Urban-focused bicycle research may need modification to fit the rural context to promote bicycling and physical activity.

Subject Areas: Bicycling; Urban; Rural; Commuting; Bike share program

1.2. Title: Pedestrian and Bicyclist: Scalable Risk Assessment Methods

Author(s): Turner, S., Hampshire, R., Redmon, T. and Fitzpatrick,K.

Abstract: Many transportation agencies are placing more emphasis on improving pedestrian and bicyclist safety and reducing the risk of a fatality or serious injury to pedestrians and bicyclists. Practitioners need a methodical approach to assess pedestrian and bicyclist risk for the purposes of identifying high-priority areas and transportation facilities for safety improvement, evaluating specific countermeasures and locations before and after improvements are made, and tracking safety performance measures over time to gauge progress toward established goals.

Subject Areas: Pedestrian; Bicyclist; Risk

1.3. Title: Transportation Safety Planning Approach for Pedestrians: An Integrated Framework of Modeling Walking Duration and Pedestrian Fatalities

Author(s): Lee, J., Abdel-Aty, M., Huang, H. and Cai, Q.

Abstract: Multiple approaches have been proposed to take traffic safety into consideration in long-term transportation plans, referred to as transportation safety planning. Some early studies used trip generation data as the explanatory variables for their macro-level crash safety performance functions, or crash prediction models. However, no study to date has attempted to integrate walking exposure and pedestrian safety at the modeling stage. Thus, a novel methodological framework for integrating the analyses of walking exposure and pedestrian crashes is proposed toward better transportation safety planning for pedestrians. In comparison with walking trips and walking miles, walking hours was identified as the best walking exposure variable by a preliminary analysis. Thus, an integrated modeling structure with walking hours as its exposure variable was developed. The modeling results indicate that climate conditions, population, and car usage patterns affect walking hours, and predicted walking hours, climate conditions, percentage of mid-elderly (64–75years), proportions of minority race/ethnicity, and percent of tertiary industry occupations have significant effects on pedestrian fatalities. In addition, the integrated modeling framework was compared with non-integrated ones, and the results indicate that the integrated framework outperforms its counterparts in relation to deviance information criterion. The proposed approach and the findings from this study are expected to provide useful insights not only to researchers but also to policy makers and practitioners in the fields of transportation planning and traffic safety.

Subject Areas: Pedestrian; Crash; Transportation Safety Planning

1.4. Title: Walking and Biking are Hurt by Lack of National Leadership: Report

Author(s): Schmitt, A.

Abstract: Blog

Subject Areas: Biking; Walking; Pedestrian fatalities

Availability: Schmitt, A., 2019. *Walking and Biking are Hurt by Lack of National Leadership: Report.* StreetsBlogUSA.
https://usa.streetsblog.org/2019/02/11/walking-and-biking-are-hurt-by-lack-of-national-leadership-report/

1.5. Title: Can this Woman save Biking in Washington State?

Author(s): Weinberger, H.

Abstract: Blog

Subject Areas: Bikes; Features; Urban design; Washington State

Availability: Weinberger, H., 2019. *Can this woman save biking in Washington state?* StreetsBlogUSA.
https://crosscut.com/2019/02/can-woman-save-biking-washington-state

1.6. Title: Uber Concerned with Lime's Issues ahead of Jump e-scooters and e-bikes Launch

Author(s): Nadkarni, A.

Abstract: Blog

Subject Areas: E-Scooters; E-Bikes; Uber

Availability: Nadkarni, A., 2019. *Uber Concerned with Lime's Issues ahead of Jump e-scooters and e-bikes Launch.* stuff.co.nz.
https://www.stuff.co.nz/business/110916170/uber-concerned-with-limes-issues-ahead-of-jump-escooters-and-ebikes-launch

1.7. Title: The Economic Value of Actually Following Through on a Bike Plan

Author(s): Schmitt, A.

Abstract: Blog

Subject Areas: Bike plan; Bike Infrastructure; Safety; Local business

Availability: Schmitt, A., 2019. *The Economic Value of Actually Following Through on a Bike Plan.* StreetsBlogUSA.
https://usa.streetsblog.org/2019/04/12/the-economic-value-of-actually-following-through-on-a-bike-plan/

1.8. Title: Why Traveling on Electric Bike is a Better Choice

Author(s): Frometa, RJ.

Abstract: Blog

Subject Areas: Electric Bike; Easy Commuting; Healthy Choice;

Availability: Frometa, RJ., 2019. *Why Traveling on Electric Bike is a Better Choice.* Vents Magazine.
https://ventsmagazine.com/2019/04/26/why-travelling-on-electric-bike-is-a-better-choice/

1.9. Title: Where should New Schools be Built to Encourage Walking and Wheeling?

Author(s): Nicholas, N.

Abstract: Blog

Subject Areas: Walking; Biking; Schools; Students

Availability: Nicholas, N., 2019. *Where should New Schools be Built to Encourage Walking and Wheeling?* StreetsBlogUSA..
https://denver.streetsblog.org/2019/05/01/guest-post-where-should-new-schools-be-built-to-encourage-walking-and-wheeling/

1.10. Title: Avid Bicyclists celebrate National Bike Month

Author(s): Chodnicki, A.

Abstract: Blog

Subject Areas: Bike; Cyclists; National Bike Month; NHTS; Benefits

Availability: Chodnicki, A., 2019. *Avid Bicyclists celebrate National Bike Month.* 25news.com. https://nbc25news.com/news/local/avid-bicyclists-celebrate-national-bike-month

1.11. Title: Walkability in Tucson: An Overview of Current Trends and Growth Potential

Author(s): Abou-Zeid, G.

Abstract: In the United States, the transportation sector was responsible for 28% of 2016 GHG emissions–the largest contribution of any industry (U.S. EPA, 2018). To reduce dependence on fossil fuels and mitigate their effects, active modes of transportation, like walking, need be planned for. This study provides an overview of walking in Tucson, AZ and subsequent guidance for future development through a) an assessment of walk-mode splits, b) a survey on residential preferences for walking, and c) a built environment case study analysis. It found that walking constituted 11% of all trips, compared to motorized vehicles, which accounted for more than 80% of all trips. Percentage of respondent walk and car trips varied significantly by income and trip purpose. Both Tucson residents and existing literature identified destination proximity as the most important built environment factor considered in deciding to walk. A complete streets project that incorporated many built environment features found to improve walkability (e.g., street connectivity, accessibility, walking infrastructure) but failed to account for destination proximity had little impact of walking behavior. To better promote walkability in Tucson, emphasis on coordination between transportation and land use planning and connection of walkability to social and cultural values is necessary.

Subject Areas: GHG emissions; Walkability; Transportation; Land use planning

Availability: Abou-Zeid, G., 2019. *Walkability in Tucson: An Overview of Current Trends and Growth Potential.* Doctoral dissertation, The University of Arizona. https://repository.arizona.edu/handle/10150/632229

1.12. Title: Examining the Influence of Network, Land Use, and Demographic Characteristics to Estimate the Number of Bicycle-Vehicle Crashes on Urban Roads

Author(s): Mukoko, K.K. and Pulugurtha, S.S.

Abstract: The focus of this paper is to examine the influence of network, land use, and demographic characteristics on the number of bicycle-vehicle crashes, and to develop area-level bicycle-vehicle crash estimation models (safety performance functions) for urban roads. Mecklenburg County in the State of North Carolina was considered as the study area. The reported bicycle-vehicle crash data, from 2010 to 2015, along with the network, land use, and demographic characteristics data were obtained from the local agencies. Data within a one-mile buffer of 119 selected locations was then captured. Data for 99 selected locations were used for the modeling purpose, while data for the remaining 20 selected locations were used for validating the models. Six alternate models were developed, considering various combinations of explanatory variables that are not correlated with each other. As the bicycle-vehicle crash dataset used in this research was observed to be over-dispersed (variance greater than the mean), Negative Binomial log-link distribution-based models were developed. The validation dataset was used to compare the estimated number of bicycle-vehicle crashes from each model with the actual number of bicycle-vehicle crashes. The results obtained from the analysis and modeling suggest that bicyclists are more often involved in crashes while traveling on segments with no bicycle lane, the traffic light, 45 mph as the speed limit, and in commercial activity, research activity, institutional, multi-family residential (densely populated), and heavy industrial areas. The computed Moran's Index values indicate weak to no spatial correlation between the residuals of each model. However, the residuals seem to depend on the area type and the number of bicycle-vehicle crashes.

Subject Areas: Bicycle; Crash; Network; Land use; Demographics; SPF

1.13. Title: How Have Travelers Changed Mode Choices for First/Last Mile Trips after the Introduction of Bicycle-Sharing Systems: An Empirical Study in Beijing, China

Author(s): Fan, A., Chen, X. and Wan, T.

Abstract: In recent years, there has been rapid development in bicycle-sharing systems (BSS) in China. Moreover, such schemes are considered promising solutions to the first/last mile problem. This study investigates the mode choice behaviors of travelers for first/last mile trips before and after the introduction of bicycle-sharing systems. Travel choice models for first/last mile trips are determined using a multinomial logit model. It also analyzes the differences in choice behavior between the young and other age groups. The findings show that shared bicycles become the preferred mode, while travelers preferred walking before bicycle-sharing systems were implemented. Gender, bicycle availability, and travel frequency were the most significant factors before the implementation of bicycle-sharing systems. However, after implementation, access distance dramatically affects mode choices for first/last mile trips. When shared bicycles are available, the mode choices of middle-aged group depend mainly on gender and access distance. All factors are not significant for the young and aged groups. More than 80% of public transport travelers take walking and shared bicycles as feeder modes. The proposed models and findings contribute to a better understanding of travelers' choice behaviors and to the development of solutions for the first/last mile problem.

Subject Areas: Bicycle-Sharing Systems (BSS); First/Last Mile Trips; Mode Choices

Availability: Fan, A., Chen, X. and Wan, T., 2019. *How Have Travelers Changed Mode Choices for First/Last Mile Trips after the Introduction of Bicycle-Sharing Systems: An Empirical Study in Beijing, China.* Journal of Advanced Transportation.
https://www.hindawi.com/journals/jat/2019/5426080/abs/

1.14. Title: Disaster Relief Trials: Perceptions of a Disaster-Themed Bicycling Event

Author(s): Kirkpatrick, S.B.

Abstract: Purpose: Bicycling enthusiasts have been organizing community events in US cities to demonstrate how bicycles may be of use in the aftermath of a disaster event. The purpose of this paper is to examine the perceived value of these events and levels of engagement in the same amongst emergency managers, community organizers and bicycling advocates.

Design/methodology/approach: Data were collected through 21 in-depth, telephone interviews with emergency management officials and bicycling advocates in bicycle-friendly jurisdictions in the USA and analyzed using initial and focused coding, analytic memos and theoretical sorting.

Findings: The study found that event organizers and other bicycle advocates widely embraced the concept as a means to change societal perceptions of bicycles as viable modes of tra nsportation, indicating at least some level of interest in taking an active role in its pursuit. Emergency managers were generally receptive to the idea, but they largely saw the value as restricted to raising public awareness about hazards and individual preparedness measures; and they mostly envisioned for themselves a minimal role in event planning and execution.

Practical implications: The findings suggest that when operating in a resource-poor environment with limited public and political support, there are innovative partnerships and ideas that can be successfully leveraged to advance multiple purposes.

Originality/value: Almost no empirical research has looked at the disaster relief trial concept, given the relative newness and novelty of the idea. An examination of perceived value of disaster-oriented community bicycling events seems warranted as such events continue to grow in existing locations and emerge in new locales each year.

Subject Areas: Disaster; Bicyclists; Preparedness; Emergency management; Community engagement; Bicycle; Disaster relief trial

1.15. Title: Utilizing Multi-Stage Behavior Change Theory to Model the Process of Bike Share Adoption

Author(s): Biehl, A., Ermagun, A. and Stathopoulos, A.

Abstract: This paper studies bike share adoption decisions as a dynamic change process from early contemplation to consolidated user status. This runs counter to the typical representation of mode adoption decisions as an instantaneous shift from pre to post usage. A two-level nested logit model that draws from the stage-of-change framework posited by the Transtheoretical Model is developed to study the adoption process. Using survey data collected from an online U.S. sample (n=910), the model illustrates how personal, psychosocial, and community-oriented factors influence the probability of transitioning between different levels of readiness to participate in a bike share scheme. The findings suggest that encouraging forward movement in the contemplation-use ladder requires tailored, stage-specific interventions that are likely be overlooked if instead a one-size-fits-all psychological theory is applied to investigate travel behavior. In particular, the intermediate stages encapsulate more flexible (i.e. less habitual) orientation among respondents. Among the explanatory variables, the pronounced elasticities for active travel identity formation and norm integration are especially significant for crafting policies that influence bike share membership decisions. This paper adds to the nascent literature on the behavioral foundations of shared mobility adoption. The findings are translated to practical interventions, from operations to design and community-initiatives to guide practitioners seeking to promote bike share. The stage-based adoption representation helps to align interventions across the spectrum of user readiness to translate intention into behavior.

Subject Areas: Bike share; Stages of change; Factor analysis; Discrete choice model; Segmentation

1.16. Title: Bicycle Safety Analysis at Intersections from Crowdsourced Data

Author(s): Saad, M., Abdel-Aty, M., Lee, J. and Cai, Q.

Abstract: Cycling is encouraged in countries around the world as an economic, energy efficient, and sustainable mode of transportation. Although there are many studies focusing on analyzing bicycle safety, they have limitations because of the shortage of bicycle exposure data. This study represents a major step forward in estimating safety performance functions for bicycle crashes at intersections by using crowdsourced data from STRAVA. Several adjustments in respect of the population distribution and field observations were made to overcome the disproportionate representation of the STRAVA data. The adjusted STRAVA data which include bicycle exposure information were used as input to develop safety performance functions. The functions are negative binomial models aimed at predicting frequencies of bicycle crashes at intersections. The developed model was compared with three counterparts: the model using the unadjusted STRAVA data, the model using the STRAVA data with field observation data adjustments only, and the model using the STRAVA data with adjusted population. The results revealed that the case of STRAVA data with both population and field observation data adjustments had the best performance in bicycle crash modeling. The results also addressed several key factors (e.g., signal control system, intersection size, bike lanes) which are associated with bicycle safety at intersections. Additionally, the safety-in-numbers effect was acknowledged when bicycle crash rates decreased as bicycle activities increased. The study concluded that crowdsourced data are a reliable source for exploring bicycle safety after the appropriate adjustments.

Subject Areas: Bicycle; Bicycle Safety; Crowdsourced Data; STRAVA

Chapter 2. Energy Consumption

2.1. Title: Fleet Right-sizing: The Corporate Average Fuel Economy Effect of a Transition to a Shared Autonomous Fleet

Author(s): Barber, E., Chernicoff, W. and Mackenzie, D.

Abstract: Prior research suggests that one of the largest opportunities for highly automated vehicles to save energy comes through enabling on-demand mobility services. Matching vehicle sizes to trip needs can reduce vehicle size compared with private consumers' preference for one vehicle that can meet all (or nearly all) their trip needs. This paper develops a framework to assess how shared mobility fleet right-sizing will affect Corporate Average Fuel Economy (CAFE) standards, while considering spatial and temporal variation in demand for different Travel party sizes. The authors develop an example implementation using National Household Travel Survey (NHTS) data and model year 2016 CAFE standard target curves, which suggest that a right-sized shared mobility fleet would face a Corporate Average Fuel Economy standard about 7 mpg (20%) higher than the actual fleet sold in MY 2016.

Subject Areas: Energy; Environment; Highways; Planning and Forecasting; Policy; Vehicles and Equipment

Availability: Barber, E., Chernicoff, W. and Mackenzie, D., 2019. *Fleet Right-sizing: The Corporate Average Fuel Economy Effect of a Transition to a Shared Autonomous Fleet.* Transportation Research Board 98th Annual Meeting.
https://trid.trb.org/view/1573054

2.2. Title: Energy Efficiency Standards Are More Regressive Than Energy Taxes: Theory and Evidence

Author(s): Levinson, A.

Abstract: Economists endorse taxes as a cost-effective means of reducing pollution. But policy makers raise concerns about their regressivity, or disproportional burden on poorer families, preferring instead to regulate energy efficiency. I first show that in theory, energy efficiency standards are more regressive than energy taxes, not less. I then provide an example using data on automobiles in the United States. Taxing gas would be less regressive than regulating the fuel economy of cars if the two policies are compared on a revenue-equivalent basis.

Subject Areas: Externalities; Redistributive effects; Environmental taxes; Subsidies

2.3. Title: Ownership and Usage Analysis of Alternative Fuel Vehicles in the United States with the 2017 National Household Travel Survey Data

Author(s): Li, X., Liu, C. and Jia, J.

Abstract: By using the 2017 National Household Travel Survey (NHTS) data, this study explores the status quo of ownership and usage of conventional vehicles (CVs) and alternative fuel vehicles (AFVs), i.e., Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs), in the United States. The young ages of HEVs (6.0 years), PHEVs (3.2 years) and BEVs (3.1 years) demonstrate the significance of the 2017 NHTS data. The results show that after two decades of development, AFVs only occupy about 5% of annual vehicle sales, and their share does not show big increases in recent years. Meanwhile, although HEVs still dominate the AFV market, the share of PHEVs & BEVs has risen to nearly 50% in 2017. In terms of ownership, income still seems to be a major factor influencing AFV adoption, with the median annual household incomes of CVs, HEVs, PHEVs and BEVs being $75,000, $100,000, $150,000 and $200,000, respectively. Besides, AFV households are more likely to live in urban areas, especially large metropolitan areas. Additionally, for AFVs, the proportions of old drivers are much smaller than CVs, indicating this age group might still have concerns regarding adopting AFVs. In terms of travel patterns, the mean and 85th percentile daily trip distances of PHEVs and HEVs are significantly larger than CVs, followed by BEVs. BEVs might still be able to replace CVs for meeting most travel demands after a single charge, considering most observed daily trip distances are fewer than 93.5 km for CVs. However, the observed max daily trip distances of AFVs are still much smaller than CVs, implying increasing the endurance to meet extremely long-distance travel demands is pivotal for encouraging consumers to adopt AFVs instead of CVs in the future.

Subject Areas: Alternative Fuel Vehicle; Hybrid Electric Vehicle; Plug-In Hybrid Electric Vehicle; Battery Electric Vehicle; 2017 National Household Travel Survey; Ownership; Travel Patterns

2.4. Title: Forecasting the Impact of Connected and Automated Vehicles on Energy Use: A Microeconomic Study of Induced Travel and Energy Rebound

Author(s): Taiebat, M., Stolper, S. and Xu, M.

Abstract: Connected and automated vehicles (CAVs) are expected to yield significant improvements in safety, energy efficiency, and time utilization. However, their net effect on energy and environmental outcomes is unclear. Higher fuel economy reduces the energy required per mile of travel, but it also reduces the fuel cost of travel, incentivizing more travel and causing an energy "rebound effect." Moreover, CAVs are predicted to vastly reduce the time cost of travel, inducing further increases in travel and energy use. In this paper, we forecast the induced travel and rebound from CAVs using data on existing travel behavior. We develop a microeconomic model of vehicle miles traveled (VMT) choice under income and time constraints; then we use it to estimate elasticities of VMT demand with respect to fuel and time costs, with fuel cost data from the 2017 United States National Household Travel Survey (NHTS) and wage-derived predictions of travel time cost. Our central estimate of the combined price elasticity of VMT demand is –0.4, which differs substantially from previous estimates. We also find evidence that wealthier households have more elastic demand, and that households at all income levels are more sensitive to time costs than to fuel costs. We use our estimated elasticities to simulate VMT and energy use impacts of full, private CAV adoption under a range of possible changes to the fuel and time costs of travel. We forecast a 2–47% increase in travel demand for an average household. Our results indicate that backfire –i.e., a net rise in energy use –is a possibility, especially in higher income groups. This presents a stiff challenge to policy goals for reductions in not only energy use but also traffic congestion and local and global air pollution, as CAV use increases.

Subject Areas: Automated vehicles; Rebound effect; Fuel economy; Energy demand; Induced travel; Travel time cost

Availability: Taiebat, M., Stolper, S. and Xu, M., 2019. *Forecasting the Impact of Connected and Automated Vehicles on Energy Use: A Microeconomic Study of Induced Travel and Energy Rebound.* Journal of Applied Energy.
https://www.sciencedirect.com/science/article/pii/S0306261919305823?via%3Dihub

2.5. Title: Charging Demand of Plug-in Electric Vehicles: Forecasting Travel Behavior Based on a Novel Rough Artificial Neural Network Approach

Author(s): Jahangir, H., Tayarani, H., Ahmadian, A., Golkar, M.A., Miret, J., Tayarani, M. and Gao, H.O.

Abstract: The market penetration of Plug-in Electric Vehicles (PEVs) is escalating due to their energy saving and environmental benefits. In order to address PEVs impact on the electric networks, the aggregators need to accurately predict the PEV Travel Behavior (PEV-TB) since the addition of a great number of PEVs to the current distribution network poses serious challenges to the power system. Forecasting PEV-TB is critical because of the high degree of uncertainties in drivers' behavior. Existing studies mostly simplified the PEV-TB by mapping travel behavior from conventional vehicles. This could cause bias in power estimation considering the differences in PEV-TB because of charging pattern which consequently could bungle economic analysis of aggregators. In this study, to forecast PEV-TB an artificial intelligence-based method -feedforward and recurrent Artificial Neural Networks (ANN) with Levenberg Marquardt (LM) training method based on Rough structure - is developed. The method is based on historical data including arrival time, departure time and trip length. In this study, the correlation among arrival time, departure time and trip length is also considered. The forecasted PEV-TB is then compared with Monte Carlo Simulation (MCS) which is the main benchmarking method in this field. The results comparison depicted the robustness of the proposed methodology. The proposed method reduces the aggregators' financial loss approximately by 16\$/PEV per year compared to the conventional methods. The findings underline the importance of applying more accurate methods to forecast PEV-TB to gain the most benefit of vehicle electrification in the years to come.

Subject Areas: Plug-in electric vehicle; Travel behavior; Artificial neural network; Rough neuron; Smart charging

Availability: Jahangir, H., Tayarani, H., Ahmadian, A., Golkar, M.A., Miret, J., Tayarani, M. and Gao, H.O., 2019. *Charging Demand of Plug-in Electric Vehicles: Forecasting Travel Behavior Based on a Novel Rough Artificial Neural Network Approach.* Journal of Cleaner Production, 229, pp.1029-1044.
https://www.sciencedirect.com/science/article/pii/S0959652619314428

2.6. Title: Fuel Cell Electric Vehicle Driving and Fueling Behavior

Author(s): Kurtz, J.M., Sprik, S., Saur, G. and Onorato, S.

Abstract: The objectives of this project are to validate hydrogen fuel cell electric vehicles in real-world settings and to identify the current status and evolution of the technology. The analysis objectively assesses progress toward targets and market needs defined by the U.S. Department of Energy and stakeholders, provides feedback to hydrogen research and development, and publishes results for key stakeholder use and investment decisions. Fiscal year 2018 objectives focused on analysis and reporting of fuel cell electric vehicle driving range, fuel economy, drive and fill behaviors, durability, fill performance, and fuel cell performance. This report specifically addresses the topics of driving range, fuel economy, drive and fill behaviors, and fill performance.

Subject Areas: 33 ADVANCED PROPULSION SYSTEMS; Fuel Cell; Hydrogen; FCEV; Driving Range, Fuel Economy; Fill Performance; Drive And Fill Behaviors; NFCTEC; National Fuel Cell Technology Evaluation Center

Availability: Kurtz, J.M., Sprik, S., Saur, G. and Onorato, S., 2019. *Fuel Cell Electric Vehicle Driving and Fueling Behavior.* (No. NREL/TP-5400-73010). National Renewable Energy Lab.(NREL), Golden, CO (United States).
https://www.osti.gov/biblio/1501674

2.7. Title: Comparison of Marginal and Average Emission Factors for Passenger Transportation Modes

Author(s): Bigazzi, A.

Abstract: Comparisons of the energy and emission intensity of transportation modes are standard features of sustainable transportation research, policy, and advocacy. These comparisons are typically based on average energy and emission factors per passenger trip or per passenger-kilometer traveled. However, as acknowledged in the energy production sector, comparing average emission factors can misinform policy and other decisions because it fails to represent the marginal impact of changing demand. The objective of this paper is to quantify the difference between average and marginal energy and emission factors for passenger transportation modes. Transportation system operations data are used to estimate energy and emission factors per passenger-kilometer traveled for U.S. urban and intercity travel. Marginal emission factors range from 30% (intercity rail) to 90% (private vehicles) of average factors. For urban travel, private vehicles and public transit have similar average emission factors, but marginal factors are 50% lower for transit. The average emission factor for intercity rail is 10% lower than air travel and 30% lower than private vehicles, but the marginal factor is 60% and 80% lower, respectively. Using average energy and emission factors to represent the impacts of travel by different modes is biased against public transit and discounts the benefits of shifting travel away from private passenger vehicles.

Subject Areas: Emission factors; Marginal effects; Transportation systems; Transportation modes; Motor vehicles

2.8. Title: Charging Load Forecasting of Electric Vehicle Based on Charging Frequency

Author(s): Wang, H.J., Wang, B., Fang, C., Li, W. and Huang, H.W.

Abstract: The rapid development of electric vehicles (EVs) will gradually increase the operating pressure of the power grid. The charging load of EVs need to be predicred to release this pressure. In this paper, the influence factors of EV charging load are analyzed and the load curve of different charging modes is obtained. According to the 2009 American families travel survey, EVs are divided into three types: private cars, buses and taxis. Then, different EVs' charging frequency, together with the starting point for state of charge (SOC) and daily mileage can be calculated. Correspondingly, the probability density function model can be established. Finally, the daily charging load is calculated by Monte Carlo algorithm, which provides the basis for the research of orderly EV charging.

Subject Areas: Electric vehicles (EVs); Power Grid; Monte Carlo algorithm

2.9. Title: Modeling Charging Behavior of Battery Electric Vehicle Drivers: A Cumulative Prospect Theory Based Approach

Author(s): Hu, L., Dong, J. and Lin, Z.

Abstract: The behavior of drivers in charging a battery electric vehicle (BEV) can be influenced by psychological factors such as personality and risk preference. This paper proposes a cumulative prospect theory (CPT) based modeling framework to describe the charging behavior of BEV drivers. CPT captures an individual's attitude and preference toward risk in the decision-making process. A BEV mass-market scenario is constructed using the 2017 National Household Travel Survey (NHTS) data. This paper applies the CPT-based charging behavior model to study the battery state-of-charge (SOC) when drivers decide to charge their vehicles, charging timing and location choices, and charging power demand profile under the mass-market scenario. In addition, sensitivity analyses are used to examine the drivers' risk attitudes and public charger network coverage. BEV drivers who display a higher degree of risk-seeking tend to charge vehicles at a lower SOC. Some home charging shifts to workplace and public charging as the public charger network expands, but home charging still plays the most significant role in BEV use. The power demand from public chargers increases significantly with BEV expansion and has a larger impact on the power grid. The time-of-use (TOU) electricity rate can shift peak power demand to off-peak periods from midnight to early morning.

Subject Areas: Battery electric vehicle; Charging behavior; Cumulative prospect theory; 2017 National Household Travel Survey (NHTS); Power grid

2.10. Title: Potential Energy Implications of Connected and Automated Vehicles: Exploring Key Leverage Points through Scenario Screening and Analysis

Author(s): Bush, B., Vimmerstedt, L. and Gonder, J.

Abstract: Connected and automated vehicle (CAV) technologies could transform the transportation system over the coming decades, but face vehicle and systems engineering challenges, as well as technological, economic, demographic, and regulatory issues. The authors have developed a system dynamics model for generating, analyzing, and screening self-consistent CAV adoption scenarios. Results can support selection of scenarios for subsequent computationally intensive study using higher-resolution models. The potential for and barriers to large-scale adoption of CAVs have been analyzed using preliminary quantitative data and qualitative understandings of system relationships among stakeholders across the breadth of these issues. Although they are based on preliminary data, the results map possibilities for achieving different levels of CAV adoption and system-wide fuel use and demonstrate the interplay of behavioral parameters such as how consumers value their time versus financial parameters such as operating cost. By identifying the range of possibilities, estimating the associated energy and transportation service outcomes, and facilitating screening of scenarios for more detailed analysis, this work could inform transportation planners, researchers, and regulators.

Subject Areas: Connected and automated vehicle (CAV); Fuel use; Operating cost

Availability: Bush, B., Vimmerstedt, L. and Gonder, J., 2019. *Potential Energy Implications of Connected and Automated Vehicles: Exploring Key Leverage Points through Scenario Screening and Analysis.* Transportation Research Record.
https://journals.sagepub.com/doi/abs/10.1177/0361198119838840

2.11. Title: Assessment of Light-Duty Plug-In Electric Vehicles in the United States, 2010–2018

Author(s): Gohlke, D. and Zhou, Y.

Abstract: This report examines properties of plug-in electric vehicles (PEVs) sold in the United States from 2010 to 2018, exploring vehicle sales, miles driven, electricity consumption, petroleum reduction, vehicle manufacturing, and battery production, among other factors. Over one million PEVs have been sold, driving over 25 billion miles on electricity since 2010, thereby reducing national gasoline consumption by 0.23% in 2018 and 950 million gallons cumulatively through 2018. In 2018, PEVs used 2.8 terawatt-hours of electricity to drive 8.6 billion miles, offsetting 320 million gallons of gasoline. The majority of these vehicles were assembled in the United States, and over 42 gigawatt-hours of lithium-ion batteries have been installed in vehicles.

Subject Areas: Plug-in electric vehicles (PEVs); Fuel consumption; Gasoline

Availability: Gohlke, D. and Zhou, Y., 2019. *Assessment of Light-Duty Plug-In Electric Vehicles in the United States, 2010–2018.* No. ANL/ESD-19/2). Argonne National Lab.(ANL), Argonne, IL (United States).
https://www.osti.gov/biblio/1506474-assessment-light-duty-plug-electric-vehicles-united-states

2.12. Title: Modeling Electric Vehicle Adoption Considering A Latent Travel Pattern Construct And Charging Infrastructure

Author(s): Nazari, F., Mohammadian, A.K. and Stephens, T.

Abstract: This paper presents a behavioral model of public, revealed preferences (RP) for various types of electric vehicles (EVs) while accounting for a latent (green) travel pattern construct and charging infrastructure characteristics. Specifically, a two-level nested logit (NL) model is estimated to explain households' fuel type choice among five alternatives and three nests: (1) battery electric vehicles (BEVs); (2) hybrid vehicles including hybrid electric vehicles (HEVs) and plug-in HEVs (PHEVs); and (3) conventional vehicles including gasoline and diesel vehicles. Further, a latent travel pattern construct which captures a week-long number of trips by non-vehicle travel modes as well as daily vehicle and tollway use is estimated in a structural equation setting and subsequently fed into the NL model. Using a recent RP dataset from the California Household Travel Survey, we identify market segments for alternative fuel types based on households' socio-economic characteristics, built environment factors concerning public plug-in EV (PEV) charging infrastructure characteristics, latent and observable travel behavior factors of a household vehicle's principal driver, and vehicle attributes. The results highlight that the number of public PEV charging stations is only significant for households choosing PHEVs and interestingly insignificant in the BEV utility. Furthermore, the sensitivity analysis of the findings reveals that PHEV users are elastic with respect to household vehicle ownership ratio and the latent green travel pattern construct, while BEV users are inelastic to any explanatory variable.

Subject Areas: Battery electric vehicle; Plug-in hybrid electric vehicle; Latent travel pattern; Charging infrastructure; Revealed preferences

2.13. Title: Should Electric Vehicle Drivers Pay a Mileage Tax?

Author(s): Davis, L. and Sallee, J.

Abstract: In many countries the revenue from gasoline taxes is used to fund highways and other transportation infrastructure. As the number of electric vehicles on the road increases, this raises questions about the effectiveness and equity of this financing mechanism. In this paper, we ask whether electric vehicle drivers should pay a mileage tax. Though the gasoline tax has been traditionally viewed as a benefits tax, we take instead the perspective of economic efficiency. We derive a condition for the optimal electric vehicle mileage tax that highlights a key trade-off. On the one hand, there are externalities from driving including traffic congestion and accidents that imply a mileage tax is efficient. On the other hand, gasoline tends to be underpriced, so a low (or even negative) mileage tax might be justified to encourage substitution away from gasoline-powered vehicles. We then turn to an empirical analysis aimed at better understanding the current policy landscape for electric vehicles in the United States. Using newly-available nationally representative microdata we calculate that electric vehicles have reduced gasoline tax revenues by $250 million annually. We show that the foregone tax revenue is highly concentrated in a handful of states and is highly regressive, as most electric vehicles are driven by high-income households, and we discuss how this motivates and informs optimal policy.

Subject Areas: Electric Vehicles; Gasoline Tax, U.S. Highway Trust Fund, Distributional Impacts

Availability: Davis, L. and Sallee, J., 2019. *Should Electric Vehicle Drivers Pay a Mileage Tax?* Energy Institute WP301.
https://ei.haas.berkeley.edu/research/papers/WP301.pdf

2.14. Title: Full-scale Electric Vehicles Penetration in the Danish Island of Bornholm — Optimal Scheduling and Battery Degradation under Driving Constraints

Author(s): Gonzàlez-Garrido, A., Thingvad, A., Gaztaǹaga, H. and Marinelli, M.

Abstract: The paper proposes an analysis of a 100% electric vehicle (EV) scenario on the energy system of the island of Bornholm in Denmark. The paper intends to present challenges and opportunities that a realistic system would face when completely shifting to electric transportation. The EVs are subject to different charging strategies in order to assess the impact on the grid, the potential savings on the charging cost and the effects on battery degradation. In contrast to uncontrolled charging, smart charging strategies are designed not only to satisfy the same charging requirements at the EV departure time, but also maximize the savings on the charging cost and avoid interconnection congestions. Smart strategies bring a reduction in annual charging cost around 12%, on top of a reduction in the degradation because of lower average SOC and number of cycles. Moreover, results show a limited benefit in bidirectional charging because of a marginal increase in savings: this more demanding operation, which allows discharges, leads to higher battery degradation, due to the increase in the number of cycles.

Subject Areas: Battery degradation; Electric vehicles; Optimization; Smart charging; User behavior; Vehicle-to-grid

Availability: Gonzàlez-Garrido, A., Thingvad, A., Gaztaǹaga, H. and Marinelli, M., 2019. *Full-scale Electric Vehicles Penetration in the Danish Island of Bornholm — Optimal Scheduling and Battery Degradation under Driving Constraints* Journal of Energy Storage, 23, pp.381-391.
https://www.sciencedirect.com/science/article/pii/S2352152X18308405

2.15. Title: Meeting 2025 Zero Emission Vehicle Goals: An Assessment of Electric Vehicle Charging Infrastructure in Maryland

Author(s): Moniot, M., Rames, C.L. and Wood, E.W.

Abstract: The National Renewable Energy Laboratory (NREL) has been enlisted to conduct a statewide assessment of the electric vehicle charging infrastructure requirements for Maryland to meet its goal of supporting 300,000 zero emission vehicles by 2025. NREL's Electric Vehicle Infrastructure Projection Tool (EVI-Pro) was used to generate scenarios of statewide charging infrastructure to support consumer plug-in electric vehicle (PEV) adoption based on travel patterns provided by INRIX (a commercial mapping/traffic company) that are used to characterize regional travel in Maryland and to anticipate future demand for PEV charging. Results indicate that significant expansion of Maryland's electric vehicle charging infrastructure will be required to support the state's PEV goal for 2025. Analysis shows that a fleet of 300,000 PEVs will require 17,400 workplace Level 2 plugs, 9,300 public Level 2 plugs, and 1,000 fast charge plugs. These estimates assume that future PEVs will be driven in a manner consistent with present day gasoline vehicles and that most charging will happen at residential locations. A sensitivity study explores edge cases pertaining to several assumptions, highlighting factors that heavily influence the projected infrastructure requirements. Variations in the makeup of the PEV fleet, evolving consumer charging preferences, and availability of residential charging are all shown to influence 2025 infrastructure requirements.

Subject Areas: 33 ADVANCED PROPULSION SYSTEMS; Zero Emission Vehicles; Electric Vehicles; Charging Infrastructure; PEVs; Electric Vehicle Supply Equipment

Availability: Moniot, M., Rames, C.L. and Wood, E.W., 2019. *Meeting 2025 Zero Emission Vehicle Goals: An Assessment of Electric Vehicle Charging Infrastructure in Maryland.* (No. NREL/TP-5400-71198). National Renewable Energy Lab.(NREL), Golden, CO (United States).
https://www.osti.gov/biblio/1496855

2.16. Title: Modeling the GHG Emissions Intensity of Plug-in Electric Vehicles using Short-Term and Long-Term Perspectives

Author(s): Kamiya, G., Axsen, J. and Crawford, C.

Abstract: Plug-in electric vehicles (PEVs) can contribute to deep greenhouse gas (GHG) reduction targets but their efficacy depends on the sources of electricity. PEV GHG intensity can vary over time (and regionally), making it unclear how policymakers should regulate PEVs in the short and long-term. To explore this uncertainty, we model the short-term (Study 1) and long-term (Study 2) well-to-wheels GHG intensity of PEVs in three regions with very different electricity grid profiles: the Canadian provinces of British Columbia, Alberta, and Ontario. Study 1 uses empirical data on vehicle preferences, driving patterns, and recharge access from a representative survey of new vehicle buyers in Canada (n=1754) to construct a temporally-explicit model of PEV usage in 2015. Fleet-wide emissions intensity of PEVs varies substantially between regions, with the greatest reduction potential relative to conventional gasoline vehicles seen in British Columbia (78–98%), followed by Ontario (58–92%) and Alberta (34–41%). Study 2 simulates the potential long-term dynamics of technology, behavior, and emissions with the CIMS energy-economy model. With the emissions intensity of electricity decreasing by at least one-third by 2050 and vehicle energy efficiency improving over time, simulation results find that, compared to 2015, 2050 fleet average PEV emissions are 40–52% lower in British Columbia, 57–74% lower in Alberta, and 36–46% lower in Ontario. Overall, we find that PEVs offer substantial GHG emissions benefits compared to conventional vehicles in all scenarios explored. Policy makers seeking deep GHG cuts may want to support PEV adoption, even in jurisdictions that presently use relatively carbon-intensive electricity.

Subject Areas: Greenhouse gas emissions; Passenger vehicles; Plug-in electric vehicles; Well-to-wheel; Consumer behavior; Climate change

2.17. Title: Acceptability, Energy Consumption, and Costs of Electric Vehicle for Ride-hailing Drivers in Beijing

Author(s): Tu, W., Santi, P., Zhao, T., He, X., Li, Q., Dong, L., Wallington, T.J. and Ratti, C.

Abstract: The acceptability, energy consumption, and environmental benefits of electric vehicles are highly dependent on travel patterns. With increasing ride-hailing popularity in mega-cities, urban mobility patterns are greatly changing; therefore, an investigation of the extent to which electric vehicles would satisfy the needs of ride-hailing drivers becomes important to support sustainable urban growth. A first step in this direction is reported here. GPS-trajectories of 144,867 drivers over 104 million km in Beijing were used to quantify the potential acceptability, energy consumption, and costs of ride-hailing electric vehicle fleets. Average daily travel distance and travel time for ride-hailing drivers was determined to be 129.4km and 5.7h; these values are substantially larger than those for household drivers (40.0km and 1.5h). Assuming slow level-1 (1.8 KW) or moderate level-2 (7.2 KW) charging is available at all home parking locations, battery electric vehicles with 200km all electric range (BEV200) could be used by up to 47% or 78% of ride-hailing drivers and electrify up to 20% or 55% of total distance driven by the ride-hailing fleet. With level-2 charging available at home, work, and public parking, the acceptance ceiling increases to up to 91% of drivers and 80% of distance. Our study suggests that long range BEVs and widespread level-2 charging infrastructure are needed for large-scale electrification of ride-hailing mobility in Beijing. The marginal benefits of increased all electric range, effects on charging infrastructure distribution, and payback times are also presented and discussed. Given the observed heterogeneity of ride-hailing vehicle travel, our study outlines the importance of individual-level analysis to understand the electrification potential and future benefits of electric vehicles in the era of shared smart transportation.

Subject Areas: Ride-hailing; Urban mobility; GPS trajectories; Electrification; Machine learning; Big data

2.18. Title: Optimization of Charging Method for Scaled EVs

Author(s): Zhang, X., Liu, Z., Cao, Y., Duan, L., Tang, G. and Liu, W.

Abstract: At present, EVs(electrical vehicles) charging strategies are mainly focusing on reasonable optimization of EVs' charging. However, previous researches have rarely studied optimizing the charging power of each EV, and the algorithms are always too complicated to implement. Based on this, this paper examines the lowest total load charging method and proposes the automatic breaking charging method which do not rely on complicated algorithms. Through Monte Carlo simulation, the simulation results of the two charging methods are compared respectively, and it is verified that the automatic breaking charging method has a better effect on peak load shifting and it can contribute to the reduction of energy loss.

Subject Areas: EVs(electrical vehicles); Monte Carlo simulation; Charging Method

2.19. Title: An Intelligent Hybrid Energy Management System for a Smart House Considering Bidirectional Power Flow and Various EV Charging Techniques

Author(s): Rafique, M.K., Khan, S.U., Saeed Uz Zaman, M., Mehmood, K.K., Haider, Z.M., Bukhari, S.B.A. and Kim, C.H.

Abstract: Compelled by environmental and economic reasons and facilitated by modern technological advancements, the share of hybrid energy systems (HES) is increasing at modern smart house (SH) level. This work proposes an intelligent hybrid energy management system (IHEMS) for an SH connected to a power network that allows a bidirectional power flow. The SH has electrical and thermal power loops, and its main components include renewable energy from wind and photovoltaics, electric vehicle (EV), battery energy storage system, a fuel cell which serves as a micro-combined heat and power system, and a boiler. The proposed IHEMS models the components of the SH, defines their constraints, and develops an optimization model based on the real coded genetic algorithm. The key features of the developed IHEMS are highlighted under six simulation cases considering different configurations of the SH components. Moreover, the standard EV charging techniques are compared, and it is observed that the charging method which is flexible in timing and power injection to the EV is best suited for the economic operation of the SH. The simulation results reveal that the proposed IHEMS minimizes the 24-hour operational cost of the SH by optimally scheduling the energy resources and loads.

Subject Areas: Micro-combined heat and power (Micro-CHP) system; Real Coded Genetic Algorithm (RCGA); Smart Home (SH); Electric Vehicle Supply Equipment (EVSE); Photovoltaics (PV)

Availability: Rafique, M.K., Khan, S.U., Saeed Uz Zaman, M., Mehmood, K.K., Haider, Z.M., Bukhari, S.B.A. and Kim, C.H., 2019. *An Intelligent Hybrid Energy Management System for a Smart House Considering Bidirectional Power Flow and Various EV Charging Techniques.* Applied Sciences, 9(8), p.1658.
https://www.mdpi.com/2076-3417/9/8/1658

2.20. Title: Joint Optimization Scheme for the Planning and Operations of Shared Autonomous Electric Vehicle Fleets Serving Mobility on Demand

Author(s): Sheppard, C.J., Bauer, G.S., Gerke, B.F., Greenblatt, J.B., Jenn, A.T. and Gopal, A.R.

Abstract: As the transportation sector undergoes three major transformations–electrification, shared/on-demand mobility, and automation–there are new challenges to analyzing the impacts of these trends on both the transportation system and the power sector. Most models that analyze the requirements of fleets of shared autonomous electric vehicles (SAEVs) operate at the scale of an urban region, or smaller. A quadratically constrained, quadratic programming problem is formulated, designed to model the requirements of SAEVs at a national scale. The size of the SAEV fleet, the necessary charging infrastructure, the fleet charging schedule, and the dispatch required to serve demand for trips in a region are treated as decision variables. By minimizing both the amortized cost of the fleet and chargers as well as the operational costs of charging, it is possible to explore the coupled interactions between system design and operation. To apply the model at a national scale, key complications about fleet operations are simplified; but a detailed agent-based regional simulation model to parameterize those simplifications is leveraged. Preliminary results are presented, finding that all mobility in the United States (U.S.) currently served by 276 million personally owned vehicles could be served by 12.5 million SAEVs at a cost of $0.27/vehicle-mile or $0.18/passenger-mile. The energy requirements for this fleet would be 1142 GWh/day (8.5% of 2017 U.S. electricity demand) and the peak charging load 76.7 GW (11% of U.S. power peak). Several model sensitivities are explored, and it is found that sharing is a key factor in the analysis.

Subject Areas: Shared Autonomous Electric Vehicles (SAEVs); Vehicle Fleets; Mobility

Availability: Sheppard, C.J., Bauer, G.S., Gerke, B.F., Greenblatt, J.B., Jenn, A.T. and Gopal, A.R., 2019. *Joint Optimization Scheme for the Planning and Operations of Shared Autonomous Electric Vehicle Fleets Serving Mobility on Demand.* Transportation Research Record and Lawrence Berkeley National Laboratory.
https://escholarship.org/uc/item/5zs7f6hg

2.21. Title: Are Consumers Poorly Informed about Fuel Economy? Evidence from Two Experiments

Author(s): Allcott, H. and Knittel, C.

Abstract: It is often asserted that consumers are poorly informed about and inattentive to fuel economy, causing them to buy low-fuel economy vehicles despite their own best interest. This paper presents evidence on this assertion through two experiments providing fuel economy information to new vehicle shoppers. Results show zero statistical or economic effect on average fuel economy of vehicles purchased. In the context of a simple optimal policy model, the estimates suggest that current and proposed US fuel economy standards are significantly more stringent than needed to address the classes of imperfect information and inattention addressed by our interventions.

Subject Areas: Fuel Economy; Consumers

2.22. Title: Distribution System Planning Considering Stochastic EV Penetration and V2G Behavior

Author(s): Wang, X., Nie, Y. and Cheng, K.W.E.

Abstract: The increasing integration of electric vehicles (EVs) is adding higher future potentials for the smart grid because the residual energy stored in EV batteries can be discharged to support the grid when needed. However, the stochasticity of EV user behaviors pose challenges to the regulators of distribution systems. How the regulators decide upon a control strategy for the vehicle to grid and how EV users respond to the strategy will significantly influence the variation of load profiles in the planning horizon. In this paper, a comprehensive cost analysis is performed to obtain the optimal planning scheme, considering the variation in EV penetration, charging preference, and customer damage cost. The economics and stability of the planned distribution system are assessed with real-world travel records and cost statistics to quantitatively show the effectiveness of the optimization algorithm and the importance of user behavior concern.

Subject Areas: Planning; Reliability; Vehicle-to-grid; Substations; Electric vehicle charging; Batteries; Regulators

Availability: Wang, X., Nie, Y. and Cheng, K.W.E., 2019. *Distribution System Planning Considering Stochastic EV Penetration and V2G Behavior.* IEEE Transactions on Intelligent Transportation Systems.
https://ieeexplore.ieee.org/abstract/document/8621612

2.23. Title: Fleet Performance and Cost Evaluation of a Shared Autonomous Electric Vehicle (SAEV) Fleet: A case study for Austin, Texas

Author(s): Loeb, B. and Kockelman, K.M.

Abstract: Shared Autonomous Vehicles (SAVs) have gained significant public interest as a possible less expensive, safer and more efficient version of today's transportation networking companies (TNCs) and taxis. One way to expand on the possible benefits of an SAV fleet is through electric vehicles (EVs), which tend to be more energy efficient, more reliable, quicker, and may reduce system-wide emissions when coupled with renewable power. EVs are quickly becoming more financially viable as the price of these vehicles drops and charging infrastructure is appearing in more and more locations across the world. EVs are disadvantaged by their relatively short range and long recharge times, so it is important to understand how these factors will affect an electrified SAV (SAEV) fleet in terms of vehicle miles traveled (VMT), vehicle productivity, and response times.

Perhaps the most important factor to consider before implementation is cost, since it is quite unlikely that a fleet operator will elect to use an EV fleet when a gasoline fleet is more profitable. This study makes in-depth estimates of the cost of this SAEV fleet based on vehicle purchasing costs, vehicle maintenance, batteries, electricity, charger construction (including land acquisition and paving), charger maintenance, insurance, registration and general administrative costs. These costs are estimated at low-, high- and mid-cost scenarios, where mid-cost is the most expected.

This study performed a simulation of SAEVs across the Austin, Texas 6-county region under 6 different fleet scenarios to assess what factors make the fleet the most profitable and provide the best customer experience. The simulation process features thoughtful charging strategies, dynamic ridesharing, mode choice, and a multi-step search algorithm. Results showed that for all metrics studied, the gasoline hybrid-electric (HEV) fleet performed better than EV fleets, while remaining more profitable, providing response times of 4.5min compared to 5.5min. The HEV fleet is the more profitable option until the cost of gasoline exceeds $10 per gallon or the cost of a long-range EV falls below $16,000 through subsidies. Of all the EVs studied, the long-range fast-charging scenario not only provides the best service in terms of all metrics studied, but is by far the most profitable. Even though EVs may not be financially advantageous in the near term, the environmental benefits could be substantial; EVs have the potential to provide zero-carbon transportation when coupled with a renewable power grid. Gasoline vehicles have no such potential. Environmentalism tends to have little effect on financial decisions, but a carbon tax could change that perspective.

Subject Areas: Shared Autonomous Vehicles (SAVs); Hybrid Electric Vehicles; Investments; Benefits

2.24. Title: Machine Learning Estimates of Plug-in Hybrid Electric Vehicle Utility Factors

Author(s): Goebel, D. and Plötz, P.

Abstract: Plug-in hybrid electric vehicles (PHEV) combine an electric drive train with a conventional one and are able to drive on gasoline when the battery is fully depleted. They can thus electrify many vehicle miles travelled (VMT) without fundamental range limits. The most important variable for the electrification potential is the ratio of electric VMT to total VMT, the so-called utility factor (UF). However, the empirical assessment of UFs is difficult since important factors such as daily driving, re-charging behaviour and frequency of long-distance travel vary noteworthy between drivers and large data collections are required. Here, we apply machine learning techniques (regression tree, random forest, support vector machine, and neural nets) to estimate real-world UF and compare the estimates to actual long-term average UF of 1768 individual Chevrolet Volt PHEV. Our results show that UFs can be predicted with high accuracy from individual summary statistics to noteworthy accuracy with a mean absolute error of five percentage points. The accuracy of these methods is higher than a simple simulation with electric driving until the battery is discharged and one full daily recharge. The most important variables in estimating UF according to a linear regression model are the variance and skewness of the daily VMT distributions as well as the frequency of long-distance driving. Thus, our findings make UF predictions from existing data sets for driving of conventional vehicles more accurate.

Subject Areas: Electric vehicles; Plug-in hybrid electric vehicle; Utility factor; Machine learning

2.25. Title: An EV Charging Demand Model for the Distribution System Using Traffic Property

Author(s): Xia, Y., Hu, B., Xie, K., Tang, J. and Tai, H.M.

Abstract: This paper proposes a mathematical model for the spatial-temporal charging demand for electric vehicle (EV). The determination of spatial-temporal charging demand is a key step for the planning of distribution systems with a scalable application of EV. The spatial-temporal allocation of EV is conventionally obtained through a simulation procedure using traffic topology data, which is not suitable for the regions lacking such information. This model converts the problem of travel distance to travel duration so that the requirement of network geographic information can be avoided. Static EV parameters, EV spatial-temporal moving parameters and system charging model parameters are treated as the deterministic factors for the charging demand allocation. A stochastic travel route simulation procedure, which relies purely on statistical data of traffic flow, is also developed to obtain the EV moving parameters by adopting the traffic property information. The designed procedure derives travel time parameters from the vehicle dynamic-location-property (DLP) model and the travel time probability distribution. The DLP model is established using the traffic property matrix and the regional origin-destination matrix. A simple case is presented to illustrate the result of stochastic travel route simulation. Then, a modified eastern China system is used as an example to analyze the EV charging demand under multiple scenarios. The feasibility and versatility of the proposed model in the large complex system are verified by the test results.

Subject Areas: Electric vehicle charging; Load modeling; Data models; Batteries; Mathematical model; Resource management; Roads

Availability: Xia, Y., Hu, B., Xie, K., Tang, J. and Tai, H.M., 2019. *An EV Charging Demand Model for the Distribution System Using Traffic Property.* IEEE Access. https://ieeexplore.ieee.org/abstract/document/8654186

2.26. Title: CalAmp and Swiftmile Partner to Deliver First-Ever Solar-Powered Parking and Charging Station Providing "Power Nap" for Micro-Mobility

Author(s): NA

Abstract: Blog

Subject Areas: Light Electric Vehicle (LEV) Charging Systems; Solar-Powered Parking and Charging Station

Availability: 2019. *CalAmp and Swiftmile Partner to Deliver First-Ever Solar-Powered Parking and Charging Station Providing "Power Nap" for Micro-Mobility.* PRNewswire. https://www.barchart.com/story/news/344317/calamp-and-swiftmile-partner-to-deliver-first-ever-solar-powered-parking-and-charging-station-providing-power-nap-for-micro-mobility

2.27. Title: Risk Evaluation of Distribution Networks Considering Residential Load Forecasting with Stochastic Modelling of Electric Vehicles

Author(s): Habib, S., Khan, M.M., Abbas, F., Ali, A., Hashmi, K., Shahid, M.U., Bo, Q. and Tang, H.

Abstract: Large-scale integration of electric vehicles (EVs) into residential distribution networks (RDNs) is an evolving issue of paramount significance for utility operators. Similarly, electric load forecasting is an operational process permitting the utilities to manage demand issues for optimal energy utilization. Unbalanced voltages prevent the effective and reliable operation of RDNs. This study implements a novel framework to examine risks associated with RDNs by applying a residential forecasting model with a stochastic model of EVs charging pattern. Diversified EV loads require a stochastic approach to predict EVs charging demand; consequently, a probabilistic model is developed to account for several realistic aspects comprising charging time, battery capacity, driving mileage, state-of-charge, travelling frequency, charging power, and time-of-use mechanism under peak and off-peak charging strategies. Peak-day forecast of various households is obtained in summer and winter by implementing an optimum nonlinear auto-regressive neural-network (NN) with time-varying external input vectors (NARX). Outputs of the EV stochastic model and residential forecasting model obtained from Monte-Carlo simulations and the NARX-NN model, respectively, are utilized to evaluate power quality parameters of RDNs. Performance specifications of RDNs including voltage unbalance factor (VUF) and voltage behavior are assessed in context to EV charging scenarios with various charging power levels under different penetration levels.

Subject Areas: Distribution Networks; Stochastic Modelling; Electric Vehicles

2.28. Title: Consumer Valuation of Fuel Economy: Findings from Recent Panel Studies

Author(s): Klemick, H., Elizabeth, K. and Wolverton, A.

Abstract: Engineering-based studies of energy efficiency often find that firms and consumers fail to adopt technologies that appear to provide net private benefits absent regulation. We examine the recent empirical literature on the extent to which expected future fuel costs are reflected in vehicle prices and therefore valued by consumers when making purchase decisions. These studies improve upon the prior literature due to their use of highly disaggregated panel data that allows for defensible identification strategies. These studies found that vehicle purchase prices reflect about 50 to 100 percent of future fuel expenses, assuming static consumer expectations about future gasoline prices and a discount rate of five to six percent. Recent regulatory analyses have estimated the benefits of more stringent vehicle standards implicitly assuming that no improvements in fuel economy will occur in the baseline, absent regulation. This assumption is consistent with consumers placing no value on future fuel costs when making vehicle purchase decision. The recent empirical evidence supports using a range of consumer valuation assumptions and applying this range consistently in the baseline and regulatory scenarios when modeling consumer purchase and firm investment decisions.

Subject Areas: Consumer valuation; Fuel economy; Vehicle purchase decisions; Benefit-cost analysis

Availability: Klemick, H., Elizabeth, K. and Wolverton, A., 2019. *Consumer Valuation of Fuel Economy: Findings from Recent Panel Studies.* Working Paper, National Center for Environmental Economics.
https://ageconsearch.umn.edu/record/283626/

2.29. Title: Subsidy and Pricing Model of Electric Vehicle Sharing Based on Two-Stage Stackelberg Game — A Case Study in China

Author(s): Yang, J., Lin, Y., Wu, F. and Chen, L.

Abstract: Electric vehicle sharing provides an effective way to improve the traffic situation and relieve environmental pressure. The government subsidy policy and the car-sharing operator's pricing strategy are the key factors that affect the large-scale application of electric vehicle sharing. To address this issue, a subsidy and pricing model for electric vehicle sharing based on the two-stage Stackelberg game is proposed in this paper according to the current situation in China. First, an electric vehicle sharing operation mode under government participation is constructed. Then, a two-stage Stackelberg game model involving the government, the car-sharing operator and the consumers is proposed to determine the subsidy rates and pricing strategies. The improved particle swarm optimization algorithm is used to obtain the Nash equilibrium of the model. Also, the influence of private car cost and shared travel comfort on subsidy rates and pricing strategies is analyzed. Finally, the simulation of electric vehicle sharing in a town of China is carried out to investigate the performance of the proposed subsidy and price model. The simulation results show that the model rationally formulates subsidy policies and pricing strategies of the electric vehicle sharing to balance the interests of the three participants, mobilizing users' enthusiasm while guaranteeing the benefits of the government and operator, making the overall benefit optimal.

Subject Areas: Two-stage Stackelberg game; Electric vehicle sharing; Subsidy policy; Pricing strategy

2.30. Title: Electric Car Subsidies Hurt Middle Class Americans

Author(s): Landrith, G.

Abstract: Blog

Subject Areas: Electric Vehicles; American taxpayers; AAA study

Availability: Landrith, G., 2019. *Electric Car Subsidies Hurt Middle Class Americans.* RealclearEnergy.Org.
https://www.realclearenergy.org/articles/

2.31. Title: How well do Electric Vehicles perform in our Extreme Weather?

Author(s): Harlow, T.

Abstract: Blog

Subject Areas: Electric Vehicles; Environment friendly; Temperature

Availability: Harlow, T., 2019. *How well do Electric Vehicles perform in our Extreme Weather?* StarTribune.
http://www.startribune.com.

2.32. Title: An Electric Vehicle in Every Driveway?

Author(s): Davis, L.

Abstract: Blog

Subject Areas: Electric Vehicles; Households; Household income category; Tesla

Availability: Davis, L., 2019. *An Electric Vehicle in Every Driveway?* Energy Institute.
https://energyathaas.wordpress.com/2019/05/13/an-electric-vehicle-in-every-driveway/

2.33. Title: Fueling Up for Your Summer Travel Plans

Author(s): NA

Abstract: Blog

Subject Areas: Gas Prices; NHTS; Long-distance trip

Availability: 2019. *Fueling Up for Your Summer Travel Plans* Fox40.com
https://fox40.com/2019/05/24/fueling-up-for-you-summer-travel-plans/

2.34. Title: A Comparison Study on Stochastic Modeling Methods for Home Energy Management System

Author(s): Yousefi, M., Hajizadeh, A. and Soltani, M.N.

Abstract: Obtaining an appropriate model is very crucial to develop an efficient energy management system (EMS) for the smart home including, Photovoltaic array (PV), Plug-in Electric Vehicle (PEV), home loads and Heat Pump (HP). Stochastic modeling methods of smart home explain random parameters and uncertainties of the above components. In this paper, a concise yet comprehensive analysis and comparison are presented for these techniques. First, modeling methods are implemented to find appropriate and precise forecasting models for PV, PEV, HP and home load demand. Then, the accuracy of each model is validated by the real measured data. Finally, the pros and cons of each method are discussed and reviewed. The obtained results show the conditions, under which the methods can provide a reliable and accurate description of smart home dynamics.

Subject Areas: Comparison; Stochastic modeling; Uncertainties; Smart home; Energy management system; Modeling techniques

Availability: Yousefi, M., Hajizadeh, A. and Soltani, M.N., 2019. *A Comparison Study on Stochastic Modeling Methods for Home Energy Management System.* IEEE Transactions on Industrial Informatics.
https://ieeexplore.ieee.org/abstract/document/8678456

2.35. Title: Optimal Energy-Emission Management in Hybrid AC-DC Microgrids with Vehicle-2-Grid Technology

Author(s): Papari, B., Edrington, C.S. and Gonsoulin, D.

Abstract: This article focuses on the optimal operation management challenges in hybrid AC-DC microgrids considering optimal feeder switching, renewable energy sources, and plug-in electric vehicles. In comparison with the traditional hybrid AC-DC microgrid concept, the reconfigurable hybrid AC-DC microgrids provide more flexibility for better supporting consumers and reducing the operation costs through the remotely controlled switches. In addition, the reconfigurable structure of the hybrid microgrid along with the vehicle-to-grid technology supports the high penetration of plug-in electric vehicles by changing their role from only consuming loads into mobile storages. The proposed problem is prepared as a constrained multi-objective problem optimizing both cost and emission objectives. Due to the high complication and nonlinearity of the problem, an effective optimization algorithm called the theta-crow search algorithm is developed to solve the problem optimally. Also, a stochastic framework based on the point estimate method is used to model the high uncertainties of the problem. The high reliable and satisfying performance of the new method is shown on a test AC-DC microgrid.

Subject Areas: Renewable energy; Vehicle-2-Grid; AC-DC microgrids; plug-in electric vehicles

2.36. Title: Reliability-based Metrics to Quantify the Maximum Permissible Load Demand of Electric Vehicles

Author(s): Kamruzzaman, M. and Benidris, M.

Abstract: The continuous increase of electric vehicles (EVs) is expected to introduce several challenges to power systems among which is deteriorating the reliability of power supply. This paper proposes two adequacy metrics to quantify the maximum permissible EV loads for a power system without deteriorating its reliability and the required improvements to power systems to accommodate high penetrations of EVs which are defined as follows: (1) extra effective available energy for EVs' charging (EEAE-EVs) and (2) extra effective required generation to accommodate EVs (EERG-EVs). The EEAE-EVs provides a measure to the maximum amount of EV loads that a power system can accommodate without adding new generation while maintaining its reliability. The EERG-EVs provides a measure to the minimum amount of new generation that is needed to restore the reliability level of a power system if the load of EVs exceeds the maximum permissible load of the system. These metrics provide a decision aid to power system planners and operators on when and how to perform generation expansion. The importance of the proposed metrics is demonstrated on the IEEE Reliability Test System (IEEE RTS) with real EV charging data. The sequential Monte Carlo simulation method is used in evaluating the well-known power system reliability indices, the EEAE-EVs, and the EERG-EVs. The results show that a power system can accommodate EV loads without deteriorating its reliability as long as EV loads do not exceed the EEAE-EVs of the system.

Subject Areas: Power system reliability; Reliability; Power measurement; Maintenance engineering; Electric vehicles

Availability: Kamruzzaman, M. and Benidris, M., 2019. *Reliability-based Metrics to Quantify the Maximum Permissible Load Demand of Electric Vehicles.* IEEE Transactions on Industry Applications.
https://ieeexplore.ieee.org/abstract/document/8705332

2.37. Title: Electric Vehicle Charging Station Placement Method for Urban Areas

Author(s): Cui, Q., Weng, Y. and Tan, C.W.

Abstract: For accommodating more electric vehicles (EVs) to battle against fossil fuel emission, the problem of charging station placement is inevitable and could be costly if done improperly. Some researches consider a general setup, using conditions such as driving ranges for planning. However, most of the EV growths in the next decades will happen in the urban area, where driving ranges is not the biggest concern. For such a need, we consider several practical aspects of urban systems, such as voltage regulation cost and protection device upgrade resulting from the large integration of EVs. Notably, our diversified objective can reveal the trade-off between different factors in different cities worldwide. To understand the global optimum of large-scale analysis, we studied each feature to preserve the problem convexity. Our sensitivity analysis before and after convexification shows that our approach is not only universally applicable but also has a small approximation error for prioritizing the most urgent constraint in a specific setup. Finally, numerical results demonstrate the trade-off, the relationship between different factors and the global objective, and the small approximation error. A unique observation in this study shows the importance of incorporating the protection device upgrade in urban system planning on charging stations.

Subject Areas: Electric vehicle charging station; Distribution grid; Convexification; Protective devices upgrade.

Availability: Cui, Q., Weng, Y. and Tan, C.W., 2019. *Electric Vehicle Charging Station Placement Method for Urban Areas.* IEEE Transactions on Smart Grid.
https://ieeexplore.ieee.org/abstract/document/8673613

2.38. Title: Online EV Charging Scheduling with On-Arrival Commitment

Author(s): Alinia, B., Hajiesmaili, M.H. and Crespi, N.

Abstract: The rapid proliferation of electric vehicles has resulted in a drastic increase in the total energy demand of EVs. Given the limited charging rate capacity of charging stations and uncertainty of EV arrivals, the aggregate demand might go beyond the charging station capacity, even with proper scheduling. This paper formulates a social welfare maximization problem for EV charging scheduling with charging capacity constraint. Even though the underlying problem is linear, it is difficult to tackle since the input to the problem, i.e., the charging profile of EVs, reveals in online fashion. We devise charging scheduling algorithms that not only work in the online scenario, but also provide the following two key features: 1) on-arrival commitment; respecting the capacity constraint may hinder fulfilling charging requirement of the deadline-constrained EVs entirely. Therefore, committing a guaranteed charging amount upon arrival of each EV is highly essential; 2) (group)-strategy-proofness as a salient feature to promote EVs to reveal their true type and do not collude with other EVs. Extensive simulations using real traces demonstrate the effectiveness of our online scheduling algorithms as compared to the optimal non-committed offline solution.

Subject Areas: Electric vehicle charging; Charging stations; Aggregates; Scheduling algorithms; Batteries; Scheduling

Availability: Alinia, B., Hajiesmaili, M.H. and Crespi, N., 2019. *Online EV Charging Scheduling with On-Arrival Commitment.* IEEE Transactions on Intelligent Transportation Systems.
https://ieeexplore.ieee.org/document/8610387

2.39. Title: Modelling of Distributed Energy Components and Optimization of Energy Vector Dispatch within Smart Energy Systems

Author(s): Kong, Q.

Abstract: The smart energy system concept provides an integrated framework for the adoption of renewable energy resources and novel energy technologies, such as distributed battery energy storage systems and electric vehicles. In this effort, large-scale transition towards smart energy systems can significantly reduce the environmental emissions of energy production, while leveraging the more operation of numerous distributed grid components to improve upon the energy utility, reliability, and flexibility of existing power grids. Most importantly, transitioning from fossil fuels to renewable energy resources provides environmental benefits within both the building and transportation sectors, which must adapt to address both increasing pressure from international climate change-related policy-making, as well as to meet the increasing power demands of future generations.

Subject Areas: Energy Components; Renewable Energy Resources; Smart Energy Systems; Power Grids

Availability: Kong, Q., 2019. *Modelling of Distributed Energy Components and Optimization of Energy Vector Dispatch within Smart Energy Systems.* Master's thesis, University of Waterloo.
https://uwspace.uwaterloo.ca/handle/10012/14491

Chapter 3. Environment

3.1. Title: Decoupling the Value of Leisure Time from Labor Market Returns in Travel Cost Models

Author(s): Lloyd-Smith, P., Abbott, J.K., Adamowicz, W. and Willard, D.

Abstract: Understanding the extent to which people substitute activities across time is important for evaluating behavior and welfare impacts in many contexts, including assessing the damages caused by oil spills and climate change impacts. We implement a flexible, individualized approach to measuring how people value their leisure time. We incorporate these heterogeneous values into a structural demand model that explicitly focuses on intertemporal substitution and incorporates time constraints on behavior. The model is estimated using data on recreation demand for for-hire offshore fishing trips in the US Gulf of Mexico. We find that respondents value their leisure time heterogeneously and substantially differently from their implied wage rate. We also find that accounting for this heterogeneity has significant impacts on estimated welfare measures for policies with large intertemporal substitution effects. These findings raise concerns with the common practice of solely relying on labor market information to value people's leisure time.

Subject Areas: Intertemporal Substitution; Value of Time; Demand System

3.2. Title: Developing Commute Optimization System to Minimize Negative Environmental Impacts and Time of Business Commuters

Author(s): Abdallah, M., Tawfik, A.M., Monghasemi, S., Clevenger, C.M. and Adame, B.A.

Abstract: The objective of this research is to develop a novel and innovative system, called Business+ Commute Optimization System (B+COS) that is capable of identifying the optimal selection of individualized commute alternatives of employees in a business to minimize their greenhouse gas (GHG) emissions, air pollution, and commute time. B+COS is designed to identify the optimal travel behavior for each commuter (e.g., drive car, carpool, use public transit, bike or walk) while maintaining convenience and incentivizing commuters using monetary incentives. The system consists of a geographical information system (GIS) and a multi-objective optimization model. The GIS is designed to measure and quantify business commute attributes such as emissions, commute cost, and time of each commute option. The multi-objective optimization model is designed to generate optimal trade-offs among two optimization objectives (1) minimizing equivalent social cost of GHG emissions and air pollution, and (2) minimizing total commute time of business commuters. Performance of the system is evaluated and verified using a case study of 21 commuters. Results show the capabilities of the new system in identifying Pareto-optimal solutions of the two optimization objectives for various tolerances of commute time increase ranging from 5 to 25min. The promising results highlight the effectiveness of such an innovative system to minimize transportation-related emissions and commute time for businesses.

Subject Areas: Incentivized emission reduction; Selection of commute alternatives; Multi-objective optimization; Minimizing commute time

3.3. Title: Evaluating the Potential Environmental Impacts of Connected and Automated Vehicles

Author(s): Gawron, J.

Abstract: Although recent studies of connected and automated vehicles (CAVs) have begun to explore the potential energy and greenhouse gas (GHG) emission impacts from an operational perspective, little is known about how the full life cycle of the vehicle will be impacted. We report the results of a life cycle assessment (LCA) of Level 4 CAV sensing and computing subsystems integrated into internal combustion engine vehicle (ICEV) and battery electric vehicle (BEV) platforms. The results indicate that CAV subsystems could increase vehicle primary energy use and GHG emissions by 3–20% due to increases in power consumption, weight, drag, and data transmission. However, when potential operational effects of CAVs are included (e.g., eco-driving, platooning, and intersection connectivity), the net result is up to a 9% reduction in energy and GHG emissions in the base case. Overall, this study highlights opportunities where CAVs can improve net energy and environmental performance.

Subject Areas: Autonomous Vehicle; Life Cycle Assessment; Greenhouse Gas Emissions; Primary Energy

Availability: Gawron, J., 2019. *Evaluating the Potential Environmental Impacts of Connected and Automated Vehicles.* Doctoral dissertation, University of Michigan. https://deepblue.lib.umich.edu/handle/2027.42/148652

3.4. Title: Material Efficiency Strategies to Reducing Greenhouse Gas Emissions Associated with Buildings, Vehicles, and Electronics — A Review

Author(s): Hertwich, E.G., Ali, S., Ciacci, L., Fishman, T., Heeren, N., Masanet, E., Asghari, F.N., Olivetti, E., Pauliuk, S., Tu, Q. and Wolfram, P.

Abstract: As one quarter of global energy use serves the production of materials, the more efficient use of these materials presents a significant opportunity for the mitigation of greenhouse gas (GHG) emissions. With the renewed interest of policy makers in the circular economy, material efficiency (ME) strategies such as light-weighting and downsizing of and lifetime extension for products, reuse and recycling of materials, and appropriate material choice are being promoted. Yet, the emissions savings from ME remain poorly understood, owing in part to the multitude of material uses and diversity of circumstances and in part to a lack of analytical effort. We have reviewed emissions reductions from ME strategies applied to buildings, cars, and electronics. We find that there can be a systematic trade-off between material use in the production of buildings, vehicles, and appliances and energy use in their operation, requiring a careful life cycle assessment of ME strategies. We find that the largest potential emission reductions quantified in the literature result from more intensive use of and lifetime extension for buildings and the light-weighting and reduced size of vehicles. Replacing metals and concrete with timber in construction can result in significant GHG benefits, but trade-offs and limitations to the potential supply of timber need to be recognized. Repair and remanufacturing of products can also result in emission reductions, which have been quantified only on a case-by-case basis and are difficult to generalize. The recovery of steel, aluminum, and copper from building demolition waste and the end-of-life vehicles and appliances already results in the recycling of base metals, which achieves significant emission reductions. Higher collection rates, sorting efficiencies, and the alloy-specific sorting of metals to preserve the function of alloying elements while avoiding the contamination of base metals are important steps to further reduce emissions.

Subject Areas: Greenhouse Gas Emissions; Global Energy; Material Efficiency Strategies; Life Cycle Assessment

3.5. Title: Winter is Finally Gone: How We're Getting Our Cars Shining Again

Author(s): Anthony, C.

Abstract: Blog

Subject Areas: Environment; Average car age; Temperature

Availability: Anthony, C., 2019. *Winter is Finally Gone: How We're Getting Our Cars Shining Again.* Automoblog.net
https://www.automoblog.net/2019/05/28/turtle-wax-review/

Chapter 4. Health

4.1. Title: Integrating Multiple Transportation Modes into Measures of Spatial Food Accessibility

Author(s): Zhang, J. and Mao, L.

Abstract: Introduction: People can access to healthy food via different modes of transportation, such as traveling by car, transit, bicycle and foot. We categorize current measures of food accessibility under an origin-destination-mode framework and find that few of them integrate multiple travel modes. As a result, these measures can bias the identification of truly low-access areas.

Method: To fill this gap, we propose two new measures that integrate sub-populations of various travel modes, and estimate the overall food accessibility of a whole population. Taking Florida, USA, as a study area, we illustrate our measures with actual multiple mode commuting data from the U.S census transportation planning products (CTPP). We then compare the results to those from conventional single-modal measures.

Results The proposed multiple-mode measures tend to estimate a larger population with low accessibility and fewer accessible supermarkets for a census tract, as compared to single-mode measures. The incorporation of multiple travel modes into food accessibility measures also narrows the disparities between urban and rural areas, which are indicated by conventional measures.

Conclusions: By considering modal-split subpopulations, our measures offer a more realistic representation of local people's travel for grocery shopping, and thus a better identification of populations with low food access. The finer modeling scale at a subpopulation level provides health and urban planners more flexibility in policy design, in that interventions can be tailored to not only a neighborhood but also a specific subpopulation within it. Such knowledge could improve the cost-effectiveness of food intervention programs.

4.2. Title: Active Transport, Not Device Use, Associates with Self-Reported School Week Physical Activity in Adolescents

Author(s): Burns, R.D., Pfledderer, C.D. and Brusseau, T.A.

Abstract: The purpose of this study was to examine the relationships among active transport, electronic device-use, and self-reported school week moderate-to-vigorous physical activity (MVPA) in a sample of adolescents. The sample consisted of 1445 adolescents enrolled in the Family Life, Activity, Sun, Health, and Eating study. A panel research organization invited panel members balanced to the US population on sex, census division, household income and size, and race/ethnicity. Web-based surveys were administered to each selected adolescent. Adolescents answered questions pertaining to out-of-school electronic device-use and active transport to and from school. Predicted weekly minutes of MVPA were calculated from the Youth Activity Profile. The outcome variable was predicted school week MVPA (in minutes). The predictive utility of device-use and active transport variables on self-reported school week MVPA were examined using weighted multiple linear regression models. After adjusting for age, sex, and BMI, active transport to school (b=12.32, 95% CI [9.72–14.93], p<0.001) and from school (b=7.18, 95% CI [4.79–5.57], p<0.001) were significantly associated with self-reported school week MVPA. No device-use variables were significantly associated with school week MVPA. Active transport to and from school may have an impact on school week MVPA in adolescents.

Subject Areas: Adolescent health; Behavioral science; Epidemiology; Physical activity; School health

4.3. Title: A Time-Based Objective Measure of Exposure to the Food Environment

Author(s): Scully, J.Y., Moudon, A.V., Hurvitz, P.M., Aggarwal, A. and Drewnowski, A.

Abstract: Exposure to food environments has mainly been limited to counting food outlets near participants' homes. This study considers food environment exposures in time and space using global positioning systems (GPS) records and fast food restaurants (FFRs) as the environment of interest. Data came from 412 participants (median participant age of 45) in the Seattle Obesity Study II who completed a survey, wore GPS receivers, and filled out travel logs for seven days. FFR locations were obtained from Public Health Seattle King County and geocoded. Exposure was conceptualized as contact between stressors (FFRs) and receptors (participants' mobility records from GPS data) using four proximities: 21 m, 100 m, 500 m, and 1/2 mile. Measures included count of proximal FFRs, time duration in proximity to ≥ 1 FFR, and time duration in proximity to FFRs weighted by FFR counts. Self-reported exposures (FFR visits) were excluded from these measures. Logistic regressions tested associations between one or more reported FFR visits and the three exposure measures at the four proximities. Time spent in proximity to an FFR was associated with significantly higher odds of FFR visits at all proximities. Weighted duration also showed positive associations with FFR visits at 21-m and 100-m proximities. FFR counts were not associated with FFR visits. Duration of exposure helps measure the relationship between the food environment, mobility patterns, and health behaviors. The stronger associations between exposure and outcome found at closer proximities <100 m) need further research.

Subject Areas: Fast food; Spatio-temporal exposure; Mobility patterns; GPS; Selective mobility bias

4.4. Title: Human Behavior Modeling and Calibration in Epidemic Simulations

Author(s): Singh, M.

Abstract: Human behavior plays an important role in infectious disease epidemics. The choice of preventive actions taken by individuals can completely change the epidemic outcome. Computational epidemiologists usually employ large-scale agent-based simulations of human populations to study disease outbreaks and assess intervention strategies. Such simulations rarely take into account the decision-making process of human beings when it comes to preventive behaviors. Absence of realistic agent behavior can undermine the reliability of insights generated by such simulations and might make them ill-suited for informing public health policies. In this thesis, we address this problem by developing a methodology to create and calibrate an agent decision-making model for a large multi-agent simulation, in a data driven way. Our method optimizes a cost vector associated with the various behaviors to match the behavior distributions observed in a detailed survey of human behaviors during influenza outbreaks. Our approach is a data-driven way of incorporating decision making for agents in large-scale epidemic simulations.

Subject Areas: Health policies; Epidemic Simulations; Human Behavior

Availability: Singh, M., 2019. *Human Behavior Modeling and Calibration in Epidemic Simulations.* M.S. Thesis, Virginia Tech.
https://vtechworks.lib.vt.edu/handle/10919/87050

Chapter 5. Policy and Mobility

5.1. Title: Smart Cities and Mobility: Does the Smartness of Australian Cities Lead to Sustainable Commuting Patterns?

Author(s): Yigitcanlar, T. and Kamruzzaman, M.

Abstract: Smart cities have become a popular concept because they have the potential to create a sustainable and livable urban future. Smart mobility forms an integral part of the smart city agenda. This paper investigates "smart mobility" from the angle of sustainable commuting practices in the context of smart cities. This paper studies a multivariate multiple regression model within a panel data framework and examines whether increasing access to broadband Internet connections leads to the choice of a sustainable commuting mode in Australian local government areas. In this case, access to the Internet is used as a proxy for determining urban smartness, and the use of different modes of transport including working at home is used to investigate sustainability in commuting behavior. The findings show that an increasing access to broadband Internet reduces the level of working from home, public transport use, and active transport use, but increases the use of private vehicles, perhaps to overcome the fragmentation of work activities the Internet creates. How to overcome the need for car-based travel for fragmented work activities while increasing smartness through the provisioning of broadband access should be a key smart city agenda for Australia to make its cities more sustainable.

Subject Areas: Smart Cities; Smart Mobility; Sustainable Commuting; Sustainable Urban Development; Australian Cities

5.2. Title: Evaluation of The Effects of Trends on Vehicle Concepts based on a Forecast of Travel Demand

Author(s): Peters, P.L., Demuth, R. and Schramm, D.

Abstract: Today, vehicle concepts are developed on the basis of technical design. For the respective positioning of the concept, the customer requirements of the relevant target group determined by market research and the competitive comparison are decisive. Technological trends (FAD) and business model innovations (ODM) have the potential to change the mobility behavior of users and thus the characteristics of vehicle concepts.

Subject Areas: Mobility behavior; Vehicle concepts; Fully automated driving (FAD); Dema

5.3. Title: Estimating the Social Cost of Congestion Using the Bottleneck Model

Author(s): Kim, J.

Abstract: This paper uses the bottleneck model of Vickrey (1969) to empirically measure the social cost of traffic congestion in the US. Using a detailed trip-level data, we estimate extra travel time over and above hypothetical free-flow travel time, which we call "queuing time", for each average commute trip. The estimated individual queuing time implies that the annual cost of congestion borne by all US commuters is about 29 billion dollars. We find that a higher level of congestion in a city may be attributed to a smaller per capita road stock in the city. This paper also empirically quantifies a toll that depends both on the commuter's arrival time and trip distance.

Subject Areas: Mobility; Traffic congestion; Bottleneck; Economic inefficiency; Causal effect

Availability: Kim, J., 2019. *Estimating the Social Cost of Congestion Using the Bottleneck Model.* California State University, Long Beach.
https://www.sciencedirect.com/science/article/abs/pii/S2212012218301151

5.4. Title: Improving Structural Models of Congestion

Author(s): Hall, J.D.

Abstract: We need structural models of traffic congestion to answer a wide variety of questions, but the standard models fail to match the data on travel times across the day. I establish the nature and magnitude of the problem, and show its source lies in how we model traveler preferences, not in the specifics of the congestion technology. The poor fit of the models suggests that we are abstracting away from features with a first-order impact on model predictions, which limits our ability to use these models to evaluate counterfactuals quantitatively and – when travelers are heterogeneous – qualitatively as well. I explore several ways of improving the fit of these models, concluding with recommendations for tractable and intuitive ways of doing so.

Subject Areas: Structural model; Congestion; Model fit; Calibration; Dynamic; Bottleneck model; Traffic

Availability: Hall, J.D., 2019. *Improving Structural Models of Congestion.* University of Toronto.
https://ideas.repec.org/p/tor/tecipa/tecipa-590.html

5.5. Title: Role of Flying Cars in Sustainable Mobility

Author(s): Kasliwal, A., Furbush, N.J., Gawron, J.H., McBride, J.R., Wallington, T.J., De Kleine, R.D., Kim, H.C. and Keoleian, G.A.

Abstract: Interest and investment in electric vertical takeoff and landing aircraft (VTOLs), commonly known as flying cars, have grown significantly. However, their sustainability implications are unclear. We report a physics-based analysis of primary energy and greenhouse gas (GHG) emissions of VTOLs vs. ground-based cars. Tilt-rotor/duct/wing VTOLs are efficient when cruising but consume substantial energy for takeoff and climb; hence, their burdens depend critically on trip distance. For our base case, traveling 100km (point-to-point) with one pilot in a VTOL results in well-to-wing/wheel GHG emissions that are 35% lower but 28% higher than a one-occupant internal combustion engine vehicle (ICEV) and battery electric vehicle (BEV), respectively. Comparing fully loaded VTOLs (three passengers) with ground-based cars with an average occupancy of 1.54, VTOL GHG emissions per passenger-kilometer are 52% lower than ICEVs and 6% lower than BEVs. VTOLs offer fast, predictable transportation and could have a niche role in sustainable mobility.

Subject Areas: Mobility; Vertical takeoff and landing aircraft (VTOLs); Greenhouse Gas (GHG) emissions

5.6. Title: Would Uber Help to Reduce Traffic Congestion?

Author(s): Zheng, Q.

Abstract: This research explores the effects of Uber entry on New York City's traffic. The two major questions I am trying to answer that might be of vital importance to transportation authorities are 1) does Uber substitute public transits? 2) does an introduce of Uber slow down average travel speed? After Uber was first introduced in year 2009, there are continuous debates on distinguishing its impact on traffic (Rayle et al., 2014; Li et al., 2016; Schaller, 2018; Castiglione et al., 2018). Considering that Uber is relatively new, relevant traffic data such as congestion indices are in general unavailable, which appears as a common limitation in previous analysis. In this research, I use monthly number of public transit trips in NYC to estimate a substitution effect of Uber on public transit ridership. To measure its direct impact on road traffic, I use Average Travel Speed generated from NYC yellow cab trips as a proxy for the citywide Average Travel Speed. A further application of monthly number of vehicles crossing nine major bridges and tunnels is used to capture a trend of traffic volume in NYC. The final dataset comprises 133 observations range from January 2008 to January 2018. Perceiving that Uber was introduced to NYC on May 2011 and was suspended on issuance of new vehicle licenses starting from August 2018, I use a regression discontinuity (RD) design and set the two events as cutoff points in the model. Additional use of Google Trend helps to more precisely determine the cutoff point. The regression results suggest that after Uber was introduced to NYC, 1) number of public transit trips has increased by about 3%; 2) average travel speed has decreased by 127 mph; and 3) traffic volume was not affected.

Subject Areas: Uber; Public transit; Traffic Congestion; Average travel speed

Availability: Zheng, Q., 2019. *Would Uber Help to Reduce Traffic Congestion?* B.S. Thesis, Skidmore College.
https://creativematter.skidmore.edu/econ_studt_schol/129/

5.7. Title: Dynamic Shared Autonomous Taxi System Considering On-Time Arrival Reliability

Author(s): Liu, Z., Miwa, T., Zeng, W., Bell, M.G. and Morikawa, T.

Abstract: Dynamic shared autonomous taxi (SAT) systems are regarded as a promising means of improving travel flexibility. With no human drivers, SATs urgently require precise traffic information in order to plan accurate paths independently; in addition, on-time arrival is an essential service quality in SAT systems. In this study, taxis are assumed to be replaced with ride-sharing autonomous vehicles. To improve the probability of on-time arrival, the reliable path concept and collected travel time information are used to facilitate path finding for SATs, and the potential benefits are examined. Two simulation scenarios – one based on historical traffic information and the other based on real-time traffic information – are executed to evaluate the information's usefulness in reliable path finding. In simulation results, reliable path scenarios showed a higher on-time arrival ratio than shortest path scenarios, in which the shortest path algorithm is used in path finding for SATs, and the historical information-based scenarios showed a higher on-time arrival ratio than the real-time information-based scenarios. A system-beneficial path finding method is proposed and is verified to be effective for mitigating road network congestion.

Subject Areas: Shared autonomous taxi system; On-time arrival reliability; Historical travel time information; System-beneficial path; Travel time

Chapter 6. Special Population Groups

6.1. Title: Comparing Immigrant Travel Assimilation among Racial/Ethnic Groups

Author(s): Hu, L., Klein, N.J. and Smart, M.J.

Abstract: This research investigates differences in travel assimilation among immigrants of different races/ethnicities in the United States. Using the 2017 National Household Travel Survey (NHTS) data, the authors compare commute distance and commute mode between immigrants and native-born Americans in three groups: whites, Hispanics, and Asians. The results show that when the authors consider racial/ethnic groups separately, the initial difference in commuting travel between immigrants and native-born Americans in the same racial/ethnic group is smaller, and the time it takes to reduce the difference is shorter, compared with the results when the authors consider all native-born Americans together. Therefore, the authors suggest that transportation policymakers consider racial/ethnic differences when providing services for immigrants.

Subject Areas: Commuting; Ethnic groups; Immigrants; Mode choice; Race; Trip length

6.2. Title: Aging in Activity Spaces: How Does Individual Accessibility Compare across Age Cohorts?

Author(s): Wood, B.S. and Horner, M.W.

Abstract: The proportion of individuals age sixty-five and over is growing at an astronomical rate in the United States, and some estimate that this demographic age group will double by the year 2025. Older adults and adults nearing retirement age tend to reside in suburban neighborhoods and rely heavily on personal vehicles. This study uses travel diary data on automobile trips to construct activity spaces to explore whether or not travel patterns across age groups result in differential access to particular goods and services in the Orlando Metropolitan Statistical Area (MSA). Using an approach based on time geographic density estimation, this research identifies activity spaces across different age cohorts to identify differences in the automobility of different age groups. Results indicate that the geographic dispersion of activities with the Orlando MSA currently favors younger adults. Adults age fifty to sixty-four had the lowest accessibility scores compared to other age cohorts. If this preretirement group has poor access now, holding other effects constant, their access might only get worse as they get older and stop commuting. Transportation is an important consideration in planning for aging populations, and analyzing differences in how older adults travel compared to their younger counterparts can offer insight into the diverse needs of this group.

Subject Areas: Accessibility; Aging Populations; Mobility; Time Geography; Transportation.

6.3. Title: The Effects of Driver Licensing Laws on Immigrant Travel

Author(s): Barajas, J.M.

Abstract: Car use is critical to improving access to regional opportunities, especially for low-wage immigrants. But many states have restricted the ability of undocumented immigrants to obtain drivers licenses, making it potentially difficult for them to improve their economic standing. The effects of these laws have been tested for their association with traffic safety, but not on mode choice itself. Using the 2017 National Household Travel Survey, the author fits a series of logistic regression models to test the influence of permissive immigrant driver licensing on mode choice decisions. The author finds that immigrants in states with permissive licensing laws are more likely to drive in carpools but not necessarily to drive alone. The results suggest permissive licensing has positive impacts for all immigrants, in addition to positive safety externalities documented in the literature.

Subject Areas: Automobile travel; Driver licensing; Immigrants; Travel behavior

Availability: Barajas, J.M., 2019. *The Effects of Driver Licensing Laws on Immigrant Travel.* Transportation Research Board 98th Annual Meeting.
https://trid.trb.org/view/1573175

6.4. Title: Use of Ride-Hailing Services among Older Adults in the United States

Author(s): Mitra, S.K., Bae, Y. and Ritchie, S.G.

Abstract: This paper presents an analysis of data from the 2017 National Household Travel Survey to examine the factors influencing the adoption and the frequency of use of on-demand ride-hailing services such as Uber and Lyft among older adults. Using a zero-inflated negative binomial model (ZINB), the results indicate that the determinants of adoption of on-demand ride-hailing services (users versus non-users) are different from the determinants of the frequency of use of these services among older adult users. Seniors that are younger, living alone, urban dwelling, more highly educated, more affluent, or male with a medical condition that results in asking others for rides, are more likely to be adopters of ride-hailing services. However, seniors who are middle elderly, less educated, or are carless older adults, are more likely to be frequent users of on-demand ride-hailing services as long as they adopt these services. In addition, smartphone possession plays an important role in the adoption behavior of on-demand ride-hailing services among older adults. Results of bivariate analysis showed that older adult ride-hailing users make more transit trips than their non-user counterparts, suggesting that ride-hailing services have the potential to serve as a complementary form of public transportation for older adults. The findings of this research will help ride-hailing operators in identifying potential market segments of their services and in developing campaign strategies for potential adopters.

Subject Areas: Older Adults; Seniors; Ride-Hailing; Zero-Inflated Negative Binomial Model (ZINB)

Availability: Mitra, S.K., Bae, Y. and Ritchie, S.G., 2019. *Use of Ride-Hailing Services among Older Adults in the United States.* Transportation Research Record, p.0361198119835511. https://journals.sagepub.com/doi/abs/10.1177/0361198119835511

6.5. Title: Exploring Patterns of Heterogeneity in Activity-Travel Behaviors of Older People

Author(s): Hutchinson, J., da Silva, D.C., Dias, F.F., Bhat, C.R., Khoeini, S., Pendyala, R.M. and Lam, W.H.

Abstract: The travel behavior and mobility needs of older people have been topics of much interest to transport planners and policy makers for a number of reasons. The desire to provide mobility to older people even as their capabilities diminish, and the need to recognize their vulnerability when they do attempt to navigate the transportation network on their own, has motivated a rich stream of research dedicated to studying their activity-travel behavior. Many studies in the past, and most travel models to date, consider older people as a single market segment of 65 years of age or over. To better understand differences among various subgroups of the older population, this paper presents a detailed analysis and comparison of older population subgroups using data derived from the 2017 National Household Travel Survey (NHTS) of the United States. The paper includes a review of earlier studies on the activity-travel patterns of the older segment of our population, and a detailed descriptive statistical analysis on technology and time use patterns with a view to identify how these behaviors evolve as people age. In addition, the paper presents three modeling efforts to understand the differential effects of age on the action space, the use of transportation modes, and the activity participation and time allocation behavior of older people. The analysis suggests that there is considerable heterogeneity among older people, which calls for more targeted policy interventions and a more disaggregate treatment of older population subgroups in travel models. The analysis reveals that an individual's medical condition and need for use of a medical device are significant explanatory variables affecting all three of the choice dimensions modeled in this study. This calls for the development of policies and mobility options that serve the disabled regardless of age, while recognizing the inherent correlation between age and disability status.

Subject Areas: Travel of Older People; Heterogeneity; Action Space; Time Use; Technology Use; Activity travel Engagement

Availability: Hutchinson, J., da Silva, D.C., Dias, F.F., Bhat, C.R., Khoeini, S., Pendyala, R.M. and Lam, W.H., 2019. *Exploring Patterns of Heterogeneity in Activity-Travel Behaviors of Older People.* University of Texas.
http://www.caee.utexas.edu/prof/bhat/ABSTRACTS/OlderPeople.pdf

6.6. Title: A Hierarchical Game Approach on Real-Time Navigation Scheduling of Agricultural Harvesters

Author(s): Si, H., Li, Y., Sun, C., Qiao, H. and Hu, X.

Abstract: A navigation scheduling framework for agricultural harvesters (AHs) is proposed, which takes the impacts from both farmer's demands and dispatch system (DS) into consideration. Farmer's demands with AHs and the DS are linked in this framework. It benefits farmers and AHs owners by attracting AHs to schedule at rush hours and saving the time of AHs owners with real-time navigation. A hierarchical game approach is proposed based on the formulated framework to effectively navigate AHs to farms that need to harvest (FNHs). And a non-cooperative game is proposed to model the competition between FNHS at the upper level of the hierarchical game. At the lower level, multiple evolutionary games are formulated based on the pricing strategies obtained from the non-cooperative game to evolve AHs' strategies in choosing FNHs. The simulation results show that the proposed navigation scheduling method is effective in improving both the reliability of the DS and economic profits of AHs owners.

Subject Areas: Agricultural harvester; Navigation scheduling; Hierarchical game

6.7. Title: Spatio-temporal Travel Patterns Of Elderly People –A Comparative Study Based On Buses Usage in Qingdao, China

Author(s): Shao, F., Sui, Y., Yu, X. and Sun, R.

Abstract: With the increasing demographic shift towards a larger population of elderly, it is essential for policy makers and planners to have an understanding of travel characteristics of elderly and their difference with younger counterparts. Existing studies emphasize elderly's travel mode, travel frequency, travel distance, travel purpose and affecting factors, however, very few aim at comparing the spatio-temporal characteristics difference between weekday and weekend. In this paper, based on GPS data and Smart Card data of buses in Qingdao, the two cohorts' basic spatio-temporal travel patterns in aspects of travel distance, travel frequency and travel start time in weekday and weekend are compared. In addition, directed weighted networks of elderly's trips and younger people's trips in weekday and weekend are constructed for analyzing spatial characteristics. Results show that although the number of elderly experiences a reduction on weekend their travel frequency and travel distance show growth on weekend. In contrast with younger people, larger geospatial expansion of elderly's travel on weekend is observed. Elderly are found to prefer traveling in areas with high elderly people's residential density. Our study provides a deeper and nuanced understanding of elderly's spatio-temporal travel characteristics difference between weekday and weekend, so as to support better traffic policy making and the promotion on age-friendly public transport service.

Subject Areas: Elderly; Spatio-temporal travel characteristics; Weekday and weekend; Trip network

6.8. Title: The Association of Commuting Time and Wages for American Workers with Disabilities

Author(s): Brucker, D.L. and Rollins, N.G.

Abstract: Background: Transportation research suggests that persons who travel further to work earn higher hourly wages.

Objective:To explore whether workers with disabilities who have longer commute times earn higher wages.

Methods: Data from the 2016 American Community Survey is used to examine commuting time and wages for workers with and without disabilities, controlling for individual characteristics.

Results: Travel time to work is quite similar between workers with and without disabilities, but workers with disabilities who travel similar amounts of time as workers without disabilities earn substantially less per hour, even when controlling for individual characteristics.

Conclusions: Commuting time does not contribute to the wage gap between workers with and without disabilities.

Subject Areas: Transportation; Commuting; Wage; American community survey

6.9. Title: The Poverty of the Carless: Toward Universal Auto Access

Author(s): King, D.A., Smart, M.J. and Manville, M.

Abstract: We document the falling socioeconomic status of American households without private vehicles and the continuing financial burden that cars present for low-income households that own them. We tie both these trends to the auto-orientation of America's built environment, which forces people to either spend heavily on cars or risk being locked out of the economy. We first show that vehicle access remains difficult for low-income households and vehicle operating costs remain high and volatile. Using data from the Panel Study of Income Dynamics, Survey of Consumer Finances, and Census Public Use Microdata, we then show that in the last fifty years households without vehicles have lost income, both in absolute terms and relative to households with vehicles. We link these trends to the built environment by examining the fortunes of carless households in New York City, and particularly in Manhattan. Most of New York's built environment did not change to accommodate cars, and in New York the fortunes of the carless did not fall. Our results suggest that planners should see vehicles, in most of the United States, as essential infrastructure, and work to close gaps in vehicle access.

Subject Areas: Elderly; Urban Form; Urban History; Transportation Poverty; Income Inequality

6.10. Title: Synchronization of Home Departure and Arrival Times in Dual Earner Households with Children: Panel Regression Model of Time Gaps

Author(s): Han, B. and Timmermans, H.

Abstract: Organizing schedules and allocating time to different activities is always a challenge in dual-earner households, especially when they have children. Parents may need to link their schedule to those of their children to allow them escorting their children to school or to take care or be with their children at home. This paper reports the results of an analysis of the degree of synchronization of home departure and arrival times in dual earner households with children, where the degree of synchronization is defined as the gap between departure and arrival times of a parent and child. Using activity-travel diary data of different household members, a random parameters regression model is estimated to examine differences in time gaps in home departure and arrival times between parents and children as a function of gender, day of the week, age of the youngest child, and other socio-demographic characteristics. The results of the analysis provide insight into factors influencing the degree of synchronization and coordination of double activity-travel scheduling decisions in households with children. Findings indicate that gender, number of children in the household, age of the youngest child, travel within or outside peak hours, day of the week, transport mode used for the work commute and household income level significantly affect time gaps, especially arrival time gaps.

Subject Areas: Home departure and arrival times; Synchronization; Time gap; Dual-earner; Households; Random parameters panel regression model

6.11. Title: Five Innovative Ways Cities Are Improving Life for Seniors

Author(s): Oliver, S.

Abstract: Blog

Subject Areas: Seniors; Cities

Availability: Oliver, S., 2019. *Five Innovative Ways Cities Are Improving Life for Seniors.* The Wall Street Journal. https://www.wsj.com/articles/five-innovative-ways-cities-are-improving-life-for-seniors-11558450968

6.12. Title: What kinds of Vehicles do Americans drive?

Author(s): NA

Abstract: Blog

Subject Areas: Vehicle type; Demographic groups; NHTS

Availability: 2019. *What kinds of Vehicles do Americans drive?* Engaging-data.com
https://engaging-data.com/vehicles-state/

6.13. Title: A Resurgence in Urban Living? Trends in Residential Location Patterns of Young and Older Adults since 2000

Author(s): Blumenberg, E., Brown, A., Ralph, K., Taylor, B.D. and Turley Voulgaris, C.

Abstract: Some have heralded a resurgence of urban living in the U.S., particularly among young adults. Are Americans abandoning suburbs in favor of more urban lifestyles? What is the scope and scale of this urban resurgence? We develop a typology of neighborhoods to analyze the residential location of young and older U.S. adults from 2000 to 2011–15. Census and national travel survey data reveal that suburban population growth continues to outpace that in urban neighborhoods. Although young adults are more likely than older adults to live in urban neighborhoods, recent urban population growth is neither associated with suburban decline, nor being led by young adults. Significant recent population growth in the newest, suburban neighborhoods suggests that greenfield development remains the primary means to increase American housing supply. Shifting metropolitan growth from the suburban fringe would likely require expanding housing supply in urban neighborhoods, and bringing urban amenities to established inner-ring suburbs.

Subject Areas: Urban living; Young adults; Residential location

6.14. Title: University Students' Transportation Patterns, and the Role of Neighbourhood Types and Attitudes

Author(s): Nash, S. and Mitra, R.

Abstract: Research on the millennial generation's travel behaviour is emerging, but little is known about the socio-demographic, attitudinal and environmental factors that influence day-to-day trips by these young adults. In this study, data collected from four universities in Toronto, Canada, was analyzed to explore patterns in transportation behaviour, or transportation life-styles, of post-secondary students. A latent class analysis identified five distinct student groups based on a one-day travel diary data and self-reported long-term travel behaviour, namely: Transit dependent (31%), Active and neighbourhood oriented (23%), Multi-modal (11%), Occasional driver (12%) and Driver (23%). Two-thirds of students (65%) predominantly relied on either walking/cycling or transit. Logistic regression models indicated that a student's socio-demographic characteristics and life-course situations might explain their travel behaviour. Neighbourhood type of residence was an important indicator of a student's transportation life-style. Strong associations between travel attitudes, residential location preferences and a student's transportation life-style was also observed. Post-secondary students are at an important stage in their life-course where they begin to form habitual travel behaviour as young adults. Findings from this study contribute an improved understanding of travel behaviour, which may also inform planning, policy and service provision relating to transportation, land development and affordable housing.

Subject Areas: Young adults; Life-course; Transportation life-style; Modality style; Neighbourhood typology; Mobility biography

6.15. Title: Car Brands with the Youngest Drivers

Author(s): Kamenov, A.

Abstract: Blog

Subject Areas: Young drivers; Driver's Age; Car Brand; CarMax; NHTS

Availability: Kamenov, A., 2019. *Car Brands with the Youngest Drivers.* City-Data.com
http://www.city-data.com/blog/6719-car-brands-with-the-youngest-drivers/

6.16. Title: African-American Millennials Prefer Cadillac

Author(s): Gazdik, T.

Abstract: Blog

Subject Areas: African-American; Millennials; Full size cars; Demographic group

Availability: Gazdik, T., 2019. *African-American Millennials Prefer Cadillac.* Media-post.com https://www.mediapost.com/publications/article/331449/african-american-millennials-prefer-cadillac.html

6.17. Title: Despite 'Car-Free' Hype, Millennials Drive a Lot

Author(s): Bliss, L.

Abstract: Blog

Subject Areas: Millennials; Driving; Older generations

Availability: Bliss, L., 2019. *Despite 'Car-Free' Hype, Millennials Drive a Lot.* Citylab. https://www.citylab.com/transportation

6.18. Title: The Rural Telecommuter Surplus in Southwestern Ontario, Canada

Author(s): Hambly, H. and Lee, J.D.

Abstract: This paper asks the question: what kind of economic benefits do rural telecommuters experience in Southwestern Ontario? This is a relevant question in Canada where, according to Statistics Canada (2017) one in 14 people work from home. This paper presents an overview of the current literature on telecommuting. We estimate the telecommuter surplus in Southwestern Ontario where the region is currently deploying one of Canada's largest publicly-funded ultra-high-speed broadband initiatives known as SouthWest Integrated Fibre Technology Inc. (SWIFT). The analysis is based on SWIFT residential and farm surveys (n=3948) conducted in 2017. We find that an average telecommuter's surplus in terms of costs saved, including opportunity cost ranges from $8820 to $23964 per annum per telecommuter, depending on the number of days telecommuted per week for home and primary residence dwelling type. The social net benefits of telecommuting differ from its private net benefit (the focus of our paper) since the former includes both positive and negative externalities associated with telecommuting such as reduced traffic congestion, reduced probability of road accidents, as well as some workers shirking their duties (a negative impact). We leave this for future work.

Subject Areas: Telecommuting surplus; Teleworking; Economics of telecommuting; Opportunity cost of commuting

Chapter 7. Survey, Data Synthesis, and Other Applications

7.1. Title: State of the Practice of Long Distance and Intercity Travel Modeling in US Metropolitan Planning Organizations and State Departments of Transportation

Author(s): Cordero, F.

Abstract: Long distance and intercity travel represent a small percentage of total trips in the U.S., yet they represent a large percentage of total VMT. Long distance trips represent an important travel market with over $317 billion in business-travel and $718 billion in leisure travel profits in 2017. Metropolitan Planning Organizations (MPOs) and State Department of Transportation (DOTs) are responsible for developing the Long-Range Transportation Plan (LRTP) and Statewide Transportation Plan, respectively. Within these plans, future infrastructure and funding investment is defined based on model estimation from past, current, and future travel and socio-economic variables. Currently, the lack of guidance in long distance travel modeling has derived concerns among practitioners and scholars. Therefore, two national state-of-practice surveys on long distance travel modeling were conducted among MPOs and State DOTs to gain insight in long distance travel modeling among these agencies. The purpose of this thesis is to draw recommendation for future guidance on long distance travel.

Subject Areas: Long distance travel; Intercity travel; Long-Range Transportation Plan (LRTP); Statewide Transportation Plan; State-of-practice Surveys

Availability: Cordero, F., 2019. *State of the Practice of Long Distance and Intercity Travel Modeling in US Metropolitan Planning Organizations and State Departments of Transportation.* University of Auburn, M.S. Thesis.
https://etd.auburn.edu/handle/10415/6689

7.2. Title: Recommended Mounting Heights for Freestanding On-Premise Signs

Author(s): Garvey, P.M. and Klena, M.J.

Abstract: Freestanding on-premise signs are commercial signs that are not attached to buildings or other structures and include ground-mounted, monument, pylon, and pole signs. This report focuses on issues related to the appropriate mounting height of freestanding signs. The objective of this report is to develop best practices for optimal freestanding on-premise sign mounting height based on roadway factors, sign visibility, and traffic safety, relying on existing research and practice and basic geometry, and describing variations for different road types and sign lateral offsets. To achieve this, the existing on-premise and traffic sign mounting height research was reviewed, and the current state-of-the-practice was summarized. In addition, a technical analysis of on-premise sign height and sign visibility based on roadway cross-section and driver-to-sign sightlines was conducted.

Subject Areas: Mounting; Height; On-premise; Sign

7.3. Title: Filling in the Gaps of Connected Car Data Helps Transportation Planners

Author(s): Miller, J.A., 2019.

Abstract: Blog

Subject Areas: Vehicle Data; Connected Cars; Models

Availability: Miller, J.A., 2019. *Filling in the Gaps of Connected Car Data Helps Transportation Planners.* Michigan Technological University Blog. https://www.mtu.edu/news/stories/2019/april/filling-in-the-gaps-of-connected-car-data-helps-transportation-planners.html

7.4. Title: 2045 Long-range Transportation Plan

Author(s): NA

Abstract: NA (Transportation Plan)

Subject Areas: Transportation Plan; MPO; Long-range; Policy

Availability: 2018. *2045 Long-range Transportation Plan.* Black Hawk County, Metropolitan Area Transportation Board, INRCOG.
http://www.inrcog.org/pub.htm

7.5. Title: Overestimation of Self-reported Driving Exposure: Results from the SHRP2 Naturalistic Driving Study

Author(s): Friedrich, T.E., Duerksen, K.N. and Elias, L.J.

Abstract: Objectives: The accuracy of self-reported driving exposure has questioned the validity of using self-reported mileage to inform research questions. Studies examining the accuracy of self-reported driving exposure compared to objective measures find low validity, with drivers overestimating and underestimating driving distance. The aims of the current study were to (1) examine the discrepancy between self-reported annual mileage and driving exposure the following year and (2) investigate whether these differences depended on age and annual mileage.

Methods: Two estimates of drivers' self-reported annual mileage collected during vehicle installation (obtained via prestudy questionnaires) and approximated annual mileage driven (based upon Global Positioning System data) were acquired from 3,323 participants who participated in the Strategic Highway Research Program 2 (SHRP2) Naturalistic Driving Study.

Results: A Wilcoxon signed rank test showed that there was a significant difference between self-reported and annual driving exposure during participation in SHRP 2, with the majority of self-reported responses overestimating annual mileage the following year, irrespective of whether an ordinal or ratio variable was examined. Over 15% of participants provided self-reported responses with over 100% deviation, which were exclusive to participants underestimating annual mileage. Further, deviations in reporting differed between participants who had low, medium, and high exposure, as well as between participants in different age groups.

Conclusions: These findings indicate that although self-reported annual mileage is heavily relied on for research, such estimates of driving distance may be an overestimate of current or future mileage and can influence the validity of prior research that has utilized estimates of driving exposure.

Subject Areas: Driving exposure; Naturalistic driving; Measurement; Self-report; Age

7.6. Title: Trail Users in the Cincinnati Metropolitan Region: Purposes, Patterns, and Preferences

Author(s): Chen, N., Lindsey, G., Johnston, W., Adcock, K. and West, E.

Abstract: The benefits of using multi-use trails have been recognized from different perspectives, such as improving public health, expanding active transportation options, and enhancing environmental quality. Trail managers in Greater Cincinnati have developed a 212-mile trail network, with plans to expand and connect the system. Given regional priorities for trail development, trail managers and advocates need to understand more about trail users and how they use the network. In response, two nonprofit organizations in this region, Tri-State Trails and Interact for Health, along with the assistance from researchers at the University of Minnesota, launched Greater Cincinnati's first comprehensive trail measurement program including both trail traffic monitoring and an intercept survey of trail users. Monitoring results show the network is heavily used: in 2017, monitoring results on 137 miles of the network showed users traveled an estimated 11 million miles on those segments annually (Lindsey et al. 2019).
This paper describes results of the survey which was designed with questions covering trip characteristics, perceptions of the trails, socio-demographics, and locational information. Between August 2017 and October 2017, 31 trail staff and volunteers administered the survey at 20 locations. 734 responses were obtained. Three methods are used to analyze the survey: descriptive summary, statistical association analysis, and geographical mapping. The descriptive results show 89% of respondents are recreational users while only 8.8% are utilitarian users. These utilitarian users cluster in areas close to Cincinnati downtown and along a centrally located, long trail that connects several communities. Most recreational users are female, white, between 35 and 64 years old, well-educated, and with relatively high incomes. These users primarily bicycled and walked on trails, drove less than 25 minutes to trail, and traveled less than 5 miles. In contrast, most utilitarian users are male, with income of less than $59,999, walked or biked to trail, and traveled no more than 2 miles on trails. Recreational and utilitarian users' preferences are consistent with positive attitudes towards trail use and environment. Some differences between recreational and utilitarian users are statistically supported using the statistical association analysis. Geographically, the neighborhood context of trail users with different socio-demographics is displayed to illustrate clustering phenomenon among trail users by race and income. The differences between recreational and utilitarian users imply the importance of developing policies to satisfy various needs of trail users. This analysis provides a valuable framework for local governments to evaluate, manage, and improve the multi-use trail network.

Subject Areas: Survey; Trip characteristics and perceptions; Trail users

7.7. Title: Are Estimates of Early Education Programs Too Pessimistic? Evidence from a Large-Scale Field Experiment that Causally Measures Neighbor Effects

Author(s): List, J.A., Momeni, F. and Zenou, Y.

Abstract: We estimate the direct and spillover effects of a large-scale early childhood intervention on the educational attainment of over 2,000 disadvantaged children in the United States. We show that failing to account for spillover effects results in a severe underestimation of the impact. The intervention induced positive direct effects on test scores of children assigned to the treatment groups. We document large spillover effects on both treatment and control children who live near treated children. On average, spillover effects increase a child's non-cognitive (cognitive) scores by about 1.2 (0.6 to 0.7) standard deviations. The spillover effects are localized, decreasing with the spatial distance to treated neighbors. Our evidence suggests the spillover effect on non-cognitive scores are likely to operate through the child's social network. Alternatively, parental investment is an important channel through which cognitive spillover effects operate. We view our results as speaking to several literatures, perhaps most importantly the role of public programs and neighborhoods on human capital formation at an early age.

Subject Areas: Education; Neighborhood; Field experiment; Spillover effects; Non-cognitive skills

7.8. Title: Genesis: Trip Generation Model using ACS, CTPP, and NHTS data

Author(s): Kim, K. and Chang, Y.

Abstract: Poster

Subject Areas: Trip Generation Model; NHTS data

Availability: Kim, K. and Chang, Y., 2019. *Genesis: Trip Generation Model using ACS, CTPP, and NHTS data.* Poster at Transportation Research Board 98th Annual Meeting http://www.trbcensus.com/TRB2019/

Chapter 8. Traffic Safety

8.1. Title: Self-reported Handheld Device Use while Driving

Author(s): Kim, K., Ghimire, J., Pant, P. and Yamashita, E.

Abstract: In spite of research and awareness of the hazards associated with handheld mobile device use while driving, many motorists continue to engage in this risky behavior. The mobile device use while driving has a detrimental effect on the operation of the vehicle. It contributes significantly to distraction which is a leading cause of accidents. Especially, the use of text messaging and the dialing of a 10-digit number while driving can be attributable to crash risks. Phone use bans have a positive role in reducing mobile phone use for texting while operating vehicles. There are limited studies on whether drivers admit to the use of handheld devices while driving. The aim of this study was to identify the experiences, practices, and attitudes of handheld device use while driving. A total of 337 respondents nationwide replied to the survey on the attitudes and self-reported behaviors of handheld device use while driving. In the survey, the characteristics of handheld device users, use of handheld devices, and the differences in self-reported behaviors across states with and without device use restrictions were compared. The perceptions and experiences of device users are also examined. Based on the background of device users and their attitudes, a multivariate logistic regression is used to identify the characteristics of those who use handheld devices while driving. The model is relevant to this research because it allows the consideration and comparison of many variables to identify the attitudes of people towards distracted driving. The affirmative self-reporting of 59 percent of the respondents is a surprising result given that there are state bans on texting and the use of handheld mobile phones while driving. Older drivers are least likely to engage in these behaviors, compared to younger drivers and adult drivers. Based on the findings, targeted educational and enforcement campaigns to reduce device use during driving are suggested. Additional promising areas for further inquiry and research are also proposed.

Subject Areas: Handheld device use; Distracted driving; Accident analysis; Prevention

8.2. Title: Analysis of Factors Affecting Hit-and-Run and Non-Hit-and-Run in Vehicle-Bicycle Crashes: A Non-Parametric Approach Incorporating Data Imbalance Treatment

Author(s): Zhou, B., Li, Z., Zhang, S., Zhang, X., Liu, X. and Ma, Q.

Abstract: Hit-and-run (HR) crashes refer to crashes involving drivers of the offending vehicle fleeing incident scenes without aiding the possible victims or informing authorities for emergency medical services. This paper aims at identifying significant predictors of HR and non-hit-and-run (NHR) in vehicle-bicycle crashes based on the classification and regression tree (CART) method. An oversampling technique is applied to deal with the data imbalance problem, where the number of minority instances (HR crash) is much lower than that of the majority instances (NHR crash). The police-reported data within City of Chicago from September 2017 to August 2018 is collected. The G-mean (geometric mean) is used to evaluate the classification performance. Results indicate that, compared with original CART model, the G-mean of CART model incorporating data imbalance treatment is increased from 23% to 61% by 171%. The decision tree reveals that the following five variables play the most important roles in classifying HR and NHR in vehicle-bicycle crashes: Driver age, bicyclist safety equipment, driver action, trafficway type, and gender of drivers. Several countermeasures are recommended accordingly. The current study demonstrates that, by incorporating data imbalance treatment, the CART method could provide much more robust classification results.

Subject Areas: Bicyclist; Hit-and-run; Traffic safety; Classification and regression tree; Data imbalance

8.3. Title: Evaluation of Not-At-Fault Assumption in Quasi-Induced Exposure Method using Traffic Crash Data at Varied Geographical Levels

Author(s): Zhao, S., Wang, K. and Jackson, E.

Abstract: Acquiring real-world driver distribution data on roadways is a challenge. The quasi-induced exposure (QIE) method is a promising alternative as it only requires the available crash data. The question to be answered through this study is whether the not-at-fault driver assumption of the QIE still holds when the population is broken down to smaller geographical levels, such as counties, towns, or routes. This is important because the result will provide statistical support to choose for or against the application of QIE at disaggregate levels. In this study, the distributions of driver gender, age, and vehicle type between four groups of drivers in the crash data were examined, using data obtained from the state of Connecticut from 2015 to 2017. Namely, they are the not-at-fault drivers and at-fault drivers in two-vehicle crashes (NF2 and AF2) and the not-at-fault drivers and at-fault drivers in three-or-more vehicle crashes (NF3 and AF3). Chi-square tests and Wilcoxon Mann-Whitney tests were used to provide statistical evidence of whether the driver groups come from the same population. The evidence shows that there are no statistical differences between the distributions of NF2 and NF3. The QIE assumption of not-at-fault drivers is valid at all tested geographical levels. Driver characteristic distribution in the NF2 (and NF3) groups in the crash data should be a good representation of the driving population. The results also revealed the similarities of distributions between AF2 and AF3 and the significant differences between the not-at-fault drivers (NF2 and NF3) and at-fault-drivers (AF2 and AF3).

Subject Areas: Traffic Crash; Varied Geographical Levels; Traffic safety; Quasi-Induced Exposure Method; Not-at-fault drivers and At-fault drivers

8.4. Title: Safety Evaluation of Statewide Off-Highway Vehicle Use in Alaska

Author(s): Belz, N.

Abstract: Standard measures of risk and conflict, design guidelines, and informed policies and regulations for off-highway vehicle users (e.g., all-terrain vehicles and snow machines) near and on the traveled way are not well established from a rural safety perspective. The State of Alaska currently has a Department policy to not prohibit their travel within the off-pavement area, but it does not currently design for or address crossings or other conflicts when these users approach roads and other publicly traveled ways. There is a need for statewide assessment of conflicts between these users and traditional roadway users. A recent all terrain vehicle (ATV)-related fatality in Akiachak, discussions on safety concerns surrounding ATV/off highway vehicle (OHV) use and policies in Wasilla, Bethel, and Kotzebue, and requests for AKDOT&PF to address conflicts in rural Native Alaska communities off the main road network make this very timely research. This research presents a statewide review of the data and types of conflicts occurring on highways, a compilation of borough and city/town OHV policies, and the results of a discourse analysis of nationwide news articles on OHV issues. Findings build on previous work related to mixed-use safety and provide greater insight on special user groups and modes to address safety concerns and the transportation needs of rural and small-urban areas of Alaska.

Subject Areas: Off-Highway Vehicle (OHV); Transportation Safety; Safety Analysis; Trauma Registry; Field Data Collection

Availability: Belz, N., 2019. *Safety Evaluation of Statewide Off-Highway Vehicle Use in Alaska.* Pacific Northwest Transportation Consortium University of Alaska Fairbanks, Alaska Department of Transportation & Public Facilities.
https://digital.lib.washington.edu/researchworks/handle/1773/43585?show=full

Chapter 9. Transit Planning

9.1. Title: Socioeconomic and Usage Characteristics of Public Transit Riders in the United States

Author(s): Grahn, R., Hendrickson, C., Qian, Z.S. and Matthews, H.S.

Abstract: Urbanization trends and the emergence of alternative modes of transportation have influenced the way individuals travel. The authors use the 2017 National Household Travel Survey (NHTS) to explore socioeconomic and frequency of use characteristics associated with public transit users. The results indicate that transit riders are younger than the general population and reside in urban regions. Low and high income households represent large proportions of the transit rider population. Low income users tend to use bus services while high income users often use rail. Minority groups rely on public transit more heavily than the white population. A higher proportion of African Americans and Asians use bus and rail services respectively compared to the general NHTS population. High frequency transit users own fewer household vehicles on average and tend to be more frequent rideshare users. The private vehicle commuter mode share decreased by 3% between 2009 and 2017 while increases were observed for walking, biking, and public transit.

Subject Areas: Modal split; Socioeconomic factors; Transit riders; Travel surveys

9.2. Title: Charting Public Transit's Decline

Author(s): O'Toole, R.

Abstract: Blog

Subject Areas: Transit; Ridership; NHTS

Availability: O'Toole, R., 2018. *Charting Public Transit's Decline.* Cato Institute. https://www.cato.org/publications/policy-analysis/charting-public-transits-decline#full

9.3. Title: A Comparison of the Personal and Neighborhood Characteristics associated with Ridesourcing, Transit Use, and Driving with NHTS Data

Author(s): Deka, D. and Fei, D.

Abstract: The opportunity to conduct an overarching national study to examine the characteristics of ridesourcing users and their neighborhoods was absent until the 2017 National Household Travel Survey (NHTS) dataset was released in 2018. As the 2017 NHTS combines ridesourcing with taxi and limo in the trip file, ridesourcing trip characteristics cannot be separately analyzed. Thus, the paper examines the characteristics of users and neighborhoods associated with ridesourcing trip frequency from the person file, defined as the number of rides taken in 30days. Because the public-use NHTS dataset includes only limited information about the neighborhoods where the respondents live, additional data from the NHTS DOT files were analyzed so that the characteristics of the neighborhoods could be fully comprehended. In an effort to examine the proximity of those neighborhoods to public transit stations and stops, GIS data on transit stations and stops were analyzed from the Bureau of Transportation Statistics and the US Department of Homeland Security. A zero-inflated negative binomial (ZINB) model was used to identify the variables associated with ridesourcing trip frequency. Two similar models were used to identify the variables associated with public transit trip frequency and annual vehicle miles driven. The analysis showed that the direction of the effects of the personal and neighborhood characteristics on ridesourcing and transit trip frequency is mostly similar, but often dissimilar to their effects on miles driven. A significant finding of this research is that people living near transit stations/stops use ridesourcing more frequently.

Subject Areas: Ridesourcing; Transit Use; Neighborhood Characteristic; Zero-Inflated Negative Binomial (ZINB) Model

9.4. Title: A Direct Demand Model for Commuter Rail Ridership in the San Francisco Bay Area

Author(s): Kwong, J.

Abstract: This thesis documents the development of a direct travel demand model for commuter rail in the San Francisco Bay Area. A direct demand model simultaneously estimates trip generation and attraction, which for this thesis would be trips between an origin-destination pair of stations. In the model, the number of trips assigned to an origin-destination pair of stations is dependent on land use characteristics at the origin and destination stations in combination with travel time on the network during congested peak periods and via transit. The model uses a multiplicative direct demand model to estimate ordinary least square regression parameters for the origin-destination trips. From the model form, the resultant estimated regression parameters are elasticities, and as such, can be used to postulate the effects of the selected land use characteristics and network travel times upon the number of trips made.
At both the origin and destination, the location of the station within the central business districts of the San Francisco Bay region had the largest effect on trip generation and attraction. Higher employment density at the destination and a larger number of workers per household at the origin had a positive effect on trips, while the total number of industrial workers at the destination and an increased number of two car households had a negative effect on trips. Longer travel times on transit appeared to have a positive effect on trips, yet longer travel times in congested peak periods appeared to have a negative effect on trips.

Subject Areas: Commuter Rail; Direct Demand Model; Origin-destination; Transit

Availability: Kwong, J., 2019. *A Direct Demand Model for Commuter Rail Ridership in the San Francisco Bay Area.* Doctoral dissertation, UC Irvine.
https://escholarship.org/uc/item/7q20v7dz

9.5. Title: Transit Access Equity in Richmond, VA

Author(s): Jordan, R.

Abstract: The purpose of this thesis is to analyze the extent of public transit access equity issues in Richmond, VA. The City of Richmond has an established public transportation network system, and the thesis explores the level of access for urban residents to use existing public transportation services. Technologies and programs have begun to emerge across the United States to help solve transit accessibility challenges. The thesis assesses the level of transit access equity that exists in Richmond and introduces technologies and services that could help improve accessibility and equity. The thesis uses a mixed methods approach that will consist of accessibility and equity measures, Geographic Information System (GIS), and key informant interviews.

Subject Areas: Public Transit; Urban Residents; Geographic Information System (GIS)

Availability: Jordan, R., 2019. *Transit Access Equity in Richmond, VA.* Doctoral dissertation, Virginia Commonwealth University.
https://scholarscompass.vcu.edu/etd/5772/

Chapter 10. Travel Behavior

10.1. Title: Exploring the Relationship between Vehicle Type Choice and Distance Traveled: A Latent Segmentation Approach

Author(s): Angueira, J., Konduri, K.C., Chakour, V. and Eluru, N.

Abstract: In the context of vehicle usage decisions, there are two important choice dimensions namely, the choice of vehicle from household fleet that will be utilized for trips and second, the distance traveled to pursue the planned activities. There are interrelationships between these two choice dimensions with one dimension potentially influencing the other. The direction of the interrelationship has important implications for transportation planning and policy analyses. In an effort to explore the interrelationships, a latent segmentation-based modeling approach is proposed in this paper. The approach allows for exploring alternative interrelationship structures between choice dimensions in the same modeling framework. The methodology is demonstrated using data from the latest wave of the National Household Travel Survey (NHTS) in the United States. The results show the need for accommodating alternative structures between choice dimensions to accurately describe the vehicle usage decision processes exhibited by individuals.

Subject Areas: Latent Segmentation Models; Short-Term Vehicle Usage Decisions; Vehicle Type Choice; Distance Traveled

10.2. Title: A Machine-Learning Decision-Support Tool for Travel-Demand Modeling

Author(s): Brown, C.S., Garikapati, V. and Hou, Y.

Abstract: Utility maximization(UM) models are the lifeblood of virtually all travel demand models (TDM) in practice. Be it the traditional travel demand models or more advanced activity-based models, utility maximization models are used extensively to model and predict myriad travel choices such as location choice, mode choice, route choice etc. More recently machine learning (ML) models are being applied in a variety of contexts to predict choice patterns (product suggestions on Amazon, restaurant suggestions on Yelp etc.,). In the TDM arena, there has been interest in incorporating ML models where they can enhance prediction accuracy. Though there have been sporadic efforts at comparing specific utility maximization models to machine learning models, there is a need for a standard comparison tool which can evaluate ML models against UM models for a given choice context. Addressing this need, we present a tool for applying an array of models including logit, nested logit, neural network, Naive Bayes and decision tree classifiers. The tool is specifically tailored to aid in the deciding the best model for a given choice context and can be used to choose an appropriate model family or to construct a model ensemble to improve upon current modeling standards in travel demand modeling. We test our proposed system on household vehicle count and work schedule targets from the 2017 National Household Travel Survey. Results demonstrate that for some variables, logit are not the most effective models, and the proposed system can aid in selecting a better model.

Subject Areas: 33 ADVANCED PROPULSION SYSTEMS; Machine Learning; Decision Support Tool; Travel Demand Modeling

Availability: Brown, C.S., Garikapati, V. and Hou, Y., 2019. *A Machine-Learning Decision-Support Tool for Travel-Demand Modeling.* (No. NREL/PO-5400-72993). National Renewable Energy Lab.(NREL), Golden, CO (United States).
https://www.osti.gov/biblio/1494741

10.3. Title: Not Parking Lots but Parks: A Joint Association of Parks and Transit Stations with Travel Behavior

Author(s): Park, K., Choi, D.A., Tian, G. and Ewing, R.

Abstract: Urban design literature says that public open space in a station area could promote walking and other types of physical activity, enhance place attractiveness, and increase property values. In the context of station areas, however, there is a lack of empirical studies on the relationship between the presence of parks and sustainable travel behavior, which is one of the primary goals of transit-oriented developments (TODs). This study examined the impact of park provision on transit users' mode choice in three U.S. regions: Atlanta (GA), Boston (MA), and Portland (OR). This study utilized multilevel multinomial logistic regression to account for hierarchical data structures — trips nested within station areas — and multiple travel modes — automobiles, transit, and walking. After controlling for the built environment and trip attributes, this study showed that when there was a park, people were more likely to walk or take transit to access or egress a transit station. A transit station having a park nearby may provide a more pleasant first-mile/last-mile travel experience. This paper demonstrated that station areas need to incorporate more public space, an overlooked element in current TOD plans.

Subject Areas: Mode Choice; Transit-Oriented Development; Public Space; First-Mile And Last-Mile Connection

10.4. Title: Exploring the Relationships Among Travel Multimodality, Driving Behavior, Use of Ridehailing and Energy Consumption

Author(s): Circella, G., Lee, Y. and Alemi, F.

Abstract: In the last decade, advances in information and communication technologies and the introduction of the shared economy engendered new forms of transportation options and, in particular, shared mobility. Shared mobility services such as carsharing (e.g., Zipcar and Car2go), dynamic ridesharing (e.g., Carma), ridehailing (e.g., Uber and Lyft), and bike/scooter sharing (e.g., CitiBike, Jump Bike, Bird, and Lime) have gained growing popularity especially among subgroups in the population including college-educated or urban-oriented young adults (e.g., millennials). These emerging transportation services have evolved at an unprecedented pace, and new business models and smartphone applications are frequently introduced to the market. However, their fast-changing nature and lack of relevant data have placed difficulties on research projects that aim to gain a better understanding of the adoption/use patterns of such emerging services, not to mention their impacts on various components of travel behavior and transportation policy and planning, and their related environmental impacts.
This report builds on an on-going research effort that investigates emerging mobility patterns and the adoption of new mobility services. In this report, the authors focus on the environmental impacts of various modality styles and the frequency of ridehailing use among a sample of millennials (i.e., born from 1981 to 1997) and members of the preceding Generation X (i.e., born from 1965 to 1980). The total sample for the analysis included in this report includes 1,785 individuals who participated in a survey administered in Fall 2015 in California. In this study, the researchers focus on the vehicle miles traveled, the energy consumption and greenhouse gas (GHG) emissions for transportation purposes of various groups of travelers. They identify four latent classes in the sample based on the respondents' reported use of various travel modes: drivers, active travelers, transit riders, and car passengers. They further divide each latent class into three groups based on their reported frequency of ridehailing use: non-users, occasional users (who use ridehailing less than once a month), and regular users (who use it at least once a month). The energy consumption and GHG emissions associated with driving a personal vehicle and using ridehailing services are computed for the individuals in each of these groups (12 subgroups), and the authors discuss sociodemographics and economic characteristics, and travel-related and residential choices, of the individuals in each subgroup.

Subject Areas: Mobility patterns; Mode Choice; Travel Multimodality; Driving Behavior

10.5. Title: Socioeconomic and Usage Characteristics of Transportation Network Company (TNC) Riders

Author(s): Grahn, R., Harper, C.D., Hendrickson, C., Qian, Z. and Matthews, H.S.

Abstract: The widespread adoption of smartphones followed by an emergence of transportation network companies (TNC) have influenced the way individuals travel. The authors use the 2017 National Household Travel Survey to explore socioeconomic, frequency of use, and spatial characteristics associated with TNC users. The results indicate that TNC riders tend to be younger, earn higher incomes, have higher levels of education, and are more likely to reside in urban areas compared to the aggregate United States population. Of the TNC users, 60% hailed a ride three times or less in the previous month, indicating that TNC services are primarily used for special occasions. TNC users use public transit at higher rates and own fewer vehicles compared to the aggregate United States population. In fact, the TNC user population reported similar frequencies of use for both TNC services and public transit during the previous month. Approximately 40% of TNC users reside in regions with population densities greater than 10, 000 persons per square mile compared to only 15% for non-TNC users. Lastly, reported use of public transit for TNC users living in large cities (>1 million) with access to heavy rail was almost three times greater when compared to similar sized cities without heavy rail. The average monthly frequency of TNC use was also elevated when heavy rail was present.

Subject Areas: Transportation network companies (TNC); Ride sharing; Shared mobility; Travel behavior; Uber; Lyft

10.6. Title: Location Choice, Life Cycle and Amenities

Author(s): Letdin, M. and Shim, H.S.

Abstract: Our study proposes a housing location choice model where a household faces a trade-off between proximity to place of employment and proximity to amenities. We consider subsamples of high amenity cities and low amenity cities and households with and without children. We show that the roles of gender, education, homeownership, household composition, and public transportation vary significantly depending on level of amenities. Households with a female head of household, those with a working spouse and with older children prefer locating closer to downtown amenities. Female workers with and without children locate closer to work, in high and low amenity cities.

Subject Areas: Location choice; High and low amenity cities; Housing location choice model; Employment

10.7. Title: The Rise of Long-Distance Trips, in a World of Self-Driving Cars: Anticipating Trip Counts and Evolving Travel Patterns Across the Texas Triangle Megaregion

Author(s): Kockelman, K., Huang, Y. and Quarles, N.

Abstract: The Texas Triangle megaregion contains Texas' largest cities and metropolitan areas, and thereby most of the state's economic and social activities. This report anticipates the impacts of self-driving, full automated or "autonomous" vehicles (AVs), shared AVs (SAVs), and "autonomous" trucks (Atrucks) on travel across this important megaregion using Year 2040 land use (and network) forecasts. Various Statewide Analysis Model (SAM) data are leveraged to anticipate the impacts of AVs', SAVs' and Atrucks' impacts on destination and mode choices. A travel demand model with feedback is implemented to forecast changes in vehicle-miles traveled (VMT), congestion, and travel patterns across the megaregion. Results suggest that people will shift to more distant destinations, on average (evidenced by the increase in the megaregion's average travel distance: from 14miles to 16miles). Air travel will fall by more than 82%, with these long-distance travelers shifting to ground transport options. Without travel demand management (like credit-based congestion pricing and mandated tight headways between AVs), congestion issues will grow, thanks to an average VMT increase of 47%, which is more evident in the region's major cities: Houston, Dallas-Fort Worth, San Antonio and Austin. Almost 109.6% of the megaregion's link flows will suddenly exceed capacity, relative to a no-AV case which has 4.6% exceed capacity. Automobile travel will rise across all trip distance categories, with jumps most evident between suburban and urban zones. Six of the 15 commodity groups simulated are expected to see a >5% increase in their associated truck trips, due to the introduction of Atrucks, with rising truck trade largely between Houston and other major Texas employment centers.

Subject Areas: Self-driving vehicle; Passenger and freight travel; Texas Triangle megaregion; Statewide Analysis Model; Travel Patterns

Availability: Kockelman, K., Huang, Y. and Quarles, N., 2019. *The Rise of Long-Distance Trips, in a World of Self-Driving Cars: Anticipating Trip Counts and Evolving Travel Patterns Across the Texas Triangle Megaregion.* Technical Resrport CM2-22, Cooperative Mobility for Competitive Megaregions, U.S. DOT.
https://trid.trb.org/view/1597755

10.8. Title: Factors Associated with Round-trip Carsharing Frequency and Driving-Mileage Impacts in London

Author(s): Wu, C., Le Vine, S., Clark, M., Gifford, K. and Polak, J.

Abstract: This study draws on respondents from Greater London within the 2016/17 wave (n=2640) of Britain's Annual Survey of carsharing users, which we enrich with external data from the 2011 England and Wales Census and small-area income estimates. Focusing on round-trip carsharing users, we present multivariate analyses of frequency-of-usage of carsharing vehicles and impacts on annual vehicle miles traveled (VMT). Published attribute effects from other geographic and contextual circumstances are compiled and compared (where direct comparison is possible) with the specific attribute effects that we report in this paper. We demonstrate a statistically significant link between customer satisfaction with proximity of carsharing vehicles and VMT impacts. Car ownership (both current, and changes upon joining a carsharing service) is shown to have intuitive structural impacts. We find that frequent usage is associated ceteris paribus with increasing VMT after joining a carsharing service, and that subscribing to multiple types of carsharing is associated with frequent carsharing usage and a reduction in VMT. Interestingly, we did not find any significant effect of household income on either frequency-of-usage or VMT impacts.

Subject Areas: Carsharing; Travel behavior; Frequency of usage; Vehicle miles traveled

10.9. Title: The Impact of Ride Hailing on Parking (and Vice Versa)

Author(s): Henao, A. and Marshall, W.E.

Abstract: Investigating emerging transportation services is critical to forecasting mode choice and providing appropriate infrastructure. One such infrastructure is parking, as parking demand may shift with the availability of ride-hailing services. This study uses ethnographic methods–complemented with passenger surveys collected when driving for Uber and Lyft in the Denver, Colorado, region–to gather quantitative and qualitative data on ride-hailing and analyze the impacts of ride-hailing on parking, including changes in parking demand and parking as a reason to deter driving. The study also examines relationships between parking time and cost. This includes building a classification tree-based model to predict the replaced driving trips as a function of car ownership, destination land type, parking stress, and demographics.
The results suggest that: i) ride-hailing is replacing driving trips and could reduce parking demand, particularly at land uses such as airports, event venues, restaurants, and bars; ii) parking stress is a key reason respondents chose not to drive; and iii) respondents are generally willing to pay more for reduced parking time and distance. Conversely, parking supply, time, and cost can all influence travel behavior and ride-hailing use. This study provides insight into potential benefits and disadvantages of ride-hailing as related to parking.

Subject Areas: Ride-hailing; Ridesourcing; TNC; Uber; Lyft; Parking; Curb space; TDM

10.10. Title: Understand the Multi-Level Effects of the Built Environment on Trip-Chaining Behavior

Author(s): Pang, H. and Zhang, M.

Abstract: The debate on the effects of the built environment (BE) on travel behavior has been ongoing despite a large number of studies completed in the past three decades. This study aims to inform the debate by extending the BE–travel behavior investigation to the scope of trip-chaining. Specifically, the study conceptualized the contexture frame for the relationship of BE attributes and trip-chain travel behavior and estimated 2-level hierarchical linear models (HLM) of chained trip tours with travel survey data from the Puget Sound region. The results show that travelers who live in areas with better transit access, higher residential and non-residential density, and higher level of land use mixture generated low percentage of miles traveled by vehicle (PVMT) during their daily tours. Furthermore, considering the cross-level interactive effect, the study demonstrates that the impacts of the non-residential density at work location and the residential density at home location on PVMT are moderated by vehicle ownership.

Subject Areas: Built Environment; Trip-Chaining Behavior; Hierarchical linear models (HLM)

10.11. Title: Measuring Mobilities of Care, a Challenge for Transport Agendas: From One to Many Tracks

Author(s): de Madariaga, I.S. and Zucchini, E.

Abstract: This chapter proposes a methodology for accurately measuring daily travel associated with care tasks: activities performed by adults for children and other dependants, and the maintenance of the home. These activities are statistically performed by women, often as unpaid work. The travel associated with these tasks is not well described in the transport literature and is still less considered by transport policy agendas. We build the methodological framework for measuring this kind of travel around the innovative concept of mobility of care (Sànchez de Madariaga, Transporte metropolitano y grupos sociales: propuestas para una mejor planificaciòn. Madrid: Ministry of Infrastructure, 2009, Schiebinger et al. Gender innovations in science, health and medicine, engineering and environment (launched 2011: genderinnovations.stanford.edu), 2013), which provides an umbrella category for the design of transport statistics that takes into account gender dimensions in urban transport. The chapter further provides an empirical study that applies this methodology to analyse the daily mobility of women and men aged 30–45 years in the metropolitan region of Madrid.

Subject Areas: Mobility of care; Gender equality; Transport policy; Transport behaviour; Mobility survey

Availability: de Madariaga, I.S. and Zucchini, E., 2019. *Measuring Mobilities of Care, a Challenge for Transport Agendas: From One to Many Tracks.* In Integrating Gender into Transport Planning (pp. 145-173). Palgrave Macmillan, Cham. https://www.researchgate.net/publication/330905894_Measuring_Mobilities_of_Care_a_Challenge_for_Transport_Agendas_From_One_to_Many_Tracks

10.12. Title: Eliciting Preferences of Ridehailing Users and Drivers: Evidence from the United States

Author(s): Bansal, P., Sinha, A., Dua, R. and Daziano, R.

Abstract: Transportation Network Companies (TNCs) are changing the transportation ecosystem, but micro-decisions of drivers and users need to be better understood to assess the system-level impacts of TNCs. In this regard, we contribute to the literature by estimating a) individuals' preferences of being a rider, a driver, or a non-user of TNC services; b) preferences of ridehailing users for ridepooling; c) TNC drivers' choice to switch to vehicles with better fuel economy, and also d) the drivers' decision to buy, rent or lease new vehicles with driving for TNCs being a major consideration. Elicitation of drivers' preferences using a unique sample (N=11,902) of the U.S. population residing in TNC-served areas is the key feature of this study. The statistical analysis indicates that ridehailing services are mainly attracting personal vehicle users as riders, without substantially affecting demand for transit. Moreover, around 10% of ridehailing users reported postponing the purchase of a new car due to the availability of TNC services. The model estimation results indicate that the likelihood of being a TNC user increases with the increase in age for someone younger than 44 years, but the pattern is reversed post 44 years. This change in direction of the marginal effect of age is insightful as the previous studies have reported a negative association. We also find that postgraduate drivers who live in metropolitan regions are more likely to switch to fuel-efficient vehicles. These findings would inform transportation planners and TNCs in developing policies to improve the fuel economy of the fleet.

Subject Areas: Transportation Network Companies (TNCs); Ridehailing; Drivers

Availability: Bansal, P., Sinha, A., Dua, R. and Daziano, R., 2019. *Eliciting Preferences of Ridehailing Users and Drivers: Evidence from the United States.* Cornell University, arXiv preprint arXiv:1904.06695.
https://arxiv.org/abs/1904.06695

10.13. Title: Rider-to-rider Discriminatory Attitudes and Ridesharing Behavior

Author(s): Moody, J., Middleton, S. and Zhao, J.

Abstract: Using online survey data from N=2041 Uber and Lyft users in the United States collected in 2016 and 2018, this paper establishes the validity, reliability, and invariance of a measure of rider-to-rider race and social class discrimination. This measure is then incorporated into three structural models that investigate associations between rider-to-rider discriminatory attitudes and four aspects of ridesharing behavior. We find no significant relationship between rider-to-rider discriminatory attitudes and whether a TNC user has ever used a ridesharing service (such as uberPOOL or Lyft Line). However, among those who have used ridesharing services before, rider-to-rider discriminatory attitudes are strongly negatively predictive of an individual's level of satisfaction with the sharing option, and marginally negatively predictive of an individual's percentage of shared TNC trips. Furthermore, among those who have not yet used ridesharing services, rider-to-rider discriminatory attitudes are strongly negatively predictive of willingness to consider using uberPOOL or Lyft Line in the future. Together, these findings suggest that rider-to-rider discriminatory attitudes may discourage sustained and frequent use of ridesharing services among TNC users. Further research is required to identify strategies for addressing discriminatory attitudes in the ridesharing context and overcoming reluctance to sharing.

Subject Areas: Dynamic ridesharing; Race; Class Discrimination; Transportation Network Companies (TNCs)

Availability: Moody, J., Middleton, S. and Zhao, J., 2019. *Rider-to-rider Discriminatory Attitudes and Ridesharing Behavior.* Transportation Research Part F: Traffic Psychology and Behaviour, 62, pp.258-273.
https://www.sciencedirect.com/science/article/abs/pii/S1369847818306181

10.14. Title: Predicting the Ownership, Use, and Environmental Impacts of New Vehicle Technologies with a Focus on the Relationship between Travel Behavior and the Built Environment

Author(s): Nodjomian, A.T.

Abstract: The field of transportation is on the cusp of major change. Innovations in how vehicles operate and are powered have the potential to elicit changes not seen since the introduction of the interstate highway system more than half a century ago. Predicting the impacts of new vehicle technologies has interested researchers and practitioners across disciplines and continents. This thesis makes a handful of such predictions. It is divided into three parts. In the first part, the results of two large-scale preference surveys and data from the U.S. Environmental Protection Agency's (EPA) Smart Location Database (EPA, 2014) are used to estimate how land use characteristics impact Americans' perceptions of, interest in, and willingness to pay for new vehicle technologies, while controlling for demographic attributes. The surveys were conducted by Quarles and Kockelman (2018) and Gurumurthy and Kockelman (2018) in 2017 and together represented over 4,000 U.S. households. Statistical models like the ordered probit and multinomial logit are used to estimate the impacts of demographics and land use characteristics on vehicle-related behavior. Various land use variables arise as significant depending on the question being asked of the respondents. For example, poor job accessibility via automobile is associated with higher levels of interest in automated vehicles (AVs), higher anticipated use of AV technology, a willingness-to-pay (WTP) for self-driving capability, and a greater reliance on AVs for some long-distance travel. No land use variable arises as significantly more predictive than the others at this national-level scale of analysis. The results emphasize the fact that land use policy must be considered at the local level, and that there is no "one size fits all" solution for managing future transportation behavior with land use action. The second part of this thesis evaluates the connection between land use and current travel behavior. Census tract-level measures of population and employment density (provided once again by the EPA's Smart Location Database [EPA, 2014]) are evaluated across the nation to investigate the connection between the development conditions one experiences and his or her travel behavior. Travel data comes from the 2009 National Household Travel Survey (NHTS). The results highlight a stronger connection between population density and vehicle-miles traveled (VMT) and vehicle ownership, than with employment density. For both VMT and vehicle ownership, an improvement of only two to one can be expected by changing population density conditions in a census tract. In other words increasing population from the lowest density conditions to the highest results in a decline of VMT per capita per day from 20 miles to 10 miles. Similarly, vehicle ownership per capita generally ranges from 0.4 to 0.8. Notably, these improvements are not realized until the highest decile of population density (18 people per acre), thus indicating that simply building homes in rural or low-density suburban regions will likely have a negligible impact on transportation demand. Employment density was found to be less indicative of travel behavior. The third and final piece of the thesis predicts how an evolving light-duty vehicle (LDV) fleet will impact the amount of energy consumed by Americans and the emissions they create. Here, the results of a fleet evolution simulation, developed by Quarles et al.

(2019), are used to project what a vehicle fleet with more electric (and fewer gasoline-powered) vehicles will mean for energy consumption and emissions on a per capita basis. Projections are based on historic fuel efficiency data and emission production rates from the Bureau of Transportation Statistics (BTS) and EPA (BTS, 2018b; BTS, 2018c; EPA, 2018a). Conclusions from these findings highlight the need for more efficient vehicles, better emissions control technologies on existing vehicle models and power plants, and a decreased reliance on highly-polluting energy sources for power generation. Policies aimed at achieving these objectives will help ensure that Americans' future vehicle behavior and ownership will not create an undue burden on themselves or the environment in which they live. Although the analyses discussed in this thesis cover diverse topics such as human behavior, urban planning, and air quality, they establish the need for a proactive approach to cutting-edge vehicle technologies. If left to develop without any oversight or action, transportation network congestion will worsen, development will continue to sprawl, and the environment and public health will suffer. Policies aimed at limiting "empty" driving with AVs, increasing population density, and curbing vehicle and power plant emissions can help ensure the benefits of vehicle technology innovation are not realized at the expense of other considerations.

Subject Areas: Autonomous vehicles; Shared; Travel behavior survey; Models; Willingness to pay; Mode choice; Population density; Employment density; Fleet evolution; Energy usage; Emissions

Availability: Nodjomian, A.T., 2019. *Predicting the Ownership, Use, and Environmental Impacts of New Vehicle Technologies with a Focus on the Relationship between Travel Behavior and the Built Environment.* Doctoral dissertation, University of Texas. https://repositories.lib.utexas.edu/handle/2152/74510

10.15. Title: What Drives the use of Ridehailing In California? Ordered Probit Models of the Usage Frequency of Uber and Lyft

Author(s): Alemi, F., Circella, G., Mokhtarian, P. and Handy, S.

Abstract: The availability of ridehailing services, such as those provided by Uber and Lyft in the U.S. market, as well as the share of trips made by these services, are continuously growing. Yet, the factors affecting the frequency of use of these services are not well understood. In this paper, we investigate how the frequency of use of ridehailing varies across segments of the California population and under various circumstances. We analyze data from the California Millennials Dataset (N=1975), collected in fall 2015 through an online survey administered to both millennials and members of the preceding Generation X. We estimate an ordered probit model with sample selection and a zero-inflated ordered probit model with correlated error terms to distinguish the factors affecting the frequency of use of ridehailing from those affecting the adoption of these services. The results are consistent across models: sociodemographic variables are important predictors of service adoption but do not explain much of the variation in the frequency of use. Land use mix and activity density respectively decrease and increase the frequency of ridehailing. The results also confirm that individuals who frequently use smartphone apps to manage other aspects of their travel (e.g. to select a route or check traffic) are more likely to adopt ridehailing and use it more often. This is also true for long-distance travelers, in particular, those who frequently travel by plane for leisure purposes. Individuals with higher willingness to pay to reduce their travel time use ridehailing more often. Those with stronger preferences to own a personal vehicle and those with stronger concerns about the safety/security of ridehailing are less likely to be frequent users. These results provide new insights into the adoption and use of ridehailing that could help to inform planning and forecasting efforts.

Subject Areas: Uber/Lyft; Ridehailing; Travel behavior; Frequency model; Ordered probit model with sample selection; Zero-inflated probit ordered model with correlated error terms

10.16. Title: Nudging People towards More Sustainable Residential Choice Decisions: An Intervention Based on Focalism and Visualization

Author(s): Bhattacharyya, A., Jin, W., Le Floch, C., Chatman, D.G. and Walker, J.L.

Abstract: There have been numerous behavior change studies focused on sustainable travel mode choices. In this study we focused on the residential choices that in turn influence travel habits. We designed and implemented two interventions, which we term the "focalism" and "visualization" interventions, based on literature in psychological economics. The focalism intervention was motivated by literature that suggests people make suboptimal choices when looking for a new home. While focus is given to immediately tangible features like the quality of the house, important but less tangible factors like access to transportation are relatively overlooked. The visualization intervention was based on literature showing that providing information at decision points when long-ingrained habits are vulnerable to change, such as at the time of a residential move, can be influential on choices. We designed both interventions to be interactive so that the intervention was "discovered" by respondents rather than presented directly as information. With the focalism intervention, we pointed out differences in how respondents ranked their search priorities for new housing and neighborhoods, versus how they ranked what they reported makes them happy. With the visualization intervention, we explained to respondents that moving is an opportunity to make changes in one's life, and we prompted them to think through what they desired to change. We evaluated the influence of these interventions on residential housing decisions by surveying respondents about their priorities in residential search before and after the interventions, and by collecting information about their housing, neighborhoods, travel patterns, and reported well-being. The surveys were web-based, with one survey conducted before respondents moved and a second survey conducted afterward. Participants were randomly assigned to a focalism treatment group, a visualization treatment group, or a control group. 380 respondents answered the pre-move survey, and 184 of these answered the post-move survey. In the pre-move survey, we found that both the focalism and visualization interventions resulted in a significant increase in the fraction of people who planned to travel more sustainably relative to the control group. More importantly, we found that after the post-move survey, respondents in the focalism group, but not the visualization group, significantly reduced their travel time to work and increased their cycling, walking, carpooling, carsharing and transit use in comparison to the control group. Meanwhile, those in the visualization treatment group had significantly higher reported well-being after the move; those in the focalism treatment group also improved their stated well-being, though less significantly; and there was no change in the control group. These results suggest that it might be relatively easy to nudge residential choices towards both more sustainable travel and greater well-being.

Subject Areas: Travel behavior; Choice modeling; Urban Intervention

10.17. Title: Are Americans Driving Older Cars Or Just Leaving Them In The Driveway?

Author(s): Hernandez, K., Batbold, G. and Bin-Nun, A.

Abstract: Blog

Subject Areas: Travel behavior; Older Vehicles; VMT; NHTS vehicles

Availability: Hernandez, K., Batbold, G. and Bin-Nun, A., 2019. *Are Americans Driving Older Cars Or Just Leaving Them In The Driveway?* The Fuse.
http://energyfuse.org/are-americans-driving-older-cars-or-just-leaving-them-in-the-driveway/

10.18. Title: Why do we Trust Ridesharing Apps so much?

Author(s): Grinberg, E.

Abstract: Blog

Subject Areas: Travel behavior; Older Vehicles; VMT; NHTS vehicles

Availability: Grinberg, E., 2019. *Why do we Trust Ridesharing Apps so much?* KVIA.com. https://www.kvia.com/news/.../why-do-we-trust...apps.../1065648802

10.19. Title: Modeling Individuals' Willingness to Share Trips with Strangers in an Autonomous Vehicle Future

Author(s): Lavieri, P.S. and Bhat, C.R.

Abstract: With the era of fully automated vehicles (AVs) quickly approaching, ridesharing services could have an important role in increasing vehicle occupancy, reducing vehicle miles traveled, and improving traffic conditions. However, the extent to which these potentials can be achieved depends on consumers' disposition to sharing rides. From a travel behavior perspective, two essential elements to the adoption of shared rides are individuals' acceptance of increased travel times associated with pick-up/drop-off of other passengers and their approval of strangers sharing the same vehicle. The current study develops the notion of willingness to share (WTS), which represents the money value attributed by an individual to traveling alone compared to riding with strangers, to investigate the adoption of shared rides. Using a multivariate integrated choice and latent variable approach, we examine current choices and future intentions regarding the use of shared rides and estimate individuals' WTS as well as their values of travel time for two distinct trip purposes. Results show that users are less sensitive to the presence of strangers when in a commute trip compared to a leisure-activity trip. We also observe that the travel time added to the trip to serve other passengers may be a greater barrier to the use of shared services compared to the presence of a stranger. However, the potential to use travel time productively may help overcome this barrier especially for high-income individuals.

Subject Areas: Travel behavior; Value of travel time; Willingness-to-share; Ride-hailing; Dynamic ridesharing; Automated vehicles

10.20. Title: How do Activities Conducted while Commuting influence Mode Choice? Using Revealed Preference Models to Inform Public Transportation Advantage and Autonomous Vehicle Scenarios

Author(s): Malokin, A., Circella, G. and Mokhtarian, P.L.

Abstract: From early studies of time allocation onward, it has been acknowledged that the "productive" nature of travel could affect its utility. Currently, at the margin an individual may choose transit over a shorter automobile trip, if thereby she is able to use the travel time more productively. On the other hand, recent advancements toward partly/fully automated vehicles are poised to revolutionize the perception and utilization of travel time in cars, and are further blurring the role of travel as a crisp transition between location-based activities. To quantify these effects, we created and administered a survey to measure travel multitasking attitudes and behaviors, together with general attitudes, mode-specific perceptions, and standard socioeconomic traits (N=2229 Northern California commuters). In this paper, we present a revealed preference mode choice model that accounts for the impact of multitasking attitudes and behavior on the utility of various alternatives. We find that the propensity to engage in productive activities on the commute, operationalized as using a laptop/tablet, significantly influences utility and accounts for a small but non-trivial portion of the current mode shares. For example, the model estimates that commuter rail, transit, and car/vanpool shares would respectively be 0.11, 0.23, and 1.18 percentage points lower, and the drive-alone share 1.49 percentage points higher, if the option to use a laptop or tablet while commuting were not available. Conversely, in a hypothetical autonomous vehicles scenario, where the car would allow a high level of engagement in productive activities, the drive-alone share would increase by 1.48 percentage points. The results empirically demonstrate the potential of a multitasking propensity to reduce the disutility of travel time. Further, the methodology can be generalized to account for other properties of autonomous vehicles, among other applications.

Subject Areas: Travel behavior; Multitasking; Activities while traveling; Autonomous vehicles; Mode choice; Attitudes; Value of travel time

Availability: Malokin, A., Circella, G. and Mokhtarian, P.L., 2019. *How do Activities Conducted while Commuting influence Mode Choice? Using Revealed Preference Models to Inform Public Transportation Advantage and Autonomous Vehicle Scenarios.* Transportation Research Part A: Policy and Practice, 124, pp.82-114.
https://www.sciencedirect.com/science/article/pii/S0965856416306772

Chapter 11. Trend Analysis and Market Segmentation

11.1. Title: Trends of Home Deliveries in the U.S.: Changes from 2009 to 2017

Author(s): Schmid, J. and Wang, X.

Abstract: Most aspects of modern life have been significantly influenced by the internet and shopping is not immune from this. This is quite evident when analyzing the 2009 and 2017 National Household Travel Surveys (NHTS). Between 2009 and 2017, the number of online shopping deliveries received by the average American each month more than doubled. Zero-inflated negative binomial models are applied to both NHTS datasets. In both 2009 and 2017, age, education level, and technology use are major indicators of online shopping patterns. Both NHTS datasets were pooled to create a comparison model, with the main differences in demographic effects being the effect of education and large metropolitan areas on purchasing patterns. The results here reflect the trend of home deliveries. For transportation planners, it implies an increased amount of freight traffic on residential streets that communities will need to accommodate.

Subject Areas: Data analysis; Delivery service; Electronic commerce; Home shopping; Trend (Statistics)

11.2. Title: Modeling the Willingness to Work as Crowd-Shippers and Travel Time Tolerance in Emerging Logistics Services

Author(s): Le, T.V. and Ukkusuri, S.V.

Abstract: The objective of this study is to understand the different behavioral considerations that govern the choice of people to engage in a crowd-shipping market. A binary logit model and an ordinary least-square regression model have been developed. Those models are integrated by a selectivity-bias term. The results suggest that socio-demographic characteristics, freight transportation experience, and social media usage significantly influence respondents' decisions to participate in the crowd-shipping market. The selectivity is found available in the dataset and has strong heterogeneity. Moreover, the crowd-shippers' expect to-be-paid rate is found concurrent with value-of-time literature. Findings from this research are valuable to crowd-shipping companies recruiting employees and developing business strategies.

Subject Areas: Crowd-shipping; Willingness to work; Last-mile delivery; On-demand delivery; Selectivity correction; Discrete–continuous model

11.3. Title: Generational Trends in Vehicle Ownership and Use: Are Millennials Any Different?

Author(s): Knittel, C.R. and Murphy, E.

Abstract: Anecdotes that Millennials fundamentally differ from prior generations are numerous in the popular press. One claim is that Millennials, happy to rely on public transit or ride-hailing, are less likely to own vehicles and Travel less in personal vehicles than previous generations. However, in this discussion it is unclear whether these perceived differences are driven by changes in preferences or the impact of forces beyond the control of Millennials, such as the Great Recession. We empirically test whether Millennials' vehicle ownership and use preferences differ from those of previous generations using data from the US National Household Travel Survey, Census, and American Community Survey. We estimate both regression and nearest-neighbor matching models to control for the confounding effect of demographic and macroeconomic variables. We find little difference in preferences for vehicle ownership between Millennials and prior generations once we control for confounding variables. In contrast to the anecdotes, we find higher usage in terms of vehicle miles traveled (VMT) compared to Baby Boomers. Next we test whether Millennials are altering endogenous life choices that may, themselves, affect vehicles ownership and use. We find that Millennials are more likely to live in urban settings and less likely to marry by age 35, but tend to have larger families, controlling for age. On net, these other choices have a small effect on vehicle ownership, reducing the number of vehicles per household by less than one percent.

Subject Areas: Millennials; Trends; Vehicle Ownership; Prior Generations

11.4. Title: Estimating the Cost and Utility of Statewide Travel Models using Scenario-Based Interviews

Author(s): Francis, D., Tsang, F. and Erhardt, G.D.

Abstract: Statewide travel models are analysis tools that simulate transportation system conditions and are used to answer "what if" questions about proposed plans and policies. In the United States, they are in use or in development in 39 out of 50 state departments of transportation (DOTs). States without a statewide model are faced with the decision of whether to invest in one, whereas states with models need to decide when and whether to upgrade. Prior efforts to aid this decision making provided detailed synthesis on the cost of statewide modeling, but it has been difficult for other states to use the lessons learned, because cost is largely driven by each state's specific circumstances. There has also been very little research on quantifying the value of models. To address these gaps, the present research uses a novel scenario-based interview approach. Representatives from 29 DOTs and five consultancies participated in our scenario-based interviews, from which we collected cost estimates for three archetypical statewide models and willingness-to-pay estimates (i.e., perceived value) under nine model development and policy focus scenarios. Our results show that cost ranges from $500,000 for an archetypical Basic 3-Step Model to between $2.8million and $5million for an Activity-Based Model for a large state, with data collection comprising a large portion of the cost (36–66%). Further, the perceived value of statewide models exceeds the costs by a factor of 2.4–11.3, with the cost-benefit ratio being higher when a DOT is interested in a broader set of policy issues.

Subject Areas: Statewide travel models; Costs; Invest; Willingness-to-pay estimates; Cost-benefit Ratio

11.5. Title: Forecast Households at the County Level: An Application of the ProFamy Extended Cohort-Component Method in Six Counties of Southern California, 2010 to 2040

Author(s): Feng, Q., Wang, Z., Choi, S. and Zeng, Y.

Abstract: Policymakers and market analysts have long been interested in future trends of households. Among household projection methods, the ProFamy extended cohortcomponent method, as one alternative to the traditional headship-rate method, has recently been extended to the subnational levels. This paper illustrates the application of the ProFamy method at the county level by projecting household types, sizes, and elderly living arrangements for six counties of Southern California from 2010 to 2040, including Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura.Using this specific case, this paper introduces the rationales and procedure of the county-level application of the ProFamy method. The validation test for the ProFamy to project the 2010 population and households using the 2000 census data support the use of the ProFamy at the county level. And the ProFamy method also yields satisfactory results in comparison with the projections of headship-rate methods. The ProFamy forecasts on the six county of Southern California provide detailed information on the county-level trends of households and elderly living arrangement in this region, which are valuable information for the local planning agency but usually beyond the capacity of the traditional methods.

Subject Areas: Household; Household projection; Forecast; ProFamy; Headship rate; County

11.6. Title: Transportation Network Companies and Taxis: The Case of Seattle

Author(s): Leisy, C.A.

Abstract: Transportation Network Companies and Taxis: The Case of Seattle is a modern economic case history and thorough analysis of the devastating impact of the transportation network company (TNC) industry (Uber and Lyft) on the taxicab industry in Seattle, Washington, beginning in 2014. The events that transpired and lessons learned are applicable to most large cities in North America, Europe and Australia.
As the regulator of the taxicab and TNC industries in Seattle during this period, the author offers a unique insider perspective. The book also provides internal operating statistics on the TNC industry, which are available here for the first time. Despite the spectacular growth of the TNC industry, growth rates have steadily declined and may fall to zero by 2019 or 2020, while the taxicab industry appears to have begun a modest recovery. This book offers a thorough explanation of how and why this decline has happened. It explains the taxicab industry, economic deregulation, competitive market failure, market disruption, price elasticity of demand and other concepts. There is also a wealth of data, computations and analysis for the specialized reader.
This book considers the past, present and future of the taxicab and TNC industries in Seattle, It is recommended for both the general reader and industry professionals.

Subject Areas: Transportation Network Companies; Taxis; Seattle; Industry

Availability: Leisy, C.A., 2019. *Transportation Network Companies and Taxis: The Case of Seattle.* Routledge.
https://www.taylorfrancis.com/books/9780429265129

11.7. Title: Estimating Preference Heterogeneity in Discrete Choice Models of Product Differentiation

Author(s): Leard, B.

Abstract: Modeling preference heterogeneity in discrete choice models of product differentiation remains computationally challenging. I derive a new method for estimating preference heterogeneity in these models. A key advantage of the method is its simplicity: preference heterogeneity parameters are estimated with a closed-form expression or with a linear regression. I apply the method to estimate parameters of new vehicle demand and to simulate the effects of new vehicle fuel economy standards. The simulation results suggest that a marginal tightening of the standards has a modest impact on total new vehicle sales.

Subject Areas: Discrete Choice Models; Preference Heterogeneity; Microdata; Substitution Patterns

11.8. Title: Consumer Myopia in Vehicle Purchases: Evidence from a Natural Experiment

Author(s): Gillingham, K., Houde, S. and Van Benthem, A.

Abstract: A central question in the analysis of fuel-economy policy is whether consumers are myopic with regards to future fuel costs. We provide the first evidence on consumer valuation of fuel economy from a natural experiment. We examine the short-run equilibrium effects of an exogenous restatement of fuel-economy ratings that affected 1.6 million vehicles. Using the implied changes in willingness-to-pay, we find that consumers act myopically: consumers are indifferent between $1 in discounted fuel costs and 15–38cents in the vehicle purchase price when discounting at 4%. This myopia persists under a wide range of assumptions.

Subject Areas: Fuel-economy policy; Consumer; Myopia

Availability: Gillingham, K., Houde, S. and Van Benthem, A., 2019. *Consumer Myopia in Vehicle Purchases: Evidence from a Natural Experiment.* National Bureau of Economic Research, Working Paper No. 25845.
https://www.nber.org/papers/w25845

11.9. Title: Selection of Optimal Target Reliability in RBDO through Reliability-Based Design for Market Systems (RBDMS) and Application to Electric Vehicle Design

Author(s): Lee, U., Kang, N. and Lee, I.

Abstract: Reliability-based design optimization (RBDO) allows decision-makers to achieve target reliability in product performance under engineering uncertainties. However, existing RBDO studies assume the target reliability as a given parameter and do not explain how to determine the optimal target reliability. From the perspective of the market, designing a product with high target reliability can satisfy many customers and increase market demand, but it can generate a large cost leading to profit reduction of the company. Therefore, the target reliability should be a decision variable which needs to be found to maximize the company profit. This paper proposes a reliability-based design for market systems (RBDMS) framework by integrating RBDO and design for market system (DMS) approaches to find the optimal target reliability. The proposed RBDMS framework is applied to electric vehicle (EV) design problems to validate effect of the target reliability on company profit–or market share–and engineering performances of EV. Several observations about the optimal target reliability are presented from the case study with various scenarios. From the EV design case study, it is verified that the proposed RBDMS framework is an effective way of finding the optimal target reliability that maximizes the company profit, and the optimal target reliability varies depending on the situation of market and competitors.

Subject Areas: Reliability-based design optimization (RBDO); Design for market systems (DMS); Electric vehicles; Target reliability; Uncertainty

11.10. Title: Game Theory Approach on Modeling of Residential Electricity Market by Considering the Uncertainty due to the Battery Electric Vehicles (BEVs)

Author(s): Fijani, R.F., Azimian, B. and Ghotbi, E.

Abstract: Based on sophisticated metering infrastructure (AMI), one can use big data to provide demand-response (DR) solutions. There is a need to develop optimized cost structures for consumers. In this paper, Stackelberg game approaches are utilized, and residential loads are considered including battery electric vehicles (BEVs) equipped with BEV communication controllers and vehicle-to-grid (V2G) technologies. Efficient and effective optimized algorithms are developed for users (followers) based on time dependent pricing schemes. In the game, besides the followers, other participant is an electricity retailer company (leader), with a two-way bilateral communication procedure accepted and established by all participants. The user side of the games is related to the demand side management (DSM). Real-time pricing (RTP) from time-of-use (TOU) companies is used to achieve better results. Monte Carlo simulations (MCS) represent uncertain behaviors of BEV drivers. Results indicate that customers demands can be met while reaching the best efficiency.

Subject Areas: Game Theory Approach; Residential Electricity Market; Battery Electric Vehicles (BEVs)

Availability: Fijani, R.F., Azimian, B. and Ghotbi, E., 2019. *Game Theory Approach on Modeling of Residential Electricity Market by Considering the Uncertainty due to the Battery Electric Vehicles (BEVs).* Cornell University.
https://arxiv.org/abs/1902.05028

11.11. Title: Quantifying the Electric Vehicle Charging Infrastructure Gap across US Markets

Author(s): Nicholas, M., Hall, D. and Lutsey, N.

Abstract: The electrification of the United States vehicle market continues, with the most growth occurring in markets where barriers are addressed through policy, charging infrastructure, and consumer incentives. Key questions about electric vehicle market growth include how much charging infrastructure will be needed to sustain growth and whether to invest in various types of this infrastructure. This report quantifies the gap in charging infrastructure from what was deployed through 2017 to what is needed to power more than 3 million expected electric vehicles by 2025, consistent with automaker, policy, and underlying market trends. Based on the expected growth across the 100 most populous U.S. metropolitan areas, we estimate the amount of charging of various types that will be needed to power these vehicles. Our evaluation of charging needs is based on best available observed data on the growing electric vehicle market, charging availability, and emerging charging behavior patterns. Figure ES-1 illustrates the deployment of public and workplace charging infrastructure through 2017 as a percentage of what will be needed by 2025 across the 100 most populous U.S. metropolitan areas (the 50 most populous are labeled). Shades of red indicate that less than 50% of the needed charging has been installed through the end of 2017, while blues indicate that more than 50% of charging needed in 2025 was in place by 2017. Of the 100 areas, 88 had less than half of the total needed charging infrastructure in place, based on their expected electric vehicle growth.

Subject Areas: US Markets; Electric Vehicle; Trends; Charging infrastructure

Availability: Nicholas, M., Hall, D. and Lutsey, N., 2019. *Quantifying the Electric Vehicle Charging Infrastructure Gap across US Markets.* International Council on Clean Transportation. https://theicct.org/publications/charging-gap-US