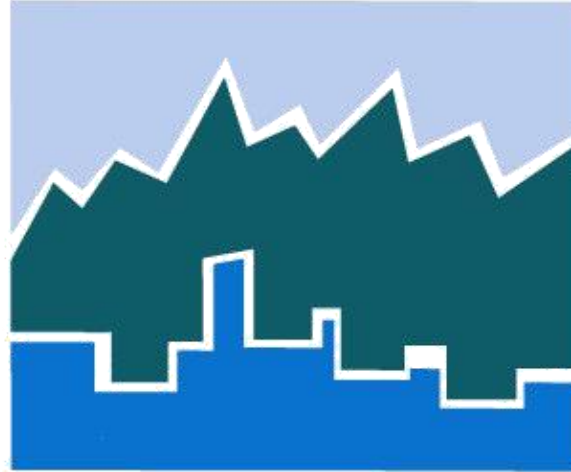


# NHTS



## **National Household Travel Survey**

### **Compendium of Uses**

January 2023–June 2023

## Foreword

This compendium contains various uses and applications of the National Household Travel Survey (NHTS) data referenced in transportation planning and research from January 2023 through June 2023. 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 *Transportation Research Record*, the *Journal of Transport Geography*, and the *Journal of Transport & Health*. Several papers were also submitted by researchers and graduate students for presentation and publication to the Transportation Research Board's (TRB's) 102nd Annual Meeting and can be found in the *2023 TRB Annual Meeting Compendium of Papers*. Source material was also identified through Google Scholar™ and Google Alerts™ using “National Household Travel Survey”, “NHTS”, “NextGen Passenger Origin-Destination”, and “NextGen Truck Origin-Destination” keyword and search engine terms.

These selected articles and reports were grouped into 13 categories using the subject areas and index terms identified in each abstract as well as category titles used in previous NHTS compendium databases. The following categories, broken out by report chapter, were used in this version of the compendium:

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.
12. Emerging travel modes.
13. Passive OD data product usage.

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 the interim 2023 compendium consists of 214 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](mailto:Daniel.Jenkins@dot.gov).

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

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## Chapter 1. Bicycle and Pedestrian Studies

### 1.1 Title: Exploring the Socio-Demographic Characteristics of Bicycle Trip Makers

**Author(s):** Javid, R., Vaziri, E., and Jeihani, M.

**Abstract:** Bikesharing is believed to improve urban mobility, save energy and the natural environment, enhance public health, and decrease public travel expenses. Moreover, prior studies have found that disadvantaged communities are subjected to disproportionately high travel costs. The main goal of this study is to investigate the effect of household demographic characteristics on bicycle usage to reduce the financial burden of travel in the U.S., both in rural and urban areas. The data has been obtained from the latest National Household Travel Survey, which was conducted in 2017. For the analysis, a Binary Logistic Regression was used to identify factors affecting the usage of bicycles to reduce the financial burden of travel. The results of the model indicate that increases in the number of household members increase the odds of using a bike to decrease transportation costs. Furthermore, African American households reduce the cost of travel by riding a bicycle more often than White households. Likewise, urban households use bikes to reduce their transportation costs more often than rural households do. The results of our investigation show that different socio-demographic groups do not use the bike equally or for the same purpose. This research provides a deeper understanding of bike-travel behavior among different households and informs policies that prioritize high-need communities through appropriately planned bike infrastructure development. This, in turn, can help transportation planners and authorities pursue bike infrastructure investment more equitably.

**Subject Areas:** Bikesharing; Bike infrastructure development; Bicycle usage; Transportation costs; Sociodemographic characteristics

**Availability:** Javid, R., Vaziri, E., and Jeihani, M. (2023). *Exploring the Socio-Demographic Characteristics of Bicycle Trip Makers*. Transportation Research Board 102nd Annual Meeting, Washington, D.C. <https://annualmeeting.mytrb.org/OnlineProgramArchive/Details/19320>

## 1.2 Title: Perceptions on Active Travel from Low-Income Households: Insights from the 2017 National Household Travel Survey

**Author(s):** Ghimire, S. and Bardaka, E.

**Abstract:** This study explores the perception of low-income households on active travel as a way to alleviate the financial expenses of travel and compares it with that of higher-income households across space. Using data from the 2017 National Household Travel Survey, this study utilizes both econometric and machine learning approaches to examine the variation in perceptions of people in different socioeconomic groups living in different geographical locations. Using generalized ordered logistic regressions, we find that people in low-income households are more likely to use cycling or walking to reduce the financial expenses associated with travel as compared to people in higher-income households. The model results also show that urban residents are more likely to use walking and cycling to alleviate financial expenses as compared to suburban and rural residents. This study also explores the factors associated with the perceived barriers to walking and cycling. A Random Forest classification model is applied to understand the factors that contribute to the perception of infrastructure and safety barriers to active travel. Significant spatial variations exist on the perceived infrastructure and safety barriers to active travel among people in different households and also among different categories of users of active travel. The findings of this study could provide valuable information to the planning agencies about the contextual policies and investments required to promote active travel in different geographical situations and for different sociodemographic groups.

**Subject Areas:** Regional trail network; Recreation and transportation access; Bay Area; Statewide economic impact; Low income; Active travel

**Availability:** Ghimire, S. and Bardaka, E. (2023). *Perceptions on Active Travel from Low-Income Households: Insights from the 2017 National Household Travel Survey*. Transportation Research Board 102nd Annual Meeting, Washington, D.C.

<https://annualmeeting.mytrb.org/OnlineProgramArchive/Details/19320>

### **1.3 Title: A Barrier Too Far: Understanding the Role of Intersection Crossing Distance on Bicycle Rider Behavior in Chicago**

**Author(s):** Aras, R.L., Ouellette, N.T., and Jain, R.K.

**Abstract:** For a variety of environmental, health, and social reasons, there is a pressing need to reduce the automobile dependence of American cities. Bicycles are well suited to help achieve this goal. However, perceptions of rider safety present a large hindrance toward increased bicycle adoption. These perceptions are largely influenced by the design of our current road infrastructure, including the crossing distances of large intersections. In this paper, we examine the role of intersection crossing distances in modifying rider behavior through the construction of a novel dataset integrating street widths and probable trip routes from Chicago’s Divvy bikeshare system. We compare real trips to synthetic trips that are not influenced by the width of intersections and exploit behavior differences that result from the semi-dockless nature of the bikeshare system. Our analysis reveals that bikeshare riders do avoid large intersections in limited circumstances; however, these preferences appear to be heavily outweighed by the relative spatial positions of origins and destinations (i.e., the urban morphology of Chicago). Our results suggest that specific infrastructural investments such as protected intersections could prove feasible alternatives to reduce the perception and safety concerns associated with large road barriers and enhance the attractiveness of non-motorized mobility.

**Subject Areas:** Bicycles; Bikeshare system; Rider safety; Design; Road infrastructure; Intersection crossing

**Availability:** Aras, R.L., Ouellette, N.T., and Jain, R.K. (2023). “A Barrier Too Far: Understanding the Role of Intersection Crossing Distance on Bicycle Rider Behavior in Chicago.” *Environment and Planning B: Urban Analytics and City Science*. <https://doi.org/10.1177/23998083221147922>

#### **1.4 Title: Relationship Between Neighborhood Walkability and the Prevalence, Type, Timing, and Temporal Characteristics of Walking**

**Author(s):** Clevenger, K.A., Berrigan, D., Patel, S., Saint-Maurice, P.F., and Matthews, C.E.

**Abstract:** We examined associations of neighborhood walkability with the prevalence, type, timing, and temporal characteristics of walking in a representative sample of United States adults. Adults (N = 2649) completed the ACT24 previous-day recall. Home address was linked to block-group National Walkability Index. Survey-adjusted Poisson and logistic regression examined the association of walkability with outcomes. Those who lived in more walkable neighborhoods were more likely to walk overall, for transport, or in the evening. In those who walked, higher walkability was associated with less morning but more evening walking. There were no associations of walkability with the frequency or duration of walking episodes.

**Subject Areas:** Built environment; Physical activity; Patterns; Pedestrian

**Availability:** Clevenger, K.A., Berrigan, D., Patel, S., Saint-Maurice, P.F., and Matthews, C.E. (2023). "Relationship Between Neighborhood Walkability and the Prevalence, Type, Timing, and Temporal Characteristics of Walking." *Health & Place*, 80. <https://doi.org/10.1016/j.healthplace.2023.102983>

## 1.5 Title: School Walk Zone: Identifying Environments That Foster Walking and Biking to School

**Author(s):** Kweon, B.-S., Shin, W.-H., and Ellis, C.D.

**Abstract:** Today, few children walk or bike to school. According to the National Household Travel Survey, only 11% of children walk or bike to school. In 1969, almost 50% of children walked or biked to school in the US. Although our understanding is limited, previous research has shown that physical environments can influence non-automobile mode choices for travel to school. For example, landscape buffers and trees affect parents' perceptions of their children's safety and increase their willingness to let their children walk to school. We investigated how a number of physical attributes in the pedestrian environment influence children's commutes to school. A total of 186 parents from four school walk zones in College Station, TX, participated in this study. We found that children walked more in neighborhoods with mature trees. Moreover, the mean walking and biking distances differed from each other, and both were influenced by the location of the school within the walk zones. Concerns about traffic safety and convenience were negatively related to walking and biking. The findings here suggest ways to shape better school walk zone guidelines that include neighborhood design, planning, and engagement in support of active and healthy children.

**Subject Areas:** Commute to school; Children's health; School walk zone; Pedestrian environments; Walking and biking to school

**Availability:** Kweon, B.-S., Shin, W.-H., and Ellis, C.D. (2023). "School Walk Zone: Identifying Environments That Foster Walking and Biking to School." *Sustainability*, 15(4).  
<https://doi.org/10.3390/su15042912>



**1.6 Title: Active Travel Among Carless and Car-Owning Low-Income Populations in the United States**

**Author(s):** Ghimire, S. and Bardaka, E.

**Abstract:** Low-income households may resort to cycling and walking to alleviate travel costs. Using data from the 2001, 2009, and 2017 National Household Travel Surveys, this study examines the spatiotemporal differences in the use of active travel among three socioeconomic groups classified based on household income and vehicle ownership. After controlling for a number of observed and unobserved factors, we find that individuals in low-income, car-owning households are associated with up to 14% more walking trips and 33% more cycling trips in a week compared to higher-income households, on average. However, in urban areas, higher-income households use active travel significantly more than low-income, car-owning households, while the opposite holds for suburban and rural areas. Individuals living in low-income, carless households are associated with even higher use of active travel. These results suggest that active travel is used, to some extent, out of necessity and lack of other viable options.

**Subject Areas:** Active travel; Spatiotemporal analysis; Carless households; Suburbs; National household travel survey; Zero-inflated negative binomial model

**Availability:** Ghimire, S. and Bardaka, E. (2023). “Active Travel Among Carless and Car-Owning Low-Income Populations in the United States.” *Transportation Research Part D: Transport and Environment*, 117. <https://doi.org/10.1016/j.trd.2023.103627>

## 1.7 Title: A Network Analysis Model to Measure the Walkability of Public Spaces

**Author(s):** Binopoulos, A., Evangelidou, E., Vlachopanagiotis, T., and Grizos, K.

**Abstract:** The ongoing shift from auto-oriented urban planning policies has led to a growing interest in the creation and management of public spaces in cities. Public spaces can act as an attraction for a city and have been proven useful for urban revitalization. However, it is not uncommon for many of those spaces to stay underutilized. The aim of this paper is to create a walkability utility index for every road segment that, when correlated with the population density of each area, is used to define the overall accessibility of public space on foot. This culminates into a set of novel equipotential mapping samples applied to a set of urban segments of Greek cities. The results of this paper lead to a different way of evaluating existing city plans, offer a useful tool to authorities in implementing urban regeneration works aimed at improving citizen well-being, and a keyway of evaluating new public space development projects.

**Subject Areas:** Accessibility; Walkability; Public spaces; Urban planning; Resilience

**Availability:** Binopoulos, A., Evangelidou, E., Vlachopanagiotis, T., and Grizos, K. (2023). “A Network Analysis Model to Measure the Walkability of Public Spaces.” In: Nathanail, E.G., Gavanas, N., and Adamos, G. (Eds.), *Smart Energy for Smart Transport. CSUM 2022. Lecture Notes in Intelligent Transportation and Infrastructure*, pp. 1121–1134. Springer, Cham. [https://doi.org/10.1007/978-3-031-23721-8\\_91](https://doi.org/10.1007/978-3-031-23721-8_91)

## 1.8 Title: The Influence of Pedestrian Plans on Walk Commuting in US Municipalities

**Author(s):** Duncan, M.

**Abstract:** A growing number of government entities have formalized their interest in making pedestrian activity more attractive by adopting a comprehensive pedestrian plan, but little is known as to whether these plans result in positive outcomes. This paper empirically examines the impact of pedestrian plans on pedestrian activity using a 13-year panel of commuting data from large US municipalities. The findings demonstrate that, while there is no significant change in walk commuting after the initial publication of a pedestrian plan, modest but statistically significant increases occur after a plan receives regular updates.

**Subject Areas:** Pedestrian plan; Walking; Commuting

**Availability:** Duncan, M. (2023). "The Influence of Pedestrian Plans on Walk Commuting in US Municipalities." *Transportation Research Part A: Policy and Practice*, 172.  
<https://doi.org/10.1016/j.tra.2023.103664>

## 1.9 Title: Association of Walking and Biking to School Policies and Active Commuting to School in Children

**Author(s):** Ganzar, L.A., Burford, K., Zhang, Y., Gressett, A., Kohl, H.W., III, and Hoelscher, D.M.

**Abstract: Background:** Active commuting to school (ACS) can be an important source of physical activity for children. Schools are an important setting for policy-related ACS promotion. The purpose of this study was to examine the association between school policies and ACS, and to assess whether this relation varied by grade. **Methods:** This cross-sectional study used data from schools recruited to the Safe Travel Environment Evaluation in Texas School study (n = 94). The percentage of trips made by active travel modes was measured through tallies among third- to fifth-grade classrooms from 5 school districts in Central Texas in 2018–2019. School ACS policies and practices were measured through 8 survey items aggregated into a score. Linear mixed effects models were used to assess the association between policies and ACS. **Results:** School health policy surveys and ACS data were collected from 69 elementary schools. An average of 14.6% of trips to/from school was made using active travel modes. Schools with higher numbers of policies had significantly higher percentages of students using active travel modes ( $P = .03$ ), and for each additional policy, the predicted percentage of trips made by active travel modes was 1.46% higher. There was a significant interaction effect between school policy and grade, with stronger correlations among higher grades ( $P = .002$ ). **Conclusions:** Results from this study demonstrate a correlation between the school policies designed to support walking and biking and ACS. Results from this study can be used to justify the use of school-based policy interventions to promote ACS.

**Subject Areas:** Active travel; School health; Physical activity

**Availability:** Ganzar, L.A., Burford, K., Zhang, Y., Gressett, A., Kohl, H.W., III, and Hoelscher, D.M. (2023). “Association of Walking and Biking to School Policies and Active Commuting to School in Children.” *Journal of Physical Activity and Health*, 20(7), pp. 648–654.  
<https://doi.org/10.1123/jpah.2022-0376>

**1.10 Title: Development and Implementation of a GIS-Based Active Route Visualization Tool to Facilitate Equitable Planning for Walking and Cycling Routes in Small Communities**

**Author(s):** Cordero, F. and LaMondia, J.

**Abstract:** Active transportation modes such as walking and bicycling have demonstrated several benefits for health, the environment, the economy, and road safety. However, the transportation planning process in rural areas rarely incorporates this mode of transportation. In fact, many small and rural towns lack the resources, experience, and capabilities to conduct detailed modeling of active transportation. In response, this research developed an Active Route Visualization (ARV) Tool to support planning and decision making in small cities and rural towns. By incorporating a modified three-step modeling process that used active trip rates developed from the 2017 National Household Travel Survey, the ARV Tool provided a map that highlighted the daily volumes of active travel in the community and ranked the roadway segments that had greater potential to support walking and bicycling. This research demonstrated application of the ARV Tool in the city of Atmore, AL. Implementation of the tool was valuable in this rural city as it supported a community coalition effort in partnership with the Alabama Cooperative Extension System to promote active transportation. In this process, the community coalition reviewed and discussed the ARV Tool outputs and provided invaluable local knowledge and feedback that were incorporated into the action plans. Small and rural towns can benefit from an easy-to-use, practical, and data-driven tool that provides insights to initiate discussions to identify priorities and opportunities for active transportation.

**Subject Areas:** Active transportation; Active Route Visualization Tool; Small cities and rural towns; Planning

**Availability:** Cordero, F. and LaMondia, J. (2022). "Development and Implementation of a GIS-Based Active Route Visualization Tool to Facilitate Equitable Planning for Walking and Cycling Routes in Small Communities." *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981231170006>

## Chapter 2. Energy Consumption

### 2.1. Title: An EVs Charging Guiding Strategy for the Coupling System of Road Network and Distribution Network Based on the PT3

**Author(s):** Zhang, C., Peng, K., Guo, L., Xiao, C., Zhang, X., and Zhao, Z.

**Abstract:** As an important load, electric vehicles (EVs) have great randomness. The integration of a large number of electric vehicles will have a great impact on the stable operation of the distribution network (DN) and road network. Therefore, in this paper a charging guiding strategy based on the third-generation prospect theory (PT3) is proposed combined with the fast charging station (FCS) integrated with photovoltaic-energy storage charging. Based on the dynamic reference point, a real-time coupling relationship model is proposed. And the full state prospect description model of coupling system is proposed and described by the prospect value. Based on the proposed model, the aggregate of the prospect value is used to describe the full state of the coupling system. Therefore, the proposed strategy can analyze the uncoordinated issues by the full state prospect description model and balance the coupling system by guiding EVs. Finally, an algorithm based on multi-time scale is used to achieve real-time traffic-distribution network simulation. It is verified that the proposed method cannot only fully coordinate the distribution of charging load, but also reasonably relieve the traffic pressure.

**Subject Areas:** Distribution network; Electric vehicles; Road network; The third-generation prospect theory

**Availability:** Zhang, C., Peng, K., Guo, L., Xiao, C., Zhang, X., and Zhao, Z. (2023). “An EVs Charging Guiding Strategy for the Coupling System of Road Network and Distribution Network Based on the PT3.” *Electric Power Systems Research*, 214(Part A).  
<https://doi.org/10.1016/j.epsr.2022.108839>

## 2.2. Title: Coordinated Scheduling of Generalized Energy Storage in Multi-Voltage Level AC/DC Hybrid Distribution Network

**Author(s):** Luo, L., He, P., Gu, W., Sheng, W., Liu, K., and Bai, M.

**Abstract:** With the diversification of electrical equipment and the large-scale popularization of renewable energy power generation, it has become a broad consensus to use schedulable resources to improve the load level and reduce network losses in power distribution networks. And meanwhile, the coverage of schedulable resources has been significantly extended due to the development of power market and network topology technologies. Based on this background, this paper proposes a coordinated scheduling model of generalized energy storage (GES) in multi-voltage level AC/DC hybrid distribution network, during which the energy storage systems (ESSs), electric vehicles (EVs), as well as transferable loads (TLs) are properly considered, and thereby the interaction in greater extent is realized. Finally, the effectiveness of the proposed model is verified through a 52-node test system, and two comparative scenarios are analyzed. Numerical results indicate that the scheduling scheme obtained from the proposed model can bring about evident reduction in network losses within the whole system.

**Subject Areas:** AC/DC hybrid distribution network; Multi-voltage levels; Generalized energy storage (GES); Voltage source converter (VSC); Mixed Integer Quadratic Program (MIQP)

**Availability:** Luo, L., He, P., Gu, W., Sheng, W., Liu, K., and Bai, M. (2023). “Coordinated Scheduling of Generalized Energy Storage in Multi-Voltage Level AC/DC Hybrid Distribution Network.” *Journal of Energy Storage*, 57. <https://doi.org/10.1016/j.est.2022.106189>

### 2.3. Title: Data-Driven Cooling, Heating and Electrical Load Prediction for Building Integrated with Electric Vehicles Considering Occupant Travel Behavior

**Author(s):** Zhang, X., Kong, X., Yan, R., Liu, Y., Xia, P., Sun, X., Zeng, R., and Li, H.

**Abstract:** The access of electric vehicles facilitates in the fluctuation and diversification of building load, accurate load prediction contributes to investigating the operation and optimization of energy supply systems for building integrated with electric vehicles (EVs). This study proposes a multivariate load prediction model for building/EVs considering occupant travel behavior. Firstly, travel variables of dissimilar occupants are obtained by fitting distribution, Markov chain and machine learning method. Besides, these variables are sampled to construct the occupant travel behavior model based on Monte Carlo method. In addition, occupancy rate and hourly load of different buildings are determined according to the occupant travel behavior. Ultimately, data-driven approaches, such as artificial neural network, long short-term memory network (LSTM) and LSTM with temporal pattern attention (TPA-LSTM), are applied to construct the load prediction model for building/electric vehicles. Results indicated that building load constructed in accordance with the occupancy rate of occupants' travel behavior exhibits a favorable cooperativity with the EVs charging load. TPA-LSTM model has a high prediction accuracy, and the maximum correlation coefficient reaches 0.987. In general, this study provides an effective tool for accurate load prediction of building integrated with EVs.

**Subject Areas:** Building/electric vehicle interaction; Load prediction; Personnel travel behavior; Data-driven approach; Cooling; Heating and electricity; Probabilistic model

**Availability:** Zhang, X., Kong, X., Yan, R., Liu, Y., Xia, P., Sun, X., Zeng, R., and Li, H. (2023). "Data-Driven Cooling, Heating and Electrical Load Prediction for Building Integrated with Electric Vehicles Considering Occupant Travel Behavior." *Energy*, 264. <https://doi.org/10.1016/j.energy.2022.126274>



#### **2.4. Title: A Method for Determining Optimal Electric Range by Considering Electric Vehicle Lightweighting on Perceived Ownership Cost**

**Author(s):** Ou, S., Zhang, S., Lin, Z., and Davis, S.

**Abstract:** The limited driving range due to high costs and low energy densities of batteries constraints the battery electric vehicle (BEV) market growth. Lightweighting in theory can reduce energy consumption rate and extend the driving range. The knowledge gap is to quantitatively link the cost-effectiveness of light-weight technologies with range extension and consumer acceptance of BEVs. In this study, a physics-based energy consumption model of BEVs is constructed and associated with a statistics-based model on the basis of travel surveys. A perceived cost of ownership (PCO) is then developed by adding intangible costs to traditional total cost of ownership models. We estimate, at the disaggregate vehicle model and driver level and the aggregate market level, 1) the extended range due to lightweighting for a given battery size; and 2) the optimal electric range based on lightweighting decisions. The cost-effectiveness of lightweighting for BEV range extension is found to vary with income-dependent daily range limitation value, driving patterns and lightweighting technology costs. In general, adopting lightweighting in BEVs is more cost-effective for consumers with higher daily limitation value, as well as for those with higher driving intensity or suitable daily driving patterns. When the lightweighting involves a higher vehicle production cost, less lightweighting could reduce the overall PCO for BEV owners. 4 of the selected top ten BEV models are found to benefit from additional 2.09–4.45% lightweighting. The method built in this study can guide automakers in planning R&D investments in battery and lightweighting technologies.

**Subject Areas:** Battery electric vehicle; Design optimization; Electric driving range; Energy consumption; Light-weighting; Perceived cost of vehicle ownership

**Availability:** Ou, S., Zhang, S., Lin, Z., and Davis, S. (2023). “A Method for Determining Optimal Electric Range by Considering Electric Vehicle Lightweighting on Perceived Ownership Cost.” *Journal of Cleaner Production*, 385. <https://doi.org/10.1016/j.jclepro.2022.135606>

## 2.5. Title: Optimal Scheduling of Battery-Swapping Station Loads for Capacity Enhancement of a Distribution System

**Author(s):** Alharbi, W. et al.

**Abstract:** A battery-swapping station (BSS) can serve as a flexible source in distribution systems, since electric vehicle (EV) batteries can be charged at different time periods prior to their swapping at a BSS. This paper presents an EV battery service transformation from charging to swapping batteries for EVs for the capacity enhancement of a distribution system. A novel mathematical model is proposed to optimally quantify and maximize the flexibility of BSS loads in providing demand response for the utility operator while considering technical operations in the distribution grid. Case studies and numerical findings that consider data from the National Household Travel Survey and a 32-bus distribution system are reported and discussed to demonstrate the effectiveness of the proposed model. Offering battery-swapping services helps reduce not only the peak load, but also the station operation cost.

**Subject Areas:** Battery-swapping station; Scheduling; Optimization; Mathematical model

**Availability:** Alharbi, W. et al. (2023). "Optimal Scheduling of Battery-Swapping Station Loads for Capacity Enhancement of a Distribution System." *Energies*, 16(1).  
<https://doi.org/10.3390/en16010186>

## 2.6. Title: Electric Vehicle Fast Charging Station Design by Considering Probabilistic Model of Renewable Energy Source and Demand Response

**Author(s):** Shafiei, M. and Ghasemi-Marzbali, A.

**Abstract:** The increased number of Electric Vehicles (EVs) in smart grids has highlighted the need for fast charging stations to provide services in the minimum time duration. This duration for charging at the station can be regarded as a challenge due to increasing the grid load. To mitigate the effects of these disadvantages, Renewable Energy Sources (RESs) and Energy Storage Systems (ESSs) can be employed. Thus, the present paper aims to design a fast-charging station while considering parameters such as the solar panel capacity, storage systems, wind turbine, Demand Response (DR) program, and stochastic model of RESs. Accordingly, two models of wind power plant ownership are proposed for the station and the grid. The correct estimation of the wind-generated power can reduce the uncertainties in programming; thus, a forecasting method based on the fuzzy-neural network and improved Particle Swarm Optimization (PSO) algorithm with time-varying coefficients is proposed. In the first ownership, based on the forecast wind-generated power, the station signs a contract with the grid, and by using EV, RES, and ESS load management, tries to reduce the imbalance and costs. In the second ownership, the wind power plant is at the service of the grid and the station owner makes revenues by servicing the grid. The objective function of the problem is based on the current net value over a 10-year time horizon, including the costs of performance and maintenance. The findings revealed that when the charging station uses load management, it increases profitability and reduces the initial capital investment in an acceptable manner. In the first and second ownerships, the total 10-year cost in the presence of Demand Response (DR) is reduced by 17.85% and 3.31%, respectively. Based on the findings, the initial capital cost for supplying internal loads and providing flexible services to the grid is slightly higher in the second than the first ownership. The simulation results also indicate that the proposed hybrid algorithm forecasts wind speed changes with proper precision.

**Subject Areas:** Fast charging station; Electric vehicle; Renewable energy sources; Load management

**Availability:** Shafiei, M. and Ghasemi-Marzbali, A. (2023). "Electric Vehicle Fast Charging Station Design by Considering Probabilistic Model of Renewable Energy Source and Demand Response." *Energy*, 267. <https://doi.org/10.1016/j.energy.2022.126545>

## 2.7. Title: Electric Vehicle Aggregation Considering Fast-Charging for Power System Applications

**Author(s):** Mingee, T.I.

**Abstract:** The electric grid has become one of the most important pieces of technology for modern society, providing power to homes and businesses at all hours of the day. Future increases of worldwide electricity demand along with growing threats of contingency scenarios such as cyberattacks cause great concerns regarding the reliability of the grid. Further, the gradual shift from fossil fuels to renewable energy sources creates a significant need for grid support services to aid in its operation. Electric vehicles will become more prevalent in coming decades; these modules present unique loads to the system that are prime candidates for use as both renewable energy storage and grid supporting devices.

This thesis focuses on the behavior of electric vehicles connected to fast-charging stations, which is largely ignored in many power systems studies. It turns out that the power drawn by the vehicles during fast-charging varies significantly throughout the charging process; experimentally derived charging curves give insight to this behavior and can be used to improve the accuracy of grid models with large electric vehicle loads. An aggregator based on charging curve data is developed to reflect the true load of an electric vehicle fleet as well as its ability to provide grid support during contingency events.

By comparing electric vehicle fleets with different levels of state-of-charge, the study shows that the aggregation of these fleets is important for power system operators to consider. During the fast-charging process, an electric vehicle fleet that is more charged overall is capable of less unidirectional grid support than a less charged fleet. The typical assumption that the vehicles are charging at their maximum rated power is insufficient for grid support planning when considering fast-charging, and this thesis demonstrates the significance of a fast-charging electric vehicle aggregator for use in these services.

**Subject Areas:** Distributed energy resources; Local flexibility market; Technical virtual power plant; Wholesale flexibility market; Roy Billinton test system

**Availability:** Mingee, T.I. (2022). *Electric Vehicle Aggregation Considering Fast-Charging for Power System Applications*. Master's Thesis, University of Tennessee, Knoxville, TN.  
[https://trace.tennessee.edu/utk\\_gradthes/7058](https://trace.tennessee.edu/utk_gradthes/7058)

## 2.8. Title: Multivariate Dependence Modeling of Electric Vehicle Charging Stochastic Parameters

**Author(s):** Farhadi, P., Moghaddas Tafreshi, S.M., and Shahirinia, A.

**Abstract:** Electric vehicles are considered a sustainable mode of terrestrial transport worldwide because of low- or zero-carbon emissions. Public charging stations, particularly fast and extra fast, play a crucial role in adopting and developing electric vehicles. To enable optimum planning of the fast charging stations, multivariate dependence of electric vehicle charging variables regarding stochastic nature should be taken into account. This paper uses multiple Elliptical and Archimedean copula functions to model the correlation/dependency between the electric vehicle charging characteristic parameters. Typically, by employing the multivariate copulas, synthetic electric vehicle charging data or observations are effectively generated for accurate simulation of multiple theoretical and practical applications, such as planning electric vehicle charging infrastructures while handling inherent variability and complex dependencies of electric vehicle charging characteristic parameters. Simulations are carried out in R.

**Subject Areas:** Copula; Correlation; Dependency; Electric vehicle; Fast charging station; Uncertainty

**Availability:** Farhadi, P., Moghaddas Tafreshi, S.M., and Shahirinia, A. (2022). “Multivariate Dependence Modeling of Electric Vehicle Charging Stochastic Parameters.” *2022 12th Smart Grid Conference (SGC)*, Kerman, Islamic Republic of Iran, pp. 1–6.  
<https://doi.org/10.1109/SGC58052.2022.9998982>

## 2.9. Title: Comparing Regional Energy Consumption for Direct Drone and Truck Deliveries

**Author(s):** Cokyasar, T., Stinson, M., Sahin, O., Prabhakar, N., and Karbowski, D.

**Abstract:** Drone delivery, once thought of as fictitious, is becoming a reality with the efforts of both forward-looking enterprises and supportive government policies. This emerging mode of E-commerce delivery raises many concerns. One important concern is the energy efficiency of direct delivery drones compared with conventional delivery trucks at a regional systems level. In this study, we develop and apply methods to quantify the regional energy impacts of drone delivery, and then we assess these impacts and compare them with the impacts of truck delivery. To study this problem, we develop an optimization model that determines an optimal set of fulfillment centers (FCs) with variable service capacities that allow drones to make direct E-commerce deliveries. We adopt two drone delivery energy estimation models from the literature and use them as inputs to demonstrate the potential range of energy needs. We also develop another optimization model to account for the energy consumption of diesel trucks (DTs) and battery electric vehicles (BEVs). We test the models using validated simulation data for the Chicago metropolitan area in the U.S. to quantify the energy implications of these three delivery modes. For drone delivery, we further extend our analyses by considering the impact of wind speed and flight patterns. Our results show that direct delivery drones require 15.8% more energy than BEVs on an average windy day, and they need 15% more energy than DTs on a very windy day. We provide essential parameter values for reproducibility and list relevant open problems.

**Subject Areas:** Drone delivery; Diesel trucks; Regional energy consumption

**Availability:** Cokyasar, T., Stinson, M., Sahin, O., Prabhakar, N., and Karbowski, D. (2023). "Comparing Regional Energy Consumption for Direct Drone and Truck Deliveries."

*Transportation Research Record: Journal of the Transportation Research Board*, 2677(2), pp. 310–327. <https://doi.org/10.1177/03611981221145137>

**2.10. Title: Optimal Management of a Virtual Power Plant Consisting of Renewable Energy Resources and Electric Vehicles Using Mixed-Integer Linear Programming and Deep Learning**

**Author(s):** Ahmadian, A., Ponnambalam, K., Almansoori, A., and Elkamel, A.

**Abstract:** Recently, renewable energy resources (RESs) and electric vehicles (EVs), in addition to other distributed energy resources (DERs), have gained high popularity in power systems applications. These resources bring quite a few advantages for power systems—reducing carbon emission, increasing efficiency, and reducing power loss. However, they also bring some disadvantages for the network because of their intermittent behavior and their high number in the grid which makes the optimal management of the system a tough task. Virtual power plants (VPPs) are introduced as a promising solution to make the most out of these resources by aggregating them as a single entity. On the other hand, VPP’s optimal management depends on its accuracy in modeling stochastic parameters in the VPP body. In this regard, an efficient approach for a VPP is a method that can overcome these intermittent resources. In this paper, a comprehensive study has been investigated for the optimal management of a VPP by modeling different resources—RESs, energy storages, EVs, and distributed generations. In addition, a method based on bi-directional long short-term memory networks is investigated for forecasting various stochastic parameters, wind speed, electricity price, load demand, and EVs’ behavior. The results of this study show the superiority of BLSTM methods for modeling these parameters with an error of 1.47% in comparison with real data. Furthermore, to show the performance of BLSTMs, its results are compared with other benchmark methods such as shallow neural networks, support vector machines, and long short-term memory networks.

**Subject Areas:** Virtual power plant; Deep learning; BLSTM networks; Uncertainty modeling; Electric vehicles

**Availability:** Ahmadian, A., Ponnambalam, K., Almansoori, A., and Elkamel, A. (2023). “Optimal Management of a Virtual Power Plant Consisting of Renewable Energy Resources and Electric Vehicles Using Mixed-Integer Linear Programming and Deep Learning.” *Energies*, 16(2). <https://doi.org/10.3390/en16021000>

## 2.11. Title: Florida Alternative Transportation Fuel Resilience Plan

**Author(s):** Johnson, C. et al.

**Abstract:** Many counties and cities in Florida are developing resilience plans to help them minimize damage from hurricanes and accelerate recovery. An Achilles' heel of these plans is their dependence on diesel fuel, which is particularly vulnerable to hurricane-related disruptions because 90% of petroleum in Florida is imported via maritime tanker (EIA 2014). Fuel diversification can add to Florida's transportation resilience because if the supply of one fuel gets disrupted during a hurricane, there is a good chance that the supplies of other fuels are still available. The four main transportation fuels in Florida have different means of distribution. If one means of transport (e.g., marine port) is removed, then other means (e.g., pipeline, rail, cable) could then be relied upon to deliver transportation fuel. This Fuel Resilience Plan aims to address these factors and create a strategy for how three alternative fuels (natural gas, propane, and electricity) can best be employed to improve transportation resilience in Florida. It does this through a combination of literature review and stakeholder engagement for best practices, vehicle technology recommendations, the creation of three tools (with descriptions and brief guides included), and charting how stakeholders coordinate to overcome these hurdles.

**Subject Areas:** Energy; Highways; Disaster resilience; Electric vehicles; Planning and forecasting; Security and emergencies

**Availability:** Johnson, C. et al. (2022). *Florida Alternative Transportation Fuel Resilience Plan*. Technical Report, NREL/TP-5400-83795, National Renewable Energy Laboratory, Golden, CO. <https://www.nrel.gov/docs/fy23osti/83795.pdf>



## 2.12. Title: Optimal Scheduling Strategy for Orderly Charging and Discharging of Electric Vehicles Based on Spatio-Temporal Characteristics

**Author(s):** Wu, S. and Pang, A.

**Abstract:** With the development of vehicle-to-grid (V2G) technology, the disorderly access of a large number of electric vehicles (EVs) will impact the operation of the power system. Considering the uncertainty of EVs charging/discharging load on the spatio-temporal scale, this paper proposes an optimal scheduling strategy for EVs with spatio-temporal characteristics. The strategy integrates EVs into the microgrid, constructs the spatio-temporal distribution models of charging load and describes the uncertainty of electric vehicle owners' (EVOs) charging behaviours by fuzzy theory. Considering the bounded rationality of EVOs, this paper takes the charging/discharging price of EVs as the decision variable, and the dynamic time-of-use price mechanism is used to guide EVOs to make charging/discharging decisions. Then, with the objective function of minimising the comprehensive operating cost (COC) and the peak-valley load difference (PVLD), an orderly charging/discharging scheduling model for EVs is established and the optimal scheduling strategy is given. Furthermore, the three scheduling scenarios are set up in the case study, and the maximum number of EVs to participate in scheduling is determined to be 4000. The numerical results show that the proposed scheduling strategy reduces the COC and PVLD by 17.96% and 5.21%, respectively, compared with the disorderly scheduling, and reduces the COC and PVLD by 13.35% and 5.21%, respectively, compared with the orderly scheduling without V2G, which verifies the effectiveness and superiority of the proposed scheduling strategy.

**Subject Areas:** Electric vehicles; Spatio-temporal characteristics; Fuzzy theory; Dynamic time-of-use price; Charging/discharging scheduling strategy

**Availability:** Wu, S. and Pang, A. (2023). "Optimal Scheduling Strategy for Orderly Charging and Discharging of Electric Vehicles Based on Spatio-Temporal Characteristics." *Journal of Cleaner Production*, 392. <https://doi.org/10.1016/j.jclepro.2023.136318>

### **2.13. Title: Multiparadigm Modeling Framework to Evaluate the Impacts of Travel Patterns on Electric Vehicle Battery Lifespan**

**Author(s):** Agrawal, S., Peeta, S., and Miralinaghi, M.

**Abstract:** The widespread adoption of electric vehicles (EVs) can help attain economic and environmental sustainability by reducing oil dependency and greenhouse gas emissions. However, several issues need to be addressed before EVs can become a popular vehicle choice among the general public. A key issue is the perpetual reduction in EV battery capacity caused by battery degradation over time with usage. This can lead to a reduced driving range and cause “range anxiety” for EV drivers. This becomes even more critical in developing countries where consumers are highly sensitive to battery replacement costs. Thus, to promote EVs in developing economies, policymakers and vehicle manufacturers need to develop attractive incentive schemes and warranty strategies preceded by a thorough assessment of the useable EV battery lifespan for a wide range of users. This paper develops a multiparadigm modeling framework to compute battery degradation for a large population of EVs by capturing the effects of travel patterns, traffic conditions, and ambient temperature. The proposed framework consists of four different building blocks: (i) a microscopic traffic simulation model to generate speed profiles, (ii) an EV power consumption model, (iii) a battery equivalent circuit model, and (iv) a semiempirical battery degradation model. The proposed framework can also be used to assess the battery life-cycle of electric-powered automated vehicles by adjusting their travel patterns accordingly. A case study is presented using travel diary data of around 700 households from the U.S. National Household Travel Survey of 2009 to simulate household travel patterns and corresponding battery lifespan distribution.

**Subject Areas:** Electric vehicles; Battery lifespan; Range anxiety; Multiparadigm modeling framework; Travel patterns

**Availability:** Agrawal, S., Peeta, S., and Miralinaghi, M. (2023). “Multiparadigm Modeling Framework to Evaluate the Impacts of Travel Patterns on Electric Vehicle Battery Lifespan.” *Journal of Advanced Transportation*, 2023. <https://doi.org/10.1155/2023/1689075>

#### **2.14. Title: Retailer Energy Management of Electric Energy by Combining Demand Response and Hydrogen Storage Systems, Renewable Sources and Electric Vehicles**

**Author(s):** Karami, M., Zadehbagheri, M., Kiani, M.J., and Nejatian, S.

**Abstract:** The increasing pollution caused by conventional cars and the problems caused by the use of fossil fuels have drawn the attention of researchers and manufacturers to the design of cars that use clean fuels. Electric vehicles connected to the network have a significant impact on reducing environmental pollution and transportation costs, especially in big cities. The cost of supplying loads to subscribers in the distribution network also includes generation and transmission costs. These costs are directly related to the intelligence of the distribution network and the total amount of energy of electric vehicles. The contribution of each generation unit and each transmission line must be calculated to determine the generation and transmission costs. In this research, in order to maximize the profit of the parking lot owner, improve voltage drop and load factor, a comprehensive framework for optimal energy management in a parking lot is presented, which can provide a method to control the charging of electric vehicles, in addition to meeting the needs of their owners, only as a series of controllable loads that they need to receive electrical energy to charge their batteries. In the next step, considering the inherent characteristic of electric cars, i.e., having a battery, and looking at them as a series of storage resources that can return the electric energy in their battery to the grid if necessary, a method to simultaneously control their charging and discharging is provided. In the final step of the paper, it is assumed that hydrogen storage systems will also enter the circuit, and thus, a comprehensive method for energy management is proposed. Finally, the linearized model of demand response and the proposed scheme along with the modeling of hydrogen storage and electric vehicles are considered to be part of contribution to improve the operation and economic situation of the network.

**Subject Areas:** Electric vehicles; Hydrogen storage systems; Smart charging strategy; Controlled charging strategy

**Availability:** Karami, M., Zadehbagheri, M., Kiani, M.J., and Nejatian, S. (2023). “Retailer Energy Management of Electric Energy by Combining Demand Response and Hydrogen Storage Systems, Renewable Sources and Electric Vehicles.” *International Journal of Hydrogen Energy*, 48(49), pp. 18775–18794. <https://doi.org/10.1016/j.ijhydene.2023.01.285>

## **2.15. Title: Electric Vehicle Charging Hub Power Forecasting: A Statistical and Machine Learning Based Approach**

**Author(s):** Lo Franco, F., Ricco, M., Cirimele, V., Apicella, V., Carambia, B., and Grandi, G.

**Abstract:** Electric vehicles (EVs) penetration growth is essential to reduce transportation-related local pollutants. Most countries are witnessing a rapid development of the necessary charging infrastructure and a consequent increase in EV energy demand. In this context, power demand forecasting is an essential tool for planning and integrating EV charging as much as possible with the electric grid, renewable sources, storage systems, and their management systems. However, this forecasting is still challenging due to several reasons: the still not statistically significant number of circulating EVs, the different users' behavior based on the car parking scenario, the strong heterogeneity of both charging infrastructure and EV population, and the uncertainty about the initial state of charge (SOC) distribution at the beginning of the charge. This paper aims to provide a forecasting method that considers all the main factors that may affect each charging event. The users' behavior in different urban scenarios is predicted through their statistical pattern. A similar approach is used to forecast the EV's initial SOC. A machine learning approach is adopted to develop a battery-charging behavioral model that takes into account the different EV model charging profiles. The final algorithm combines the different approaches providing a forecasting of the power absorbed by each single charging session and the total power absorbed by charging hubs. The algorithm is applied to different parking scenarios and the results highlight the strong difference in power demand among the different analyzed cases.

**Subject Areas:** Electric vehicles; Electric vehicle power demand forecasting; Charging hub; Urban scenarios; Machine learning

**Availability:** Lo Franco, F., Ricco, M., Cirimele, V., Apicella, V., Carambia, B., and Grandi, G. (2023). "Electric Vehicle Charging Hub Power Forecasting: A Statistical and Machine Learning Based Approach." *Energies*, 16(4). <https://doi.org/10.3390/en16042076>

## **2.16. Title: Influence of Battery Energy, Charging Power, and Charging Locations upon EVs' Ability to Meet Trip Needs**

**Author(s):** Kempton, W., Pearre, N.S., Guensler, R., and Elango, V.V.

**Abstract:** One year of high-resolution driving data from a sample of 333 instrumented gasoline passenger vehicles is used to create a trip inventory of U.S. vehicle travel requirements. A set of electric vehicles (EVs) is modeled, differing in battery size (kWh), recharging power (kW), and locations for charging when parked. Each modeled EV's remaining energy is tracked while traversing the entire sample's trip inventory in order to estimate how well each EV meets all U.S. driving requirements. The capital cost of refueling infrastructure is estimated per car, for gasoline and for each analyzed combination of charging station locations. We develop three metrics of the ability of different EV characteristics to meet trip requirements: the percentage of trips successfully met by each modeled EV, the number of days that the driver must "adapt" EV use to meet more demanding trip requirements, and the total driver time required for refueling. We also segment the market of trip patterns per car, finding that 25–37% of the vehicle population could meet all their drivers' trip needs with a smaller-battery EV combined with community charging. This potential combination of EVs and charging would enable lower-price EVs and lower-cost recharging power, and would broaden EV availability to groups for whom today's EVs and charging configurations are less accessible.

**Subject Areas:** Electric vehicles; Electric vehicle range; Charging power; Light vehicles; travel requirements; Electric vehicle access equity

**Availability:** Kempton, W., Pearre, N.S., Guensler, R., and Elango, V.V. (2023). "Influence of Battery Energy, Charging Power, and Charging Locations upon EVs' Ability to Meet Trip Needs." *Energies*, 16(5). <https://doi.org/10.3390/en16052104>

## **2.17. Title: Orderly Charging Strategy of Electric Vehicle Based on Improved PSO Algorithm**

**Author(s):** Du, W., Ma, J., and Yin, W.

**Abstract:** With the increasing penetration of electric vehicles (EVs), the harmful impact caused by EV's disorderly charging becomes larger. Aiming for mitigating the impact of disorderly charging on the grid and improving the user's satisfaction, this paper firstly performs the Monte Carlo simulation (MCS) to obtain the distribution information of EVs' disorderly charging. Then an improved particle swarm optimization (PSO) algorithm is presented to model the orderly charging strategy. In order to maintain the diversity of the population better, a rotation matrix is utilized to yaw particle's search direction slightly in the improved PSO. And by adjusting the inertia weight index and learning factor, the problems of poor local optimization ability and premature convergence of the original PSO is alleviated. Finally, the proposed approach is verified by a practical engineering case. The outcome demonstrates that the proposed orderly charging strategy can significantly lower the charging cost and peak-valley difference.

**Subject Areas:** Electric vehicles; Particle swarm optimization; Monte Carlo simulation; Charging strategy

**Availability:** Du, W., Ma, J., and Yin, W. (2023). "Orderly Charging Strategy of Electric Vehicle Based on Improved PSO Algorithm." *Energy*, 271. <https://doi.org/10.1016/j.energy.2023.127088>

## **2.18. Title: Optimal Configuration of Extreme Fast Charging Stations Integrated with Energy Storage System and Photovoltaic Panels in Distribution Networks**

**Author(s):** Wu, Z., Bhat, P.K., and Chen, B.

**Abstract:** Extreme fast charging (XFC) for electric vehicles (EVs) has emerged recently because of the short charging period. However, the extreme high charging power of EVs at XFC stations may severely impact distribution networks. This paper addresses the estimation of the charging power demand of XFC stations and the design of multiple XFC stations with renewable energy resources in current distribution networks. First, a Monte Carlo (MC) simulation tool was created utilizing the EV arrival time and state-of-charge (SOC) distributions obtained from the dataset of vehicle travel surveys. Various impact factors are considered to obtain a realistic estimation of the charging power demand of XFC stations. Then, a method for determining the optimal energy capacity of the energy storage system (ESS), ESS rated power, and size of photovoltaic (PV) panels for multiple XFC stations in a distribution network is presented, with the goal of achieving an optimal configuration. The optimal power flow technique is applied to this optimization so that the optimal solutions meet not only the charging demand but also the operational constraints related to XFC, ESS, PV panels, and distribution networks. Simulation results of a use case indicate that the presented MC simulation can estimate approximate real-world XFC charging demand, and the optimized ESS and PV units in multiple XFC stations in the distribution network can reduce the annual total cost of XFC stations and improve the performance of the distribution network.

**Subject Areas:** Electric vehicles charging; Extreme fast charging (XFC) stations; Charging demand estimation of XFC stations; Optimal configuration of XFC stations; XFC station integrated with renewable energy resources

**Availability:** Wu, Z., Bhat, P.K., and Chen, B. (2023). “Optimal Configuration of Extreme Fast Charging Stations Integrated with Energy Storage System and Photovoltaic Panels in Distribution Networks.” *Energies*, 16(5). <https://doi.org/10.3390/en16052385>

## 2.19. Title: Research on Electric Vehicle Charging Load Based on the Monte Carlo

**Author(s):** Jia, W., Chen, H., and Liu, X.

**Abstract:** With the increasing number of electric cars, they may become the most important load in the grid of the future. Due to the randomness of electric vehicles access to the grid, when large-scale electric vehicles are linked to the grid, they will fluctuate on the grid, resulting in the failure of the power supply mode and operation control means of the traditional distribution network to attain the optimal result. In view of this phenomenon, based on the Monte Carlo calculation and simulation, the charging load of electric vehicles is predicted, which can achieve comprehensive prediction under different kinds of electric cars, different battery capacities, different charging methods, etc., and provide theoretical and technical support for the effect analysis of electric vehicles access to power grid.

**Subject Areas:** Electric vehicles; Access to power grid; Monte Carlo; Charging load

**Availability:** Jia, W., Chen, H., and Liu, X. (2023). "Research on Electric Vehicle Charging Load Based on the Monte Carlo." *Journal of Physics: Conference Series*, 2450.  
<https://dx.doi.org/10.1088/1742-6596/2450/1/012002>



## 2.20. Title: Two-Area Control of Emergency Frequency Regulation Through Aggregation of Electric Vehicles

**Author(s):** Agheb, S.

**Abstract:** Frequency control has become more of a concern for the reliable operation of interconnected power systems. Due to the integration of low inertia renewable energy sources into the grid and their volatility, there is a need for emergency frequency regulation and nonlinear control of the power system in case of large disturbances incorporating quick response loads such as Electric Vehicles (EV)s. Some published literature has studied the profits that EV owners can gain by participating in frequency regulation and focused more on the contract design among different entities. Some studies have addressed how much power the EVs can provide for the grid in case of the need for frequency stabilization. However, the contribution of EVs to emergency frequency regulation in a wider area network has not been studied yet, which is the main focus of this research. In this work, the control methods are primarily based on the aggregation of EVs injecting power into grid, and the frequency control system design is such that the grid-connected EVs aim at maximizing the reduction rate of the total kinetic energy of the system based on Lyapunov energy function. The performance of the control law was evaluated in a two-area network and with different locations of aggregated charging stations in the corners or in the middle of the interconnected network. At this stage, a big virtual EV is connected to each connected area and the control inputs are formulated with no constraint on the connected EVs. However, there is always a constraint on the maximum allowed penetration of EVs to the grid without any voltage violations on any nodes of the distribution network. In chapter 4, a model is proposed for aggregation of EVs in each area at distribution network level, in which the contribution of EVs for frequency regulation is proportional to the frequency deviation and EVs' available energy. Then, the aggregate model is developed based on the probability distribution of number of EVs and their initial State of Charge (SOC) and energy. The simulation is initially done for two cases: 1- number of EVs to be fixed and their available energy to be random with a uniform distribution, 2- EVs' energy to be fixed and random number of EVs with a binomial distribution. In the same chapter, the impact of aggregate model on distribution network is studied to find the safe penetration rate of EVs under the worst case scenario where all the points in a charging station are connected to an EV. An EV-MPM algorithm is proposed to find the safe penetration rate of connected charging stations in a distribution network based on load-flow analysis and the voltage of any of the nodes not exceeding the maximum limit of 10% violation. The algorithm is tested on an IEEE 31 node 23 kV distribution system with five charging stations connected to the nodes. Given the day-ahead load profile, the daily safe penetration rate of EVs is estimated for a typical day. The derived penetration rate is then used in the aggregate model of virtual EV, and simulated in a two-area network to represent the emergency frequency control of connected EVs when contingency occurs in the system. The main contribution of this study is proposing a holistic layered structure to estimate the contribution of EVs from the distribution network level to a wider-connected areas, which hasn't been addressed in the literature.

**Subject Areas:** Electric vehicles; Frequency control; Emergency frequency regulation; Aggregate model; Distribution network; Two-area network

**Availability:** Agheb, S. (2023). *Two-Area Control of Emergency Frequency Regulation Through Aggregation of Electric Vehicles*. Master's Thesis, The University of New South Wales, Sydney, Australia. <https://doi.org/10.26190/unsworks/24736>

## 2.21. Title: Stochastic User Equilibrium Based Spatial-Temporal Distribution Prediction of Electric Vehicle Charging Load

**Author(s):** Liu, K. and Liu, Y.

**Abstract:** As the number of electric vehicles (EVs) connected to the grid increases, the EV electricity demand rises dramatically, affecting the grid's planning and operation and deepening the coupling of the power and transportation systems. Therefore, accurate spatial-temporal distribution prediction of EV charging load is vital for both power system and coupled power-transportation system studies. This paper proposes a novel method based on stochastic user equilibrium (SUE) for predicting the accurate spatial-temporal distribution of EV charging load synchronized with traffic states. A prediction framework of EV charging load based on SUE and trip chain is proposed, which can effectively reflect the actual behavior of EVs in synchronous traffic states. Then, the extended logit-based SUE and equivalent mathematical model are proposed to obtain more detailed traffic states with intersection turning flows and delays. Meanwhile, the unified reachability and charging models are established to ensure that the trip chain is reachable and the charging characteristics are suitable for different EV types. Finally, the method of the successive averages (MSA) and the Dijkstra-based K-shortest paths algorithms are integrated to solve the proposed framework iteratively with stable convergence. Test results on a realistic traffic network show that the proposed method can effectively reflect the charging and trip characteristics of different EV types while ensuring reachability. And it can also accurately predict the overall and individual EV travel costs and total charging loads in detailed synchronous traffic states. In particular, even in the case of high EV penetration with higher peak-to-valley differences and charging demand, the convergence of the prediction is still stable with even more remarkable prediction effectiveness, especially during peak load hours. Furthermore, the quantitative analysis based on proposed criticality indexes reveals that traffic network failures will affect the network-wide traffic states and EV charging loads with different node-level impact characteristics, which should be considered in joint power-transportation restoration scheduling.

**Subject Areas:** Electric vehicle; Intersection delay; Spatial-temporal distribution; Stochastic user equilibrium

**Availability:** Liu, K. and Liu, Y. (2023). "Stochastic User Equilibrium Based Spatial-Temporal Distribution Prediction of Electric Vehicle Charging Load." *Applied Energy*, 339. <https://doi.org/10.1016/j.apenergy.2023.120943>

**2.22. Title: Vehicle Attribute Tradeoffs and the Distributional Effects of US Fuel Economy and Greenhouse Gas Emissions Standards**

**Author(s):** Leard, B., Linn, J., and Springel, K.

**Abstract:** This paper presents welfare and distributional effects of US passenger vehicle fuel economy and greenhouse gas standards between 2012 and 2022. We build an equilibrium model that allows for endogenous markups, market shares, and nonprice attributes. The model includes fixed and variable costs of raising fuel economy, manufacturer substitution between fuel economy and performance, and heterogeneous consumer preferences and manufacturer costs. We estimate all demand and supply parameters from observed consumer and manufacturer choices. We find that the standards have increased social welfare and that consumer undervaluation of fuel cost savings accounts for most of the social benefits. Manufacturers achieve most fuel economy improvements by trading off horsepower rather than adjusting prices or adding fuel-saving technology. Due to this compliance strategy, the standards have been progressive because high-income households value horsepower much more than low-income households do. Consumer undervaluation of fuel cost savings also contributes to progressivity.

**Subject Areas:** Fuel economy standards; Attribute trade-offs; Medium run

**Availability:** Leard, B., Linn, J., and Springel, K. (2023). *Vehicle Attribute Tradeoffs and the Distributional Effects of US Fuel Economy and Greenhouse Gas Emissions Standards*. Working Paper, 23-04, Resources for the Future, Washington, D.C.  
[https://media.rff.org/documents/WP\\_23-04.pdf](https://media.rff.org/documents/WP_23-04.pdf)

**2.23. Title: Exploring the State of Health of Electric Vehicle Batteries at End of Use; Hierarchical Waste Flow Analysis to Determine the Recycling and Reuse Potential**

**Author(s):** Fallah, N. and Fitzpatrick, C.

**Abstract:** With the increasing adoption of electric vehicles, their end-of-life management is a timely matter. This requires recognizing the upcoming volume of retired electric vehicle batteries to the waste stream. The projection is further useful if we have an estimation of the remaining value within them to categorize the recycling or repurposing potential to allow appropriate policy development and facility planning. This qualification assessment is neglected in the current literature. This study aims to provide a hierarchical battery waste estimation based on their health and age of disposal in Ireland. These two factors are the fundamental parameters in determining the feasibility of repurposing or recycling retired batteries. Identifying this information, we defined three reuse scenarios with different state-of-health limits. Results indicate almost 50%, 30%, and below 10% repurposing potential in the year 2050 when setting a repurposing threshold of above 80%, 85%, and 90%, respectively. The authors also highlight the effect of non-regional repurposing on the recycling potential.

**Subject Areas:** Hierarchical waste estimation; End-of-life batteries; Electric vehicle; Repurposing

**Availability:** Fallah, N. and Fitzpatrick, C. (2023). *Exploring the State of Health of Electric Vehicle Batteries at End of Use; Hierarchical Waste Flow Analysis to Determine the Recycling and Reuse Potential*. Preprint Research Article, Research Square, Durham, NC.  
<https://doi.org/10.21203/rs.3.rs-2686583/v1>

#### **2.24. Title: An EV Charging Guidance Strategy Based on the Hierarchical Comprehensive Evaluation Method**

**Author(s):** Zhang, C., Gao, Q., Peng, K., and Jiang, Y.

**Abstract:** With the increasing number of electric vehicles (EVs), the randomness of the charging load will have an increasing impact on the distribution network (DN) and road network. Different guidance strategies lead to different network-related capabilities of fast charging stations (FCSs). In this paper, a hierarchical and comprehensive evaluation method is proposed for the network-related capability of FCSs. Based on the comprehensive evaluation method, a charging guidance strategy is proposed to improve the network-related capability of FCSs. Finally, the network connection capability of FCSs under four strategies is comprehensively evaluated to verify the effectiveness of the proposed method.

**Subject Areas:** Fast charging station; Electric vehicles; Analytic hierarchy process; The entropy weight method; Fuzzy comprehensive evaluation method; Charging guidance strategy

**Availability:** Zhang, C., Gao, Q., Peng, K., and Jiang, Y. (2023). “An EV Charging Guidance Strategy Based on the Hierarchical Comprehensive Evaluation Method.” *Energies*, 16(7). <https://doi.org/10.3390/en16073113>

## 2.25. Title: Forecasting Method for Sources and Loads in Virtual Power Plant Considering Uncertainties of Multiple Sources and Loads

**Author(s):** Chen, C., Xue, G., Tan, J., Niu, W., and Zhu, X.

**Abstract:** Because of the lack of primary energy and the deteriorating global environment, the key to getting rid of the existing difficulties is the development of clean and pollution-free new energy. On the one hand, to reduce the use of fossil energy, and on the other hand, to reduce emissions of polluting gases. So with the development of technology, more and more distributed power and load began to access the virtual power plant. This paper introduces PV and EVs(EVs) from the perspective of new energy applications and expounds on the background and significance of load forecasting and output power prediction. This paper introduces a variety of load prediction methods. Finally, Monte Carlo simulation is used to predict the EVs' charging load, and BP neural network is used to build a photovoltaic power forecasting model. Based on the MATLAB R2017a simulation platform, this paper analyzes the EVs' travel features in Beijing and takes the historical data and meteorological information of a photovoltaic power plant in Australia as an instance to analyze the influencing factors of PV.

**Subject Areas:** Load prediction; Photovoltaic power plant; Monte Carlo simulation; Fossil energy; Emissions reduction; Virtual power plant

**Availability:** Chen, C., Xue, G., Tan, J., Niu, W., and Zhu, X. (2023). "Forecasting Method for Sources and Loads in Virtual Power Plant Considering Uncertainties of Multiple Sources and Loads." *Journal of Physics: Conference Series*, 2465.  
<https://iopscience.iop.org/article/10.1088/1742-6596/2465/1/012002>

## 2.26. Title: Electric Vehicle Charging Load Demand Forecasting Model Based on Spatial and Temporal Characteristics

**Author(s):** Zhou, X., Zhang, K., Jia, X., and Fan, J.

**Abstract:** This paper proposes a method to predict the charging load demand of electric vehicles considering the spatial and temporal distribution characteristics of users' travel. Based on the central limit theorem and travel chain theory, the temporal distribution of the charging load of different functional sites is simulated by the Monte Carlo method and calculated by combining NHTS 2017 data to find the total daily charging load of electric private vehicles. The results show that in the case of disorderly charging, the charging loads of different areas have more obvious temporal characteristics, and the charging service can be optimized according to this charging load characteristic.

**Subject Areas:** Electric vehicles; Charging load demand; Spatial and temporal distribution characteristics; Monte Carlo method

**Availability:** Zhou, X., Zhang, K., Jia, X., and Fan, J. (2023). "Electric Vehicle Charging Load Demand Forecasting Model Based on Spatial and Temporal Characteristics." *Journal of Physics: Conference Series*, 2465. <https://iopscience.iop.org/article/10.1088/1742-6596/2465/1/012005>



## **2.27. Title: Reliability of Electric Vehicle Integrated Systems under Battery-Exchange and Plug-in Mode**

**Author(s):** Pandit, D. and Nguyen, N.

**Abstract:** The growing environmental concerns have promoted the integration of renewable energy sources (RESs) and electrical vehicles (EVs). Depending on their operation requirements and strategies, EVs can function as either load or storage, which has a substantial impact on the reliability of the power system. The increase of EV integration into the power grids requires a comprehensive reliability assessment focusing on the generation adequacy of the system. In this paper, we propose a reliability model for the battery-exchange based EVs (BEVs) with a time-series aggregated EV user load profile. The operation strategy for a battery exchange station is formulated, which accounts for the intermittency of renewable resources. A random-sampling approach is implemented to develop an hourly plug-in EV (PEV) operation algorithm based on the probability distribution of PEVs in the charging stations. An off-peak battery exchange strategy is formulated to compare the effects of controlled versus uncontrolled EV charging on the system reliability. The effect of both BEVs and PEVs on the system reliability is assessed using the sequential Monte Carlo simulation.

**Subject Areas:** Battery exchange (BE) mode; Controlled charging; Electric vehicles; Plug-in (PE) mode; Reliability

**Availability:** Pandit, D. and Nguyen, N. (2023). “Reliability of Electric Vehicle Integrated Systems under Battery-Exchange and Plug-in Mode.” *2023 IEEE Texas Power and Energy Conference (TPEC)*, College Station, TX, pp. 1–6.  
<https://doi.org/10.1109/TPEC56611.2023.10078710>

## **2.28. Title: A Practical PHEV Charging Policy to Improve Performance of Power Distribution Systems**

**Author(s):** Khandelwal, D., Bhowmick, S., Painuli, S., and Saha, R.

**Abstract:** Continuously dwindling fossil fuel reserves, high fuel costs, greenhouse gas (GHG) emissions and global warming has led to increased penetration of electric vehicles (EVs) in the transportation sector. However, EV charging increases the system load with high-peak and off-peak demand ratio in the daily load profile, thereby causing increased system losses, poor bus voltages and power quality issues in power distribution systems. Adoption of a suitable electric vehicle charging policy can minimize this load profile distortion and reduce the maximum load. In this paper, a study on the charging effects of about 3000 electric vehicles in more than 800 residents is carried out on a 240-bus real distribution grid located in the Midwest U.S. Multiple case studies were carried out to investigate the profiles of the network demand and bus voltages without and with EV charging, vis-à-vis implementation of a practical PHEV charging policy. The results confirm the improvement of load and bus voltage profiles, thus validating the proposed EV charging guidelines.

**Subject Areas:** Charging policies; Daily load profile; Distribution system; Electric vehicles; National Household Travel Survey

**Availability:** Khandelwal, D., Bhowmick, S., Painuli, S., and Saha, R. (2023). “A Practical PHEV Charging Policy to Improve Performance of Power Distribution Systems.” 2023 *International Conference on Power, Instrumentation, Energy and Control (PIECON)*, Aligarh, India, pp. 1–6. <https://doi.org/10.1109/PIECON56912.2023.10085850>

## **2.29. Title: Coordination of Plug-in Electric Vehicles to Improve Performance and Power Quality**

**Author(s):** Misra, P., Rathor, S., Saxena, D., and Jain, D.

**Abstract:** Integration of more and more distributed energy resources (DER) into the microgrid raises the concern of power quality, reliability, and economic operations. Plug-in electric vehicles (PEVs) is a cleaner technology that provides flexibility in the distribution network; however, uncoordinated operation may raise the concern of voltage imbalance. The issue of voltage imbalance is less focused in ongoing research works since most of the PEV chargers connected in residential and commercial places are single-phase or two-phase, which may alleviate the problem of voltage imbalance and result in an increase in neutral current and network losses. In this paper, the phase balancing problem is solved by mixed-integer convex quadratic programming (MICQP) approach by linear three-phase load flow method and compared with the backward forward sweep (BFS) method and tested on modified IEEE 33 bus radial distribution system.

**Subject Areas:** Microgrid; Mixed-integer convex quadratic programming; Plug-in electric vehicles; Voltage imbalance

**Availability:** Misra, P., Rathor, S., Saxena, D., and Jain, D. (2023). "Coordination of Plug-in Electric Vehicles to Improve Performance and Power Quality." *2023 IEEE IAS Global Conference on Renewable Energy and Hydrogen Technologies (GlobConHT)*, Male, Maldives, pp. 1–7. <https://doi.org/10.1109/GlobConHT56829.2023.10087889>

### **2.30. Title: Risk-Averse Integrated DR and Dynamic V2G Scheduling of Parking Lot Operator for Enhanced Market Efficiency**

**Author(s):** Sharma, S. and Jain, P.

**Abstract:** Parking lot operator (PLO) as an interface between EV owners and System Operator (SO) optimizes V2G scheduling to maximize its profit through multi-markets participation, viz., energy and regulation, while ensuring EVs battery health and daily driving needs. PLO integrates Time-of-Use (TOU) Price-based Demand Response (PBDR) with V2G as a more viable tool to unlock V2G potential, alleviate adverse impacts, enhance market efficiency, level load via boosting flexibility to the SO, and reduce charging costs of EV owners. DR integrated V2G scheduling framework is put in jeopardy from EVs' propulsive behaviour and electricity market prices uncertainties, posing financial risk to PLO. In this context, this paper puts forward a risk-averse integrated DR and dynamic V2G decision-making algorithm to maximize the expected profits of PLO. Results of PLO case study with 1000 EVs demonstrate benefits from economies of V2G operations, its resiliency to EVs' behaviour dynamics via sensitivity analysis of risk-averse and risk-neutral PLO performance with respect to round trip efficiency, battery degradation cost coefficient, number of EVs, and upper limit of charging/discharging rates. There is significant 22.2% reduction in cost, 33.82% reduction in revenue, and 14.92% reduction in profit from risk-neutral to risk-averse in V2G mode for charging/discharging rate value 12.1 kW.

**Subject Areas:** Conditional value at risk; Demand response; Parking lot operator; Risk management; Vehicle-to-Grid

**Availability:** Sharma, S. and Jain, P. (2023). "Risk-Averse Integrated DR and Dynamic V2G Scheduling of Parking Lot Operator for Enhanced Market Efficiency." *Energy*, 275. <https://doi.org/10.1016/j.energy.2023.127428>

### **2.31. Title: Supporting Gasoline-Burdened Families' Transition to EVs to Maximize Climate and Equity Benefits**

**Author(s):** London, J., Metz, M., Rosler, P., and Dietrich, T.

**Abstract:** Burning gasoline in our cars, trucks and SUVs is a primary source of carbon emissions. Unless we change our approach, gasoline consumption will not decline quickly enough to meet climate goals.

Prioritizing the biggest gasoline users (“Gasoline Superusers”) for the switch to electric vehicles (EVs) is critical to cut gasoline use at the speed and scale required by the climate crisis. This strategy would enable meeting gasoline reduction targets faster and with fewer total EVs. It would also better support lower-income households that are most burdened by gasoline expenditures.

This report uses millions of California vehicle records and other datasets to build on Coltura’s first Gasoline Superusers report. Along with the interactive gasoline consumption map, gasoline data center and EV cost savings calculator released in conjunction, this report illuminates for the first time the geographic, demographic, financial, and vehicular details of consumer gasoline use down to the zip code level, enabling policymakers and businesses to develop more effective gasoline displacement policies and investments.

**Subject Areas:** Gasoline consumption; Gasoline superusers; Electric vehicles; Gasoline displacement

**Availability:** London, J., Metz, M., Rosler, P., and Dietrich, T. (2023). *Supporting Gasoline-Burdened Families' Transition to EVs to Maximize Climate and Equity Benefits*. Report, Coltura (Headquarters), Seattle, WA. <https://coltura.org/wp-content/uploads/2023/04/Executive-Summary-Superusers-2.0.pdf>

**2.32. Title: Charging Management of Electric Vehicles on Loading Capability of Distribution System Equipment, Voltage Quality, and Energy Loss by Monte Carlo Simulation and Linear Programming**

**Author(s):** Sirisumrannukul, S.

**Abstract:** This paper presents the impact of uncoordinated and coordinated charging management of electric vehicles (EVs) on the loading capability of major distribution system equipment, voltage quality, and energy loss in a distribution system. The main emphasis is given to the overloading of distribution transformers, primary feeders, and a substation transformer. The voltage quality of load points along the feeders and the system energy loss are also underlined. The load profile for uncoordinated EV charging is simulated by a Monte Carlo method with several deterministic and stochastic variables involved. To mitigate the overloading of the system components, a coordinated charging (also known as smart charging) model formulated as a linear programming problem is proposed with the objective of maximizing the total amount of energy consumption by EVs and the sum of all individual final states of charge (SoCs), and minimizing the sum of the absolute deviation of individual SoCs from the overall average SoC. The optimization problem is subject to equipment capability loading and planning criteria constraints with low, medium, and high EV penetration levels. The voltage quality problem and energy loss are also analyzed by an unbalanced three-phased power flow model. A case study of a real and practical 115/22 kV distribution system of the Provincial Electricity Authority (PEA) with a 50 MVA substation transformer, 5 feeders, and 732 distribution transformers shows that the possibility of overloaded system components, voltage drops along the feeders, and the system energy loss can be identified in the uncoordinated charging scenario and offer the readiness for equipment replacement and network reinforcement planning. The proposed smart charging model allows the distribution system to accommodate more EVs by appropriately managing the power and the start times of charging for the individual EVs over the timeslots of a day. The study results confirm no violation of the system components and voltage regulation imposed by the system planning guidelines. In addition, the system peak demand and the system energy loss are significantly lower in the smart charging scenario, thus deferring investment upgrades, offering better asset utilization, and retaining network security and service quality.

**Subject Areas:** Electric vehicles; Charging management; Loading capability; Distribution system equipment; Voltage quality; Energy loss; Monte Carlo simulation, Linear programming

**Availability:** Sirisumrannukul, S. (2023). "Charging Management of Electric Vehicles on Loading Capability of Distribution System Equipment, Voltage Quality, and Energy Loss by Monte Carlo Simulation and Linear Programming." *International Transactions on Electrical Energy Systems*, 2023. <https://doi.org/10.1155/2023/1195648>

### 2.33. Title: A Comprehensive Scheduling Model for Electric Vehicles in Office Buildings Considering the Uncertainty of Charging Load

**Author(s):** Ding, Y., Zhu, Y., Wang, Q., Tian, Z., Yan, R., Yan, Z., and Xia, X.

**Abstract:** The access of electric vehicles (EVs) has a profound impact on the operation and scheduling of building energy system. However, due to the fixed schedules of EV charging load, few studies concerned on the coordination strategy between EVs and other potential flexible load in office buildings. In this study, uncertainty sources of EV charging load are extracted from sensitivity analysis based on regression method, and then the uncertainties are introduced into the charging load prediction model based on Monte Carlo method. An optimal scheduling model embedded with the uncertainty of charging load, with the joint operation of building air conditioning system, photovoltaic system and EVs, is proposed for building demand response period. The results show that the operation strategies obtained from the proposed model embrace the advantages of small load variance, high flexibility, low operating cost and large photovoltaic power consumption capacity. The arrival non-guarantee rate is reduced from 12.23% to 6.55% and the charging non-guarantee rate is reduced from 24.03% to 9.39%. On the basis of EV orderly charging and the air conditioning pre-cooling, 7.57–61.67% of the 8:00 startup load can be transferred to night, and the original load variance can be reduced by 3.06–17.81%. © 2017 Elsevier Inc. All rights reserved.

**Subject Areas:** Charging load prediction; Electric vehicle; Scheduling optimization; Operation strategy; Building demand response

**Availability:** Ding, Y., Zhu, Y., Wang, Q., Tian, Z., Yan, R., Yan, Z., and Xia, X. (2023). “A Comprehensive Scheduling Model for Electric Vehicles in Office Buildings Considering the Uncertainty of Charging Load.” *International Journal of Electrical Power & Energy Systems*, 151. <https://doi.org/10.1016/j.ijepes.2023.109154>

### **2.34. Title: Optimal Routing and Power Management of Electric Vehicles in Coupled Power Distribution and Transportation Systems**

**Author(s):** Aghajan-Eshkevari, S., Ameli, M.T., and Azad, S.

**Abstract:** With the increasing penetration level of electric vehicles (EVs) in the transportation network, it is necessary to control the charging and discharging process of EVs to avoid operational issues in the power grid. Therefore, in this paper, a two-stage framework is presented for EVs optimal routing and their active and reactive power control in the distribution grid. In the first stage, the EVs mobility in the transportation system is taken into consideration. On this basis, EV daily trips in the transportation network are modelled using the trip chain method. Also, the Dijkstra algorithm is utilized for optimal routing with the shortest travel time between the origin and the destination node. Furthermore, the effects of ambient temperature, traffic congestion and road type on the EVs energy consumption are assessed. In the second stage, optimal active and reactive power exchange of EVs with the distribution grid is carried out. Thus, a mixed-integer linear programming (MILP) model is proposed that simultaneously considers EV owners' and the distribution network operator's benefits as the optimization goals. The EV battery degradation cost due to the discharging of active power is also integrated into the objective function of the optimization problem. The proposed framework is implemented on a standard IEEE 33-bus system coupled with a 30-node transportation network. The simulation results show that the presented method can reduce the loss cost of the distribution grid and benefit EV owners compared to different charging strategies. In addition, with the battery technology development, the proposed framework can significantly improve the distribution system operation, decrease environmental issues, and reduce EV owners' costs.

**Subject Areas:** Electric vehicles; Active and reactive power management; Distribution network; Transportation system; Trip chain; Optimal routing

**Availability:** Aghajan-Eshkevari, S., Ameli, M.T., and Azad, S. (2023). "Optimal Routing and Power Management of Electric Vehicles in Coupled Power Distribution and Transportation Systems." *Applied Energy*, 341. <https://doi.org/10.1016/j.apenergy.2023.121126>



### 2.35. Title: Electric Vehicle Charging Capacity of Distribution Network Considering Conventional Load Composition

**Author(s):** Yang, P., Cao, Y., Tan, J., Chen, J., Zhang, C., Wang, Y., and Liang, H.

**Abstract:** At present, the large-scale access to electric vehicles (EVs) is exerting considerable pressure on the distribution network. Hence, it is particularly important to analyze the capacity of the distribution network to accommodate EVs. To this end, we propose a method for analyzing the EV capacity of the distribution network by considering the composition of the conventional load. First, the analysis and pretreatment methods for the distribution network architecture and conventional load are proposed. Second, the charging behavior of an EV is simulated by combining the Monte Carlo method and the trip chain theory. After obtaining the temporal and spatial distribution of the EV charging load, the method of distribution according to the proportion of the same type of conventional load among the nodes is adopted to integrate the EV charging load with the conventional load of the distribution network. By adjusting the EV ownership, the EV capacity in the distribution network is analyzed and solved on the basis of the following indices: node voltage, branch current, and transformer capacity. Finally, by considering the 10-kV distribution network in some areas of an actual city as an example, we show that the proposed analysis method can obtain a more reasonable number of EVs to be accommodated in the distribution network.

**Subject Areas:** Capacity; Charging load distribution; Charging load forecasting; Conventional load composition; Electric vehicle; Trip behavior

**Availability:** Yang, P., Cao, Y., Tan, J., Chen, J., Zhang, C., Wang, Y., and Liang, H. (2023). “Electric Vehicle Charging Capacity of Distribution Network Considering Conventional Load Composition.” *Energy Engineering*, 120(3), pp. 743–762.  
<https://doi.org/10.32604/ee.2023.024128>

### 2.36. Title: A Bi-level Optimal Dispatching Model for EV-Based Virtual Energy Storage System

**Author(s):** Luo, W., Yuan, Y., Dong, X., and Wu, H.

**Abstract:** Owing to shifts in global energy construction, the use of electric vehicles (EVs) has increased rapidly. In order to promote the consumption of renewable energy and eliminate the potential adverse effects of high EV penetration, this paper proposes the novel concept of the virtual energy storage system (V ESS) and a corresponding bi-level optimal dispatching model. The V ESS consists of all EV batteries currently connected to the grid in the same moment. The installation location of the V ESS depends on the distribution of available charging piles, while the V ESS' capacity is variable depending on EV parking times and quantity of electric batteries. The upper level of the associated bi-level V ESS dispatching model determines the V ESS's scheduling strategy, and a complex time-sequential trip chain model considering spatiotemporal EV distribution and road congestion level is proposed to obtain the available V ESS capacity in the distribution system. The model's lower level decides the specific power allocation for each EV. Data from National Household Travel Survey 2017 (NHTS2017) and EV database are employed to mimic the V ESS in the distribution network. A case study comparing the EV uncontrolled charging load and optimal scheduling demonstrates that the proposed V ESS dispatch strategy can consume surplus photovoltaic power and balance load fluctuation.

**Subject Areas:** Bi-level optimization; Electric vehicle; Virtual energy storage system; Spatiotemporal distribution

**Availability:** Luo, W., Yuan, Y., Dong, X., and Wu, H. (2023). "A Bi-level Optimal Dispatching Model for EV-Based Virtual Energy Storage System." *CSEE Journal of Power and Energy Systems*, pp. 1–12. <https://ieeexplore.ieee.org/document/10106191>

### **2.37. Title: An Optimal Joint Planning of DGs and Electric Vehicle Charging Stations in Grid-Connected and Islanded Microgrids**

**Author(s):** Zainab, F. et al.

**Abstract:** This paper proposes a new framework for the planning of both distributed generators (DGs) and electric vehicle charging stations (EVCSs). The proposed method efficiently produces a unified solution for the joint planning of DGs and EVCSs for both grid-connected and islanded scenarios. The problem is formulated as a novel two-stage planning problem. The first stage determines the locations and sizes of the DGs with locations of EVCSs in grid-connected scenario, whereas the second stage planning identifies the optimal islands under the islanded microgrid scenario. A non-dominated sorting genetic algorithm (NSGA-II) is applied to solve the first stage planning problem; in this stage, the algorithm minimizes two objective functions: the system losses and total cost. In the second stage, another single objective optimization problem is designed which minimizes supply voltage variations to find optimal islands for the DGs and EVCSs to ensure a secure supply of power for EVs. The proposed framework is implemented on the IEEE 33-bus system and verified with four test cases. The results demonstrate the effectiveness of the proposed method and show that the sizes and locations of DGs, and locations of EVCSs are adequate for both grid-connected and islanded microgrids.

**Subject Areas:** Distributed power generation; Distribution networks; Electric vehicles

**Availability:** Zainab, F. et al. (2023). “An Optimal Joint Planning of DGs and Electric Vehicle Charging Stations in Grid-Connected and Islanded Microgrids.” *IET Renewable Power Generation*, 17(7), pp. 1623–1634. <https://doi.org/10.1049/rpg2.12686>

### **2.38. Title: The Promise of EV-Aware Multi-Period Optimal Power Flow Problem: Cost and Emission Benefits**

**Author(s):** Kayacık, S.E., Kocuk, B., and Yüksel, T.

**Abstract:** Increased electric vehicle (EV) penetration brings considerable challenges to the daily planning of the power grid operations. A careful coordination of the grid operations and charging schedules is needed to alleviate these challenges, and turn them into opportunities. For this purpose, we study the Multi-Period Optimal Power Flow problem (MOPF) with electric vehicles under emission considerations. We integrate three different real-world datasets: household electricity consumption, marginal emission factors, and EV driving profiles. We present a systematic solution approach based on second-order cone programming to find globally optimal solutions for the resulting nonconvex optimization problem. To the best of our knowledge, our paper is the first to propose such a comprehensive model integrating multiple real datasets and a promising solution method for the EV-aware MOPF Problem. Our computational experiments on various instances with up to 2000 buses demonstrate that our solution approach leads to high-quality feasible solutions with provably small optimality gaps. In addition, we show the importance of coordinated EV charging to achieve significant emission savings and reductions in cost. In turn, our findings can provide quantitative insights to decision-makers on how to incentivize EV drivers depending on the trade-off between cost and emission.

**Subject Areas:** Multi-period optimal power flow problem; Second-order cone programming; Integration of electric vehicles to power grid; Coordinated electric vehicle charging; Emission mitigation

**Availability:** Kayacık, S.E., Kocuk, B., and Yüksel, T. (2023). “The Promise of EV-Aware Multi-Period Optimal Power Flow Problem: Cost and Emission Benefits.” *Sustainable Energy, Grids and Networks*, 34. <https://doi.org/10.1016/j.segan.2023.101062>

### 2.39. Title: Electric Vehicle Charging and Discharging Scheduling Strategy Based on Dynamic Electricity Price

**Author(s):** Ren, L., Yuan, M., and Jiao, X.

**Abstract:** The rapid growth in the number of electric vehicles (EVs) has significantly increased the demand for electricity for residents. In addition, because the charging time of EVs highly coincides with the peak period of user electricity consumption, the disorderly charging of EVs will lead to the overload of the power grid transformer. Traditional control methods lack certain robustness and do not fully consider the uncertainty of EVs. As a result, the V2G participation rate of electric vehicles cannot be determined, and the control reliability is low. To solve the above problems, this paper designs a reinforcement learning framework of Long Short-Term Memory network and Improved Linear programming algorithm (LSTM-ILP) to control the V2G of EVs. This paper comprehensively considers the overall electric vehicle charging demand, discharge potential, large grid electricity price, aggregator, and users' interests demands. Firstly, aiming to minimize the charging and discharging fee of EVs and the load peak-to-valley difference of the power grid, a dynamic electricity price based on Long Short-Term Memory neural network (LSTM) is established. Then, the improved linear programming algorithm (ILP) is used to solve the charging and discharging optimization problem of EV, and the results are fed back to the input of the next iterative update of the LSTM, and finally, the optimal electricity price and EV charging and discharging schedule are achieved. The simulation results show that the LSTM-ILP framework can not only reduce the charging fee of electric vehicles, but also achieve the Peak and valley trimming of the grid load. Charging costs for EV users were reduced by 42.1% compared with unordered charging, and by 22 percent compared with orderly charging.

**Subject Areas:** Vehicle to grid; Dynamic electricity price; Linear programming; Reinforcement learning; Electricity prices

**Availability:** Ren, L., Yuan, M., and Jiao, X. (2023). "Electric Vehicle Charging and Discharging Scheduling Strategy Based on Dynamic Electricity Price." *Engineering Applications of Artificial Intelligence*, 123(Part B). <https://doi.org/10.1016/j.engappai.2023.106320>

#### **2.40. Title: Multi-Objective Charging Station Planning Method Considering Investment Construction Cost and Safe Operation of the Power Grid**

**Author(s):** Zhang, J., Jiang, L., Wang, W., Yang, Y., Wang, R., Li, J., and Zhuang, C.

**Abstract:** The unreasonable layout of charging stations will increase the investment construction cost of charging stations and affect the safe operation of the power grid. To solve the existing unreasonable charging stations layout problem, this paper proposes a multi-objective layout planning method. Firstly, the Monte Carlo method is used to predict the charging load of electric vehicles (EVs) in time and space, and the prediction results are used as the conditions of primary location selection of charging stations. A multi-objective optimization model is established to minimize the comprehensive social cost and network loss. By setting the constraints of the maximum line power and the maximum voltage offset, the safe operation requirements of the power grid are achieved. Secondly, the model is solved by a multi-objective optimization algorithm and the Pareto optimal solution set is obtained. Besides, after eliminating the solutions that do not meet the safety requirements by N-1 running evaluation, the solution with the highest satisfaction is derived by fuzzy theory, which is 3572.38kCNY on comprehensive social cost and 214.35kW•h on network loss, respectively. Finally, the feasibility of the model and algorithm is verified by analyzing the results.

**Subject Areas:** Electric vehicle; Charging load prediction; Planning of charging stations; Multi-objective optimization

**Availability:** Zhang, J., Jiang, L., Wang, W., Yang, Y., Wang, R., Li, J., and Zhuang, C. (2023). "Multi-Objective Charging Station Planning Method Considering Investment Construction Cost and Safe Operation of the Power Grid." *2023 5th Asia Energy and Electrical Engineering Symposium (AEEES)*, Chengdu, China, pp. 1291–1297.  
<https://doi.org/10.1109/AEEES56888.2023.10114276>

#### **2.41. Title: Research on Control Method of Electric Vehicle in Residential Area Based on Soft Actor-Critic**

**Author(s):** Yu, H., Dou, X., Hu, W., and Zhang, K.

**Abstract:** This paper aims to solve the problem of orderly regulation of electric vehicles (EVs) in residential areas. Firstly, based on Monte Carlo randomization algorithm, the stochastic model of electric vehicle load in residential areas was established considering charging time, charging duration and daily driving distance. Secondly, according to the established stochastic model, the deep reinforcement learning algorithm of Soft Actor-Critic (SAC) is adopted to describe the regulation process of electric vehicles as Markov decision process. The charging and discharging process of electric vehicles is regulated by day-ahead and intra-day time scales to optimize the load curve of power grid. Finally, the feasibility of the above method is verified by relevant examples.

**Subject Areas:** Electric vehicle; Monte Carlo; Soft Actor-Critic

**Availability:** Yu, H., Dou, X., Hu, W., and Zhang, K. (2023). “Research on Control Method of Electric Vehicle in Residential Area Based on Soft Actor-Critic.” *2023 5th Asia Energy and Electrical Engineering Symposium (AEEES)*, Chengdu, China, pp. 1235–1240.  
<https://doi.org/10.1109/AEEES56888.2023.10114146>

## 2.42. Title: Estimate Long-Term Impact on Battery Degradation by Considering Electric Vehicle Real-World End-Use Factors

**Author(s):** Ou, S.

**Abstract:** Many estimates of battery capacity degradation are based on accelerated lab tests that involve charge-discharge cycles or rely on data or electrochemical modeling. These methods are reasonable for technology benchmarking but rarely consider real-world end-use factors. To address this issue, this study develops the Battery Run-Down under Electric Vehicle Operation (BREVO) model. It links the driver's travel pattern to physics-based battery degradation and powertrain energy consumption models. The model simulates the impacts of charging behavior, charging rate, driving patterns, and multiple energy management modules on battery capacity degradation. It finds that, over a 10-year time span, firstly, for a random driver situated in the New England area, daily direct-current fast charging (60 kW) could lead to up to 22% less battery capacity when compared to daily Level-1 charging (1.8 kW). Second, the battery thermal management system can delay battery degradation by approximately 0.5% in the New England area. Third, warmer ambient temperatures enhance BEV battery usage. The model indicates that the battery capacity in the Los Angeles area is 6% higher than that in the New England area. The BREVO model provides crucial information for consumers and BEV manufacturers on range anxiety, BEV battery design, and decision support of battery warranty.

**Subject Areas:** Battery capacity degradation; Driving patterns; Electric vehicle; Fast charging; Powertrain energy consumption

**Availability:** Ou, S. (2023). "Estimate Long-Term Impact on Battery Degradation by Considering Electric Vehicle Real-World End-Use Factors." *Journal of Power Sources*, 573. <https://doi.org/10.1016/j.jpowsour.2023.233133>



### **2.43. Title: Emissions Reductions from Electrifying High-Mileage Vehicles**

**Author(s):** Aemmer, Z., Malarkey, D., and MacKenzie, D.

**Abstract:** This paper evaluates a strategy that would target sales of internal combustion vehicles driven at high annual mileage for displacement by electric vehicles at the time of initial sale. Using the 2017 National Household Travel Survey data, we observe that the top 20% of light duty vehicles by kilometers traveled generate 46% of the annual greenhouse gas emissions. Displacing the sale of a combustion engine vehicle in the top mileage quintile with an electric vehicle would reduce annual greenhouse gas emissions and certain criteria pollutants by more than 15 times as much as displacing a vehicle in the bottom mileage quintile.

**Subject Areas:** Electric vehicles; Emissions; Superusers; Lifetime; Annual mileage; Subsidy

**Availability:** Aemmer, Z., Malarkey, D., and MacKenzie, D. (2023). “Emissions Reductions from Electrifying High-Mileage Vehicles.” *Findings*. <http://dx.doi.org/10.32866/001c.75133>

#### **2.44. Title: Electric Vehicles as a Sustainable Energy Technology: Observations from Travel Survey Data and Evaluation of Adoption with Machine Learning Method**

**Author(s):** Dai, Z. and Zhang, B.

**Abstract:** Governments worldwide are promoting Electric Vehicles (EVs) to achieve the energy conservation and emissions reduction goal, but low penetration of EVs means that it still has far to go before stepping into the sustainable energy future. In addition to technological breakthroughs to enhance the appeal of EVs, how to locate demand and make targeted promotions is also vital in increasing the share of EVs. This study explored the household characteristics related to EV adoption with the household travel survey data and proposed a LightGBM-based prediction modelling framework with high accuracy and explainable results. During this process, the details of sampling techniques to overcome data imbalance were discussed with the aim of improving the model performance. Furthermore, through constructing the model with high interpretability, we identified important factors regarding EV adoptions through both statistical significance and feature importance analysis. The research findings can not only assist EV manufacturers in targeting potential buyers but also help policymakers understand families' EV purchasing decisions and develop more targeted and equitable policies and incentive programs. Such two-pronged efforts have the potential to advance the sustainability transition toward greener transportation systems.

**Subject Areas:** Household Travel Survey; Electric Vehicle Adoption; Transportation Market Behavior; Electromobility Analysis; Applied Machine Learning

**Availability:** Dai, Z. and Zhang, B. (2023). "Electric Vehicles as a Sustainable Energy Technology: Observations from Travel Survey Data and Evaluation of Adoption with Machine Learning Method." *Sustainable Energy Technologies and Assessments*, 57. <https://doi.org/10.1016/j.seta.2023.103267>

#### **2.45. Title: Stress Factor Identification and Risk Probabilistic Number (RPN) Analysis of Li-ion Batteries Based on Worldwide Electric Vehicle Usage**

**Author(s):** Haber, M., Azaïs, P., Genies, S., and Raccurt, O.

**Abstract:** Having clear insights of the stress factors that the electric vehicle (EV) batteries encounter during their service lifetime is crucial for more reliable ageing testing and modelling. Since the first deployment of Li-ion battery-based EV, numerous driving campaigns with field data were published. The goal of this article is to gather, assess and analyse them in order to quantify the stress factors depending on the EV type. The targeted stress factors are the temperature of the cells, the discharging and charging rates, as well as the SOC ranges. 228 million km of driving and 7.8 million trips worth of data for over 37,000 EV were investigated. Along with this literature enquiry, data from an EV in which cells' temperature was monitored for driving, charging and parking conditions, complemented the analysis. For each stress factor, results were collected, homogenised and compared with each other in order to draw conclusions. Finally, a Risk Probabilistic Number (RPN) was used to evaluate the stress factors with respect to their impact on the ageing of Li-ion batteries, considering a central European weather. The most critical stress factors for BEV cells are cycling at high mid-SOC regions and high SOC idle times. Concerning HEV cells, high power cycling at mid-SOC regions is the most critical stress, and no stresses were identified during idle times. PHEV cells' most critical stress factors are large DOD cycling and high charge/discharge power. Mild and low temperatures are found to be the most common in such weathers. The RPN analysis serves as a guide for parametrizing and designing reliable accelerated ageing testing on Li-ion batteries depending on their application.

**Subject Areas:** Electric vehicle; Li-ion battery; Stress factors; Ageing; Usage analysis; Risk Probabilistic Number (RPN)

**Availability:** Haber, M., Azaïs, P., Genies, S., and Raccurt, O. (2023). "Stress Factor Identification and Risk Probabilistic Number (RPN) Analysis of Li-ion Batteries Based on Worldwide Electric Vehicle Usage." *Applied Energy*, 343. <https://doi.org/10.1016/j.apenergy.2023.121250>

#### **2.46. Title: Grid Peak Load Shaving Method Considering EV Charging Uncertainty Based on Interval Optimization**

**Author(s):** Zhao, Y., Wang, T., Ma, M., Zhao, W., Wang, Q., Mao, T., and Liu, Z.

**Abstract:** With the rapid development of electric vehicles, more and more electric vehicles are entering people's lives. However, the large-scale access of electric vehicles to the grid brings harm to the stability of grid operation, and the problem of how to guide the staggered charging of electric vehicles needs to be solved. In this paper, we consider the travel characteristics and charging characteristics of three different types of EVs: private cars, buses, and cabs, and set up a time-of-use tariff to guide EV users to charge reasonably, thus reducing the impact of charging load on the grid by cutting peaks and filling valleys. Since the charging load of EVs is an interval value, this paper introduces interval optimization theory, establishes an optimistic model and a pessimistic model, calculates the upper and lower bound of the interval, respectively, and finds out the interval value of grid load after peak and valley reduction.

**Subject Areas:** Electric vehicle; Grid operation; Charging load; Travel characteristics; Charging characteristics; Interval optimization

**Availability:** Zhao, Y., Wang, T., Ma, M., Zhao, W., Wang, Q., Mao, T., and Liu, Z. (2023).

“Grid Peak Load Shaving Method Considering EV Charging Uncertainty Based on Interval Optimization.” *Journal of Physics: Conference Series*, 2495.

<https://iopscience.iop.org/article/10.1088/1742-6596/2495/1/012029>

## 2.47. Title: A Transfer Learning Method for Electric Vehicles Charging Strategy Based on Deep Reinforcement Learning

**Author(s):** Wang, K., Wang, H., Yang, Z., Feng, J., Li, Y., Yang, J., and Chen, Z.

**Abstract:** Reinforcement learning (RL) is popularly used for the development of an orderly charging strategy for electric vehicles (EVs). However, a new environment (e.g., charging areas and times) will cause EV users' driving behaviors and electricity prices to change, which leads to the trained RL-based charging strategy is not suitable. Besides, developing a new RL-based charging strategy for the new environment will cost too much time and data samples. In this paper, a deep transfer reinforcement learning (DTRL)-based charging method for EVs is proposed to realize the transfer of trained RL-based charging strategy to the new environment. Firstly, we formulate the uncertainty problem of EV charging behaviors as a Markov Decision Process (MDP) with an unknown state transfer function. Furthermore, an RL-based charging strategy based on deep deterministic policy gradient (DDPG) is well-trained by using massive driving and environmental data samples. Finally, an EV charging method based on transfer learning (TL) and DDPG is proposed to perform the knowledge transfer on the trained RL-based charging strategy to the new environment. The proposed method is verified by numerous simulations. The results show that the proposed approach can reduce the outliers to meet the user charging demands and shorten the EV charging strategy development time in the new environment.

**Subject Areas:** Electric vehicle; Transfer learning; Deep reinforcement learning; Charging strategy

**Availability:** Wang, K., Wang, H., Yang, Z., Feng, J., Li, Y., Yang, J., and Chen, Z. (2023). "A Transfer Learning Method for Electric Vehicles Charging Strategy Based on Deep Reinforcement Learning." *Applied Energy*, 343. <https://doi.org/10.1016/j.apenergy.2023.121186>

**2.48. Title: Modeling the Temporal and Economic Feasibility of Electric Vehicles Providing Vehicle-to-Grid Services in the Electricity Market under Different Charging Scenarios**

**Author(s):** Zheng, Y., Shao, Z., Shang, Y., and Jian, L.

**Abstract:** Electric vehicles (EVs) could potentially act as the distributed energy storage devices to provide vehicle-to-grid (V2G) services to benefit the electric power system. Correspondingly, EV users can earn revenue based on the provision of grid services in a market environment. However, EVs would suffer the extra battery degradation incurred by the V2G operation. As such, it is essential to investigate the feasibility of EVs to conduct the V2G operation under different charging scenarios. Compared to existing studies focusing solely on the economic evaluation of V2G operation, this paper investigates the potential of EVs providing V2G services from two perspectives: time availability and economic viability. To this end, two critical indicators, viz., time indicator and economic indicator, are introduced in this paper to model the temporal and economic feasibility of EVs providing grid services to explore the applicable V2G scenarios. In addition, three charging scenarios at home, in workplace, and in fast charging stations (FCSs) are evaluated regarding the feasibility for V2G services. The simulation results reveal that there is sufficient idle time for those EVs in the home-based and workplace-based charging scenarios and it is profitable to provide V2G services in the electricity market according to the cost-benefit analysis. However, for those EVs with FCS-based charging, it is unlikely for EV users to spend the extra time to conduct the V2G operation due to the fact that the V2G operation will prolong the grid-connection time of EVs.

**Subject Areas:** Electric vehicles; Vehicle-to-grid; Electricity markets; Scenario analysis

**Availability:** Zheng, Y., Shao, Z., Shang, Y., and Jian, L. (2023). “Modeling the Temporal and Economic Feasibility of Electric Vehicles Providing Vehicle-to-Grid Services in the Electricity Market under Different Charging Scenarios.” *Journal of Energy Storage*, 68.

<https://doi.org/10.1016/j.est.2023.107579>

## 2.49. Title: GreenEVT: Greensboro Electric Vehicle Testbed

**Author(s):** Nilsson, G., Aquino, A.D.O., Coogan, S., and Molzahn, D.K.

**Abstract:** The ongoing electrification of the transportation fleet will increase the load on the electric power grid. Since both the transportation network and the power grid already experience periods of significant stress, joint analyses of both infrastructures will most likely be necessary to ensure acceptable operation in the future. To enable such analyses, this paper presents an open-source testbed that jointly simulates high-fidelity models of both the electric distribution system and the transportation network. The testbed utilizes two open-source simulators, OpenDSS to simulate the electric distribution system and the microscopic traffic simulator SUMO to simulate the traffic dynamics. Electric vehicle charging links the electric distribution system and the transportation network models at vehicle locations determined using publicly available parcel data. Leveraging high-fidelity synthetic electric distribution system data from the SMART-DS project and transportation system data from OpenStreetMap, this testbed models the city of Greensboro, NC, down to the household level. Moreover, the methodology and the supporting scripts released with the testbed allow adaptation to other areas where high-fidelity geolocated OpenDSS datasets are available. After describing the components and usage of the testbed, we exemplify applications enabled by the testbed via two scenarios modeling the extreme stresses encountered during evacuations.

**Subject Areas:** Electric vehicles; Simulator; Testbed; Power grid; Transportation network

**Availability:** Nilsson, G., Aquino, A.D.O., Coogan, S., and Molzahn, D.K. (2023). *GreenEVT: Greensboro Electric Vehicle Testbed*. arXiv preprint, arXiv:2305.12722v1 [eess.SY]. <https://doi.org/10.48550/arXiv.2305.12722>

## **2.50. Title: Collaborative Planning of Community Charging Facilities and Distribution Networks**

**Author(s):** Diao, X.-H., Zhang, J., Wang, R.-Y., Jia, J.-W., Chang, Z.-L., Li, B., and Zhao, X.

**Abstract:** The construction of community charging facilities and supporting distribution networks based on the predicted results of electric vehicle (EV) charging power in saturation year has resulted in a large initial idleness of the distribution network and a serious waste of assets. To solve this problem, this paper proposes a collaborative planning method for urban community charging facilities and distribution networks. First, based on the load density method and occupancy rate to predict the base electricity load in the community, the Bass model and charging probability are used to predict the community's electric vehicle charging load. Taking the minimum annual construction and operation costs of the community distribution network as the objective function, the power supply topology of the distribution network for a new community is optimized by using Prim and single-parent genetic algorithms. Finally, the proposed scheme is verified by using the actual community data of a certain city in China as an analysis example, and the scheme of one-time planning of the distribution network and yearly construction of charging facilities is given.

**Subject Areas:** Collaborative planning; Charging facility; Distribution network; Electric vehicle; Charging load forecasting; Community

**Availability:** Diao, X.-H., Zhang, J., Wang, R.-Y., Jia, J.-W., Chang, Z.-L., Li, B., and Zhao, X. (2023). "Collaborative Planning of Community Charging Facilities and Distribution Networks." *World Electric Vehicle Journal*, 14(6). <https://doi.org/10.3390/wevj14060143>



## 2.51. Title: Dynamic Pricing for Fast Charging Stations with Deep Reinforcement Learning

**Author(s):** Cui, L., Wang, Q., Qu, H., Wang, M., Wu, Y., and Ge, L.

**Abstract:** With the rapid development of electric vehicles (EVs) and charging infrastructures, the unbalanced utilization rate of fast charging stations (FCSTs) and the long waiting time for charging have aroused considerable attention. The incurred low operation profit of FCSTs and low satisfaction of EVs impose difficulties on the further development of EV industry. Existing literature ignored the influence of real-time charging price changes on traffic flow variation and EV charging determination during the dynamic price regulating process. This paper focuses on solving these crucial issues in the dynamic pricing for FCSTs with deep reinforcement learning (DRL). Firstly, considering the spatial–temporal interactions of different roads, a traffic flow prediction model is proposed based on the LSTM combined with the GNN-FiLM. Then, the Origin-Destination (OD) estimation is used to estimate the charging requirements of EVs based on the predicted traffic flow, and a charging demand prediction method for FCSTs is developed by converting the EV satisfaction into economic costs with different dimensions. Then, the vehicle–road learning environment is built with the Markov decision process (MDP), and a dynamic pricing strategy based on the Deep Deterministic Policy Gradient (DDPG) learning is proposed to achieve the optimal charging prices of FCSTs with maximum operation profit. Moreover, during the learning process, the real-time charging price is renewed based on the predicted charging demand, and the future charging demand is further predicted under the renewed charging price until the optimal price is achieved. Finally, simulation results validate that the proposed dynamic pricing strategy effectively improves the profit of FCSTs, alleviates the road congestion, and improves the users’ satisfaction.

**Subject Areas:** Electric vehicle (EV); Fast charging station (FCST); Dynamic pricing; User satisfaction; deep reinforcement learning (DRL)

**Availability:** Cui, L., Wang, Q., Qu, H., Wang, M., Wu, Y., and Ge, L. (2023). “Dynamic Pricing for Fast Charging Stations with Deep Reinforcement Learning.” *Applied Energy*, 346. <https://doi.org/10.1016/j.apenergy.2023.121334>

## 2.52. Title: Autonomous Demand Side Management of Electric Vehicles

**Author(s):** Ireshika, M.A.S.T.

**Abstract:** Demand-side management approaches that exploit the temporal flexibility of electric vehicles have attracted much attention in recent years due to the increasing market penetration. These demand-side management measures contribute to alleviating the burden on the power system, especially in distribution grids where bottlenecks are more prevalent. Electric vehicles can be defined as an attractive asset for distribution system operators, which have the potential to provide grid services if properly managed. In this thesis, first, a systematic investigation is conducted for two typically employed demand-side management methods reported in the literature: a voltage droop control-based approach and a market-driven approach. Then a control scheme of decentralized autonomous demand side management for electric vehicle charging scheduling which relies on a unidirectionally communicated grid-induced signal is proposed. In all the topics considered, the implications on the distribution grid operation are evaluated using a set of time series load flow simulations performed for representative Austrian distribution grids. Droop control mechanisms are discussed for electric vehicle charging control which requires no communication. The method provides an economically viable solution at all penetrations if electric vehicles charge at low nominal power rates. However, with the current market trends in residential charging equipment, especially in the European context where most of the charging equipment is designed for 11 kW charging, the technical feasibility of the method, in the long run, is debatable. As electricity demand strongly correlates with energy prices, a linear optimization algorithm is proposed to minimize charging costs, which uses next-day market prices as the grid-induced incentive function under the assumption of perfect user predictions. The constraints on the state of charge guarantee the energy required for driving is delivered without failure. An average energy cost saving of 30% is realized at all penetrations. Nevertheless, the avalanche effect due to simultaneous charging during low price periods introduces new power peaks exceeding those of uncontrolled charging. This obstructs the grid-friendly integration of electric vehicles.

**Subject Areas:** Electric vehicles; Distribution grid; Simulation models; Autonomous Demand Side Management; Market prices; Optimal power tracking; Compliant charging characteristics; Uncertainty handling

**Availability:** Ireshika, M.A.S.T. (2023). *Autonomous Demand Side Management of Electric Vehicles*. Doctoral Dissertation, University of Agder, Kristiansand, Norway.  
<https://hdl.handle.net/11250/3070730>

### 2.53. Title: V2G Optimization for Dispatchable Residential Load Operation and Minimal Utility Cost

**Author(s):** Alden, R.E., Timilsina, A., Silvestri, S., and Ionel, D.M.

**Abstract:** Electric vehicles (EVs) are gaining popularity among consumers and are expected to play a significant role in the future of transportation. Within this paper, a reverse auction is formulated through an optimization problem to minimize the utility energy cost using vehicle-to-grid (V2G) operation, as well as transition residential communities to dispatchable aggregate constant load profiles for demand response (DR). The evolutionary V2G Auction (eV2GA), including the non-dominated sorting genetic algorithm (NSGA-II), is proposed for the formulated problem. It uses co-simulation with OpenDSS for power flow analysis as part of the objective function to account for physical constraints of infrastructure on the cost analysis. The results are verified against a greedy method in two case studies on the IEEE 123 test feeder with modified residential load showing over 20% reduction in cost from no v2G. It is demonstrated that physical power system constraints, such as line active power flow limits, may be implemented into the optimization through the proposed approach and do affect the V2G design solution by placing influence on location of the selected EVs in the distribution system.

**Subject Areas:** Electrical vehicle (EV); Vehicle-to-Grid (V2G); Reverse auction; Optimization; Electrical infrastructure; Smart and micro grid; Distribution; OpenDSS

**Availability:** Alden, R.E., Timilsina, A., Silvestri, S., and Ionel, D.M. (2023). *V2G Optimization for Dispatchable Residential Load Operation and Minimal Utility Cost*. Authors' Manuscript, IEEE Transportation Electrification Conference & Expo (ITEC), Detroit, MI.

[https://sparklab.engr.uky.edu/sites/sparklab/files/2023%20UK%20SPARK%20CPS%20ITEC%20V2G%20Optimization%20Dispatchable%20Residential%20Load%20Minimal%20Cost\\_1.pdf](https://sparklab.engr.uky.edu/sites/sparklab/files/2023%20UK%20SPARK%20CPS%20ITEC%20V2G%20Optimization%20Dispatchable%20Residential%20Load%20Minimal%20Cost_1.pdf)

## 2.54. Title: Two-Stage Electric Vehicle Charging Optimization Model Considering Dynamic Virtual Price-Based Demand Response and a Hierarchical Non-Cooperative Game

**Author(s):** Lin, H., Dang, J., Zheng, H., Yao, L., Yan, Q., Yang, S., Guo, H., and Anvari-Moghaddam, A.

**Abstract:** This paper proposes a two-stage bi-layer game charging optimization model based on the background of non-coordination between a network operator (NO), a distributed generation operator (DGO), and a charging agent (CA). In the first stage, a dynamic virtual price-based demand response (DVPBDR) model is constructed to pre-optimize the charging load with the virtual charging cost as the objective. In the second stage, a strategy for adjusting output deviations based on a bi-layer Stackelberg game model is established, with the economic benefits of each participant as the objectives. Full cooperation mode and bi-layer mixed game are introduced to compare with the bi-layer Stackelberg game in Simulation Analysis. The calculation results show that (1) the DVPBDR is not constrained by the actual electricity price system and mechanism and reflect the real influence of price changes on charging demands, thus effectively reducing energy abandonment by 41.76% and net load fluctuation by 53.50%; (2) in the full cooperation mode, there is a conflict of interests and CA suffers financial loss, thus resulting in a reduction in comprehensive benefits by at least 61.08%, compared to the non-cooperative cases; (3) in the bi-layer mixed games, the cooperative gain of DGO and NO is superior than that of the cooperation between DGO and CA, so a relative win-win is achieved in the bi-layer mixed game with DGO-CA cooperation, and the comprehensive benefits are increased by 3.32%; (4) in the bi-layer Stackelberg game, each participant has a completely independent awareness of decision-making and establishes strategies for maximizing its own interests, which results in achieving the optimal comprehensive benefits (increases by at least 44.18% compared to other cases). Therefore, multi-dimensional benefits are realized in the multi-participant charging system with a bi-layer Stackelberg game.

**Subject Areas:** Electric vehicles (EV); Day-ahead and intraday charging optimization; Network, generation, and user sides; Dynamic virtual price-based demand response, Bi-layer Stackelberg game

**Availability:** Lin, H., Dang, J., Zheng, H., Yao, L., Yan, Q., Yang, S., Guo, H., and Anvari-Moghaddam, A. (2023). "Two-Stage Electric Vehicle Charging Optimization Model Considering Dynamic Virtual Price-Based Demand Response and a Hierarchical Non-Cooperative Game." *Sustainable Cities and Society*, 97. <https://doi.org/10.1016/j.scs.2023.104715>

## 2.55. Title: Estimating the Electric Vehicle Charging Demand of Multi-Unit Dwelling Residents in the United States

**Author(s):** Cheng, X. and Kontou, E.

**Abstract:** Early battery electric vehicle (EV) adopters can access home chargers for reliable charging. As the EV market grows, residents of multi-unit dwellings may face barriers in owning EVs and charging them without garage or parking availability. To investigate the mechanisms that can bridge existing disparities in home charging and station deployment, we characterized the travel behavior of multi-unit dwelling residents and estimated their EV residential charging demand. This study classifies the travel patterns of multi-unit dwelling (MUD) residents by fusing trip diary data from the National Household Travel Survey and housing features from the American Housing Survey. A hierarchical agglomerative clustering method was used to cluster apartment complex residents' travel profiles, considering attributes such as dwell time, daily vehicle miles traveled (VMT), income, and their residences' US census division. We propose a charging decision model to determine the charging station placement demand in MUDs and the charging energy volume expected to be consumed, assuming that MUD drivers universally operate EVs in urban communities. Numerical experiments were conducted to gain insight into the charging demand of MUD residents in the US. We found that charging availability is indispensable for households that set out to meet 80% state of charge by the end of the day. When maintaining a 20% comfortable state of charge the entire day, the higher the VMT are, the greater the share of charging demand and the greater the energy use in MUD chargers. The upper-income group requires a greater share of MUD charging and greater daily kWh charged because of more VMT.

**Subject Areas:** Electrical vehicle (EV); Residential charging demand; Charging station deployment; multi-unit dwellings

**Availability:** Cheng, X. and Kontou, E. (2023). "Estimating the Electric Vehicle Charging Demand of Multi-Unit Dwelling Residents in the United States." *Environmental Research: Infrastructure and Sustainability*. <http://iopscience.iop.org/article/10.1088/2634-4505/acde06>

## **2.56. Title: Highly Resolved Projections of Passenger Electric Vehicle Charging Loads for the Contiguous United States**

**Author(s):** Yip, A., Hoehne, C., Jadun, P., Ledna, C., Hale, E., and Muratori, M.

**Abstract:** This report documents enhancements made to the Transportation Energy & Mobility Pathway Options™ (TEMPO) model to project spatially, demographically, and temporally resolved national-scale electric vehicle (EV) charging load profiles and describes three scenarios and corresponding data sets created for the National Renewable Energy Laboratory's (NREL's) demand-side grid (dsgrid) project in support of bulk power systems modeling. In brief, TEMPO was enhanced to disaggregate national and annual energy demand projections into household and county-level projections of passenger EV hourly charging load profiles (8760 profiles), accounting for consumer, travel, and temperature variations that impact EV energy demand. In alignment with NREL's forward-looking grid modeling, three scenarios for EV adoption covering 2020–2050 were created—*Annual Energy Outlook (AEO) Reference Case*, *Electrification Futures Study (EFS) High Electrification*, and *All EV Sales by 2035*—and associated data sets have been included in the dsgrid platform for public use.

**Subject Areas:** Electric vehicle charging load; Transportation Energy & Mobility Pathway Options (TEMPO); Demand-side grid; Grid modeling

**Availability:** Yip, A., Hoehne, C., Jadun, P., Ledna, C., Hale, E., and Muratori, M. (2023). *Highly Resolved Projections of Passenger Electric Vehicle Charging Loads for the Contiguous United States*. Technical Report, NREL/TP-5400-83916, National Renewable Energy Laboratory, Golden, CO. <https://www.nrel.gov/docs/fy23osti/83916.pdf>

## **2.57. Title: A Comparison of Practical Electric Vehicle Charging Policies to Improve the Performance of Power Distribution Systems**

**Author(s):** Khandelwal, D., Painuli, S., Bhowmick, S., and Saha, R.

**Abstract:** Electric vehicles (EVs) lend a new paradigm to the transportation sector while introducing different challenges to the power distribution grid. The EV load presents an unbalanced, dynamic load, depending on the number of charging EVs at any instant connected to the different phases, the type(s) of the EV(s) connected, the starting time(s) of the EV charging and the charging duration(s), all of which are random functions of time. Hence, it becomes difficult to analyze the impact of EV charging on the distribution networks. In this paper, the domestic EV charging effect of approximately 3000 EVs pertaining to more than 800 U. S. residents on a 240-bus real distribution grid situated in the Midwest U.S.A is investigated using well-known travel survey data from the National Household Travel Survey (NHTS). Multiple case studies are carried out on the 240-bus network vis-à-vis profiles of the network demand, bus voltages, and system losses without and with EV charging. The distortion in the network daily load profile, the bus voltage profile, and the network losses can be reduced by implementing practical SOC-based EV charging policies. Three SOC-based EV charging policies are suggested. The results validate the proposed EV charging guidelines.

**Subject Areas:** Electrical vehicles; Charging policies; Distribution system; Hourly demand profile; Load curve; National Household Travel Survey (NHTS); Residential charging

**Availability:** Khandelwal, D., Painuli, S., Bhowmick, S., and Saha, R. (2023). “A Comparison of Practical Electric Vehicle Charging Policies to Improve the Performance of Power Distribution Systems.” *2023 International Conference on Recent Advances in Electrical, Electronics & Digital Healthcare Technologies (REEDCON)*, New Delhi, India, pp. 7–12.  
<https://doi.org/10.1109/REEDCON57544.2023.10151097>

## 2.58. Title: System Strength and Dynamic Voltage Recovery of Power Grids with High Penetration of LSPV Plants

**Author(s):** Alshareef, A.

**Abstract:** Power grids are undergoing a massive transition toward non-conventional generations (NCGs) such as photovoltaic (PV) and wind power plants. NCGs have rapidly become a significant portion of the worldwide power generation mix. Sustainability, environmentally friendliness, price volatility and supply security of fossil fuels, advancement of power electronics technology, and low bidding prices of recent NCG installations are the key driving factors for this transition. Undoubtedly, PV technologies show remarkable growth among other renewable sources. Large-scale PV (LSPV) facilities and distributed PV systems or roof-top installations are the two basic types of solar PVs. LSPV plants have recently dominated yearly installations during the last few years. Hence, the goal of this research is to find an answer to the following research questions: What is the impact of a high penetration of LSPV on system strength and dynamic voltage stability? and How can any detrimental impacts be mitigated to integrate many LSPV plants into power grids securely?

Firstly, it was noticed that their modelling has progressed to the point where the LSPV modelling has matured beyond the use of simple negative loads. Moreover, recent LSPV plant models are built and validated based on a collaborative work between industry and recognized technical committees. Therefore, the WECC model is used in this research to capture the LSPV plant behavior at their various penetration levels on system strength and dynamic voltage stability. Aside from these transitions on the generation side, numerous new loads, such as inverter-based air conditioners and industrial drives, are rising in power grids. Even though load models play a profound role in dynamic voltage stability, their representation in such stability analysis hasn't matured. Therefore, secondly, more investigations were carried out to come out with more realistic models for these load types and assess their impact on dynamic or short-term voltage stability (STVS) in the presence of LSPV plants. Thirdly, this research has also looked at establishing assessment indices for STVS. Many STVS assessment indices have been proposed in the literature to quantify local voltage recovery performance. Thus, critical investigations were conducted to develop a reliable STVS assessment index that would be employed for assessing global impact.

The final part of the research was focused on exploring mitigation measures to alleviate the detrimental impacts of LSPV plants' proliferation on STVS by suggesting effective countermeasures. Therefore, fourthly, the research shifted to investigate possible modifications within LSPV plant controllers, namely active power ramping rate in specific, to improve STVS. Moreover, the research has focused on augmenting the benefit of installing II dynamic Var sources by selecting the optimal installation site in power grids with high penetration of LSPV plants.

The research contributes to practical outcomes that will help higher penetration and demonstrated the impact of higher LSPV penetration on system strength from STVS perspective, considering the uncertainty of PV power output. Then, the research succeeds to optimize the parameters of a standard library model of directly connected induction motors (DCIMs) to closely mimic the



behavior of inverter-based drive motors for voltage response. It can be concluded that the existence of motor drives strengthened STVS compared to DCIMs. However, inverter-based drive motors' proliferation and higher LSPV penetration make the grid vulnerable to transient instability issues due to rotational mass reduction on both the generation and load sides. On STVS measuring and monitoring, an improvement in one of the STVS indices—namely, the Voltage Recovery Index (VRI)—is proposed to overcome shortcomings in the original index. Moreover, the improved index is globalized to establish overall systemwide impact and named as system voltage recovery index (VRI<sub>sys</sub>). The amended local VRI and developed global VRI<sub>sys</sub> are used in simulations and case studies to quantify the impact and interaction of various factors that could affect system strength.

Finally, the research attention is diverted into practical mitigation measures to prevent and alleviate the detrimental impacts of LSPV plants' proliferation on STVS. This is started with investigating the possibility of adopting an active current ramping rate (rrpwr) following power curtailment caused by grid disturbance to improve STVS. Of course, injecting reactive current during and after disturbance improves STVS. However, investigating active current injection on transmission networks does not get much attention in the literature. It can be concluded that adaptive rrpwr is not an influential factor to improve the short-term dynamic voltage stability. One of the most effective solutions to resolve STVS issues is to install a centralized dynamic VAR support (D-VARS). A driven-data trajectory approach using a developed alignment factor ( $K\alpha$ ) has been proposed to allocate D-VARS to STVS. The siting approach for D-VARS is based on comparing grid responses of different D-VARS sites with desired reference responses. The developed siting approach emphatically covers the full signature of grid dynamics interaction involving generation, transmission, and load characteristics. The assessment of allocation outcomes was verified using a VRI<sub>sys</sub> to assess STVS performance.

**Subject Areas:** Large-scale photovoltaic; Dynamic voltage stability; System strength; Mitigation

**Availability:** Alshareef, A. (2023). *System Strength and Dynamic Voltage Recovery of Power Grids with High Penetration of LSPV Plants*. Doctoral Dissertation, The University of Queensland, Brisbane, Queensland, Australia. <https://doi.org/10.14264/94da21f>

## 2.59. Title: Operation-Area-Constrained Adaptive Primary Frequency Support Strategy for Electric Vehicle Clusters

**Author(s):** Liu, T., Wang, P., Peng, Q., Zhang, M., Wang, T., and Meng, J.

**Abstract:** With fast response and strong short-term power throughput capacity, electric vehicles (EVs) are promising to provide primary frequency support to the power grid. However, due to complicated charging demands of drivers, efficient utilization of regulation capacity of EV clusters for providing stable primary frequency support to the power grid is challenging. An adaptive primary frequency support strategy for EV clusters constrained by the charging behavior-defined operation area is proposed in this paper. Firstly, the forced charging boundary of EVs is determined according to the drivers' charging behavior, based on which operation area is defined. It ensures full utilization of available frequency support capacity of EVs. Then, the adaptive primary frequency support strategy of the EV clusters is proposed. The EV output power is adaptively regulated according to the real-time distance from the EV operation point to the forced charging boundary. With the proposed strategy, when the EV approaches the forced charging boundary, its output power gradually decreases to zero. Then, rapid SOC declines of EVs and sudden output power drop of EV clusters caused by forced charging to meet drivers' charging demands can be effectively avoided. With the proposed strategy, the EV clusters can provide sustainable frequency support to the power grid without violating the drivers' charging needs. The simulation results validate the proposed operation area and control strategy, which performs better than the average strategy in terms of stable output maintenance and optimal utilization of EV clusters regulation capacities.

**Subject Areas:** Primary frequency control; Frequency support; Electric vehicle; Vehicle-to-grid; Operation area; Charging behavior

**Availability:** Liu, T., Wang, P., Peng, Q., Zhang, M., Wang, T., and Meng, J. (2023).

“Operation-Area-Constrained Adaptive Primary Frequency Support Strategy for Electric Vehicle Clusters.” *Journal of Modern Power Systems and Clean Energy*, pp. 1–13.

<https://ieeexplore.ieee.org/document/10161594>

## 2.60. Title: Modeling Social Equity in Energy Consumption Using Digital Twins

**Author(s):** Kishore, A., Li, B., and Atweh, J.

**Abstract:** This research examines the impact of social equity on energy consumption. We constructed a digital twin for residential energy consumption by enriching the synthetic population with real-world surveys and feeding them with other environmental and appliance data to the energy modeling framework. We analyzed household hourly energy consumption data from Albemarle County and Charlottesville City in Virginia, USA, for the year 2019. We used clustering analysis to identify patterns in social equity and energy consumption. The results demonstrated the impact of different residential attributes on energy poverty. Statistical analyses, including ANOVA and Chi-squared tests, were conducted to test for significant differences between racial groups in quantitative and categorical variables. The study found that race is significant in determining the location and quality of housing. People of color often live in areas with higher pollution and less access to green spaces. Additionally, income levels and the age of the house are influential factors in determining energy efficiency. Future work should focus on collecting and analyzing data at the country level and using qualitative data collection methods to gain a more comprehensive understanding of social equity issues concerning energy consumption. Overall, this study provides valuable insights into the relationship between different residential attributes and energy consumption, which can inform policy development to promote more equitable and sustainable communities.

**Subject Areas:** Social equity; Residential energy Modeling; Digital twins; Engineering

**Availability:** Kishore, A., Li, B., and Atweh, J. (2023). *Modeling Social Equity in Energy Consumption Using Digital Twins*. Preprint article, Preprints.org, Basel, Switzerland.  
<https://doi.org/10.20944/preprints202306.1890.v1>

## Chapter 3. Environment

### 3.1. Title: Interactions Between U.S. Vehicle Electrification, Climate Change, and Global Agricultural Markets

**Author(s):** Dumortier, J., Carriquiry, M., and Elobeid, A.

**Abstract:** Future agricultural production is influenced by climate change and changes in policies and behavior, such as the proliferation of battery electric vehicles (BEV). For the United States (U.S.), the influence of the latter is more pronounced due to the size of the U.S. biofuel industry. Using a global agricultural trade model and different climate change pathways until 2050, we show that global commodity price increases triggered by declining yields due to climate change are dampened by an accelerated increase of U.S. BEV sales, which decrease maize ethanol demand. Accelerated BEV sales also reduce cropland requirements compared to baseline electrification scenarios. The accelerated market share of BEVs also (1) lowers the decrease in caloric intake for maize, rice, and wheat, which has important food security implications in the presence of climate change and (2) changes trade relationships. The implications of those findings are that policy discussions surrounding policies to promote BEVs should include lower commodity prices and increased food security that dampen some of the negative effects of climate change. Those are additional benefits besides the direct emissions reduction (assuming low- or no-carbon electricity production) from reducing vehicles with internal combustion engines.

**Subject Areas:** Land-use change; Crop yield; International trade; Representative concentration pathway; Shared socioeconomic pathway; Road transportation decarbonization

**Availability:** Dumortier, J., Carriquiry, M., and Elobeid, A. (2022). “Interactions Between U.S. Vehicle Electrification, Climate Change, and Global Agricultural Markets.” *Environmental and Resource Economics*, 84, pp. 99–123. <https://doi.org/10.1007/s10640-022-00716-8>

### 3.2. Title: Quantifying Start Emissions and Impact of Reducing Cold and Warm Starts for Gasoline and Hybrid Vehicles

**Author(s):** Zhai, Z., Xu, J., Zhang, M., Wang, A., and Hatzopoulou, M.

**Abstract:** In this study, a portable emissions measurement system (PEMS) was used to measure trip emissions of a gasoline vehicle (2020 Hyundai Tucson Preferred) and a hybrid vehicle (2020 Ford Fusion Hybrid Titanium) under various soak times (12 h–1 min) along two driving routes in Toronto, Canada (highway and city core). A new method was proposed to identify start emissions in a PEMS test, employing confidence intervals (CIs) of hot-running emission rates, and distributions of hot-running coolant and catalyst temperatures. In addition, GPS data reflecting one week of travel for 82 drivers in Toronto were used to quantify the contributions of start emissions under realistic trip schedules and to estimate the benefits of reducing cold and warm starts. In Toronto, over 95% of the trips have a soak time over 1 h, and over 33% of the trips are within 5 km. Compared to the Tucson, the Fusion Hybrid generates approximately 43.4% less carbon dioxide (CO<sub>2</sub>) and 77.7% less nitrogen oxides (NO<sub>x</sub>), but 183.6% more carbon monoxide (CO) and 15.8% more ultrafine particles (measured in particle number, PN), on a representative Toronto drive schedule. For soak times greater than 12 h and trip distance less than 5 km, the contributions of starts to total trip emissions for CO<sub>2</sub>, CO, NO<sub>x</sub>, and PN are in the ranges of 13.4–70.0%, 93.5–99.9%, 22.3–73.9%, and 80.3–99.3%, respectively, for the Tucson. For the Fusion Hybrid, these contributions are in the ranges of 31.4–95.6%, 25.1–73.2%, 58.7–95.9%, and 25.6–87.7%. With engine and catalyst preheating, total trip emissions for CO<sub>2</sub>, CO, NO<sub>x</sub>, and PN decrease on average by 5.1%, 81.3%, 20.2%, and 48.1%, respectively, for the Tucson. For the Fusion Hybrid, these reductions are 10.4%, 16.3%, 40.8%, and 7.9%.

**Subject Areas:** Start emissions; Soak time; Cold start; Warm start; Hot start; Portable emissions measurement system

**Availability:** Zhai, Z., Xu, J., Zhang, M., Wang, A., and Hatzopoulou, M. (2023). “Quantifying Start Emissions and Impact of Reducing Cold and Warm Starts for Gasoline and Hybrid Vehicles.” *Atmospheric Pollution Research*, 14(1). <https://doi.org/10.1016/j.apr.2022.101646>

**3.3. Title: What Are the Climate, Air Pollution, and Health Benefits of Electric Vehicles?**

**Author(s):** Funke, C., Linn, J., Robson, S., Russell, E., Shawhan, D., and Witkin, S.

**Abstract:** This working paper models the climate and health benefits of plug-in vehicles under five different policy and market scenarios.

**Subject Areas:** Environmental benefits; Health benefits; Plug-in vehicles; Air pollution; Policy

**Availability:** Funke, C., Linn, J., Robson, S., Russell, E., Shawhan, D., and Witkin, S. (2023). *What Are the Climate, Air Pollution, and Health Benefits of Electric Vehicles?* Working Paper, Resources for the Future, Washington, D.C. <https://www.rff.org/publications/working-papers/what-are-the-climate-air-pollution-and-health-benefits-of-electric-vehicles/>

### 3.4. Title: Data Centers on Wheels: Emissions from Computing Onboard Autonomous Vehicles

**Author(s):** Sudhakar, S., Sze, V., and Karaman, S.

**Abstract:** While much attention has been paid to data centers' greenhouse gas emissions, less attention has been paid to autonomous vehicles' (AVs') potential emissions. In this work, we introduce a framework to probabilistically model the emissions from computing onboard a global fleet of AVs and show that the emissions have the potential to make a non-negligible impact on global emissions, comparable to that of all data centers today. Based on current trends, a widespread AV adoption scenario where approximately 95% of all vehicles are autonomous requires computer power to be less than 1.2 kW for emissions from computing and AVs to be less than emissions from all data centers in 2018 in 90% of modeled scenarios. Anticipating a future scenario with high adoption of AVs, business-as-usual decarbonization, and workloads doubling every three years, hardware efficiency must double every 1.1 years for emissions in 2050 to equal 2018 data center emissions. The rate of increase in hardware efficiency needed in many scenarios to contain emissions is faster than the current rate. We discuss several avenues of future research unique to AVs to further analyze and potentially reduce the carbon footprint of AVs.

**Subject Areas:** Data centers emissions; Greenhouse gas emissions; Autonomous vehicles; Carbon footprint; Hardware efficiency; Probabilistic model

**Availability:** Sudhakar, S., Sze, V., and Karaman, S. (2022). "Data Centers on Wheels: Emissions from Computing Onboard Autonomous Vehicles." *IEEE Micro*, 43(1), pp.29–39. <https://doi.org/10.1109/MM.2022.3219803>

### 3.5. Title: A Systematic Review of the Pros and Cons of Digital Pollution and Its Impact on the Environment

**Author(s):** Oo, K.T., Jonah, K., and Thin, M.M.Z.

**Abstract:** Digital technologies are becoming more important in our daily lives. Because of digital technology, our carbon footprint has significantly increased and caused ecological consequences. As gadgets get smaller and have more internal components, there is more trash produced during manufacture. By 2023, more than 70% of the world's population will own a mobile phone. From the start of the COVID-19 pandemic and the numerous ensuing lockdowns, there has been an exponential increase in the use of video transmission (streaming) all over the world. In fact, according to the International Energy Agency (IEA), watching an hour of video streaming on Netflix entails emissions of 36 g CO<sub>2</sub>. Between 2020 and 2030, the overall amount of data transmission will increase fourteen times. Digital technologies can contribute up to 20% to net-zero energy, materials, and mobility reduction required by IEA by 2050. However, there aren't many summaries of the digital transformation of environmental sustainability. This review presents the implications of the digital world on environmental sustainability, including both beneficial and detrimental aspects. Some methods are based on the network and its energy consumption. The outcomes also show how changes in three key areas—waste management and handling, pollution prevention and control, and sustainable resource management—have preserved the environment. The footprints are also significantly smaller than previously predicted. While subscriptions and data traffic have continued to rise, the footprint of the ICT and E&M sectors has shrunk. As countless individuals are used to digital daily life, this study points out the challenges to govern this issue. This review also points out the potential and problems in this field, which tries to provide a vision for future research, based on the literature overview.

**Subject Areas:** Climate change; CO<sub>2</sub> emission; Digital footprint; Digital pollution

**Availability:** Oo, K.T., Jonah, K., and Thin, M.M.Z. (2023). "A Systematic Review of the Pros and Cons of Digital Pollution and Its Impact on the Environment." *Journal of Sustainability and Environmental Management*, 2(1), pp. 61–73. <http://dx.doi.org/10.3126/josem.v2i1.53118>



### 3.6. Title: A Comprehensive Environmental Assessment of Beef Production and Consumption in the United States

**Author(s):** Putman, B., Rotz, C.A., and Thoma, G.

**Abstract:** Life cycle assessments of have been completed documenting the environmental sustainability of beef, but these studies have often focused on specific cattle production systems with an emphasis on global warming potential. A need exists for a national-scale full life cycle assessment of beef production through consumption in the United States. Process level simulation of archetypical cattle production systems throughout the nation were combined with information gathered for harvest, processing, retail, and consumption of beef to provide inventory data for a cradle-to-grave life cycle assessment. A set of 18 environmental impact categories were quantified, and important sources of each were identified. In 13 of the categories, the major sources of impact were related to cattle production, and for 10 of these categories, cattle production and related upstream sources contributed more than half of the total impact. These categories were fine particulate matter, global warming, land use, mineral resource scarcity, ozone formation, stratospheric ozone depletion, terrestrial acidification, and water consumption. Categories where most of the impact occurred post farmgate were fossil resource scarcity, freshwater ecotoxicity, freshwater eutrophication, human carcinogenic toxicity, human non-carcinogenic toxicity, ionizing radiation, marine ecotoxicity, and terrestrial ecotoxicity. Mitigation strategies for reducing these environmental impacts are normally specific to the impact category. Because electricity use is an important contributor to many of the potential impacts throughout the full chain, reducing electricity use is an important mitigation strategy. We evaluated the sensitivity associated with greening of the electric grid in which the Northeast US power grid, which has a larger percentage of renewables, was used as the source of electricity for all systems. The impact remained constant or were reduced in 15 of the 18 impact categories including a 6% reduction in global warming and 22% reduction in particulate matter formation. Another major contributor to all impact categories was food loss and waste. A 50% reduction in food waste, primarily by the consumer, resulted in an across-the-board reduction of approximately 11% in each of the impact categories, which makes food waste reduction one of the most important strategies for improving the environmental sustainability of beef. This assessment provides a current baseline for evaluating mitigation strategies and measuring future improvements in sustainability for the U.S. beef industry.

**Subject Areas:** Beef; Environmental sustainability; Life cycle assessment; Carbon footprint

**Availability:** Putman, B., Rotz, C.A., and Thoma, G. (2023). "A Comprehensive Environmental Assessment of Beef Production and Consumption in the United States." *Journal of Cleaner Production*, 402. <https://doi.org/10.1016/j.jclepro.2023.136766>

### 3.7. Title: Quantifying Disparities in Air Pollution Exposures Across the United States Using Home and Work Addresses

**Author(s):** deSouza, P. et al.

**Abstract:** While human mobility plays a crucial role in determining air pollution exposures and health risks, research to-date has assessed risks based solely on residential location. Here we leveraged a database of ~130 million workers in the US and published PM<sub>2.5</sub> data between 2011 and 2018 to explore how incorporating information on both workplace and residential location changes our understanding of disparities in air pollution exposure. In general, we observed higher workplace exposures (W) relative to home exposures (H), as well as increasing exposures for non-white and less educated workers relative to the national average. Workplace exposure disparities were higher among racial and ethnic groups and job types than by income, education, age, and sex. Not considering workplace exposures can lead to systematic underestimations in disparities to exposure among these subpopulations. We also quantified the error in assigning workers H, instead of a weighted home-and-work (HW) exposure. We observed that biases in associations between PM<sub>2.5</sub> and health impacts by using H instead of HW were highest among urban, younger populations.

**Subject Areas:** Air pollution; Environmental justice; Mobility; Epidemiology; Bias

**Availability:** deSouza, P. et al. (2023). *Quantifying Disparities in Air Pollution Exposures Across the United States Using Home and Work Addresses*. arXiv preprint, arXiv:2303.12559v1 [stat.AP]. <https://doi.org/10.48550/arXiv.2303.12559>

### 3.8. Title: Environmental Impacts of Shared Mobility: Potential, Factors, and Assessments

**Author(s):** Arbelaez Velez, A.M.

**Abstract:** Environmental impacts from passenger transportation continue to increase globally due to a rise in kilometers traveled and a shift to emission-intensive environmental impacts from passenger transportation continue to increase globally due to a rise in kilometers traveled and a shift to emission-intensive transportation modes (from public transportation and active modes such as walking and cycling to motorcycle and car ridership). The electrification of the passenger fleet, coupled with low-carbon energy sources, is expected to decrease some of the environmental impacts associated with passenger transportation, including local air pollution, greenhouse gas emissions, and fuel depletion. However, different environmental impacts might increase due to this shift, including rare metal depletion and increased pressure on the already-overloaded electrical grid in some parts of the world. Moreover, this shift does not address the increase in transportation activity and the shift to more emission-intensive transportation modes.

Shared mobility is a demand-side mechanism that has the potential to change travel behavior and vehicle ownership rates among users. This dissertation aims to understand the potential of shared mobility to decrease the environmental impacts of passenger transportation and to understand the factors that might affect this potential. Here I focus on car sharing, with additional attention to ridesharing, bikesharing, and scooter and moped sharing. In this research I design and apply assessments using life-cycle analysis and multiregional input and output analysis to evaluate the environmental potential of shared mobility. My findings add to our knowledge and understanding of the potential of shared mobility. This study also adds to environmental assessments methods by applying multiregional input and output analysis in a novel way.

Changes in both travel behavior and expenditures influenced the impacts of car sharing. Greenhouse gas (GHG) emissions from passenger transportation may either decrease or increase after people engage in car sharing. People who give up private vehicle ownership and shift to active, public, and shared transportation decrease their emissions, while people who increase their solo driving increase them. Changes in travel behavior affect the way people spend their income: for example, decreasing spending on fuel, insurance, and maintenance while increasing consumption of other products and services. These changes in spending are related to rebound effects that have the potential to decrease reductions in GHG due to car sharing by 71–80%.

The potential of car sharing to decrease the environmental impacts of passenger transportation is also affected by how it was designed and implemented. Differences in ownership models—i.e., whether shared cars are owned by a company or individuals—are found to have a limited influence on GHG emissions.

The specific context of a car sharing system will determine the best form of implementation and its transformational potential. Contextual factors include variables such as the robustness of public transportation networks, cyclist and pedestrian safety, and the availability of charging infrastructure. Car sharing can be a tool to drive a shift away from car ownership; however, countries that have a higher share of public and active transportation users are more likely to

witness a shift away from car ownership with the incorporation of car sharing than countries that have high rates of car ownership and use.

This study suggests that shared mobility does not, by default, lead to a decrease in the environmental impacts from passenger transportation. It instead suggests that shared mobility needs to be designed, implemented, and used in a certain way in order to achieve this goal. Shared mobility might be implemented in several contexts as one of several tools to reduce environmental impacts from passenger transportation, and in this work I find that a combination of several tools has the greatest potential to achieve such a reduction

**Subject Areas:** Shared mobility; Environmental impacts; Sustainable transportation; Input and output analysis; Lifecycle assessment; Transportation assessment; Demand-side solutions

**Availability:** Arbelaez Velez, A.M. (2023). *Environmental Impacts of Shared Mobility: Potential, Factors, and Assessments*. Doctoral Dissertation, Lund University, Sweden.  
[https://lucris.lub.lu.se/ws/portalfiles/portal/146652317/Avhandling\\_Ana\\_Mar\\_a\\_Arbel\\_ez\\_V\\_lez\\_ut%C3%A5n\\_papers.pdf](https://lucris.lub.lu.se/ws/portalfiles/portal/146652317/Avhandling_Ana_Mar_a_Arbel_ez_V_lez_ut%C3%A5n_papers.pdf)

### 3.9. Title: The Environmental Cost of Shopping: A Comparison Between Online and In-Person Shopping

**Author(s):** Joly, E.

**Abstract:** Over the past twenty years, online shopping has grown in popularity as more and more companies began expanding their business online. A common belief is that online shopping is an environmentally friendly substitute for in-person shopping because consumers stop taking individual shopping trips. This paper challenges this substitution assumption. I also investigate how consumers' gas consumption patterns vary according to their shopping practices and interpret those results from a sustainability point of view. The shopping behavior correlated with a decrease in gas consumption, and therefore a reduction in greenhouse gas emissions, will be ruled as the more environmentally responsible practice from a consumer point of view. Using the National Household Travel Survey data set from 2017, I investigated the sociodemographic characteristics of in-person shoppers. I also analyzed the relationship between the number of shopping trips, number of deliveries, and total gas consumption. I find evidence that online shoppers keep practicing in-person shopping, meaning that both practices are complementary. I also find evidence that online shopping decreases gas expenditure, which means that from a gas consumption and consumer point of view, online shopping is better for the environment, but this conclusion needs to be interpreted with caution.

**Subject Areas:** Online shopping; In-person shopping; Gas consumption; Greenhouse gas emissions; Environment

**Availability:** Joly, E. (2023). *The Environmental Cost of Shopping: A Comparison Between Online and In-Person Shopping*. Senior Honors Project, Antonian Scholars Honors Program, St. Catherine University, Saint Paul, MN. [https://sophia.stkate.edu/shas\\_honors/74](https://sophia.stkate.edu/shas_honors/74)

### **3.10. Title: The Hidden Economic and Environmental Costs of Eliminating Kerb-Side Recycling**

**Author(s):** Anshassi, M. and Townsend, T.G.

**Abstract:** Local governments provide household collection of garbage and recyclables on a routine schedule, and these recycling programmes represent the most visible opportunity for everyday citizens to engage in sustainable practices. In the face of unprecedented challenges, and citing costs as the major driver, many US communities are shrinking or eliminating kerb-side recycling. Here we show that when recycling commodity markets were most lucrative in 2011, net US recycling costs were as little as US\$3 per household annually, and when markets reached a minimum (in 2018–2020), the annual recycling-programme costs ranged from US\$34 to US\$42 per household. This investment offsets the greenhouse gas emissions from non-recycled household waste buried in landfills. If local governments restructure recycling programmes to target higher value and embodied carbon-intensive materials, recycling can pay for itself and reduce greenhouse gas emissions. Our analysis highlights that kerb-side recycling provides communities a return on investment similar to or better than climate change mitigation strategies such as voluntary green power purchases and transitioning to electric vehicles. Eliminating recycling squanders one of the easiest opportunities for communities and citizens to mitigate climate change and reduce natural resources demands.

**Subject Areas:** Climate-change mitigation; Governance

**Availability:** Anshassi, M. and Townsend, T.G. (2023). “The Hidden Economic and Environmental Costs of Eliminating Kerb-Side Recycling.” *Nature Sustainability*. <https://doi.org/10.1038/s41893-023-01122-8>

### 3.11. Title: Essays on Environmental Policies in the Transportation Sector

**Author(s):** Zhou, H.

**Abstract:** This dissertation consists of three essays studying the effects of environmental regulations and policies in the transportation sector in China.

The first chapter studies the effectiveness, efficiency, and distributional effect of using trade restrictions on used vehicles to protect the local environment. Leveraging comprehensive data on the bilateral trade of vehicles across Chinese prefecture cities and the staggered rollout of import restrictions on used vehicles implemented by city governments from 2013 to 2015, this chapter shows empirical evidence that import restrictions reduce net imports of used vehicles, and cities' import restrictions are strategic complements. With a multi-sector multi-region structural trade model, this study shows that unilaterally restricting imports of used vehicles leads to welfare trade-offs between economic losses vs. environmental benefits. Restricting heavy-polluting vehicles makes some cities better off, especially lower-income cities. However, decentralized restrictions are socially inefficient due to strategic interactions, and the effectiveness and efficiency of using import restrictions as an environmental instrument are limited compared to emission taxes. The second chapter, joint with Jie Bai, Danxia Xie, and Shanjun Li, explores the import restrictions on used vehicles in China from the perspective of local protectionism. Leveraging the universe of new and used vehicle registration/sales data and the staggered removal of the restrictions across cities from 2016 to 2018, this analysis shows that the removal of restrictions led to a sharp increase in the cross-city flow of used vehicles but had no significant impacts on local air quality in the short run. Interestingly, the new vehicle market points to a prisoner's dilemma among city governments: A unilateral removal of the policy would reduce new vehicle sales in a city but increase new vehicle sales in other cities. The effect is stronger in cities with a large automobile industry. The findings highlight alternative motives behind local environmental regulations and the need for coordinated efforts at the national level. The third chapter, joint with Shanjun Li, Xianglei Zhu, Yiding Ma, and Fan Zhang, examines the effectiveness of various policy measures that underlie the rapid development of the EV market in China, based on detailed data on EV sales, local and central government incentive programs, and charging stations in 150 cities from 2015 to 2018. This research finds that consumer subsidies for vehicle purchases accounted for more than half of EV sales in China. Nevertheless, investments in charging infrastructure were much more cost-effective than consumer subsidies. An inexpensive policy that merely provided EVs with a distinctive, green license plate was strikingly effective. These findings demonstrate the varying efficacy of different policy instruments and highlight the critical role of the government in promoting clean technologies.

**Subject Areas:** Environmental regulations and policies; Transportation sector; Vehicle usage; Electric vehicles market

**Availability:** Zhou, H. (2023). *Essays on Environmental Policies in the Transportation Sector*. Doctoral Dissertation, Cornell University, Ithaca, NY.

<https://www.proquest.com/openview/dbd6f5766a897c9966bb7121b28846cc/1?pq-origsite=gscholar&cbl=18750&diss=y>

### 3.12. Title: A Comparative Analysis of Carbon Emissions of Grocery Pickup and Delivery in Urban and Rural Regions

**Author(s):** Huang, L.

**Abstract:** The majority of life cycle studies on E-commerce indicate that direct-to-consumer delivery models tend to have lower environmental impacts than traditional retail; however, most studies contain assumptions associated with relatively high population densities, rather than rural consumption patterns. This study quantifies the greenhouse gas (GHG) emission differences between grocery pickup and grocery delivery in urban and rural areas comparing multiple operational logistics scenarios. The study's results showed that grocery E-commerce has lower GHG emissions in both urban and rural areas compared with brick and mortar (14–55% GHG and 15–52% GHG improvement), but the overall values of urban grocery shopping are lower than rural grocery shopping with moderate difference (116 Kg GHG/wk vs. 122.2 Kg GHG/wk). In addition, E-commerce that involves delivering directly from a distribution center has greater benefits than E-commerce models that involve a physical store (110.5–115.6 Kg GHG/wk vs. 114.9–120 Kg GHG/wk). If the availability and convenience of grocery delivery increases the frequency of grocery shopping, the overall GHG benefits of E-commerce will likely be reduced. Although the study showed substantial variation in last-mile emissions across the scenarios analyzed, delivery method is significantly less important than the embodied emissions of food and food waste of groceries (6–8% downstream vs 34–38% food and 24–27% food waste). Any induced changes to food consumption patterns resulting from E-commerce will likely have a much greater effect on the impacts of the food system than any last-mile differences.

**Subject Areas:** Grocery e-commerce; Greenhouse gas emission; Last-mile emissions; Food consumption patterns; Urban and rural areas

**Availability:** Huang, L. (2023). *A Comparative Analysis of Carbon Emissions of Grocery Pickup and Delivery in Urban and Rural Regions*. Master's Thesis, University of Michigan, Ann Arbor, MI. <https://dx.doi.org/10.7302/7127>



### **3.13. Title: Integration of Consumer Preferences into Dynamic Life Cycle Assessment for the Sharing Economy: Methodology and Case Study for Shared Mobility**

**Author(s):** Fernando, C., Buttriss, G., Yoon, H.-J., Soo, V.K., Compston, P., and Doolan, M.

**Abstract: Purpose:** The rising of the sharing economy (SE) has lowered the barrier of purchase price to accessing many different products, thus changing the consumer decision paradigm. This paper addresses the challenge of assessing the life cycle impacts of SE systems in the context of this new consumer decision-making process. The paper proposes a methodological framework to integrate consumer preferences into the Dynamic Life Cycle Assessment (dynamic-LCA) of SE systems.

**Methods:** In the proposed consumer preference integrated dynamic-LCA (C-DLCA) methodological framework, system dynamics (SD) is used to combine consumer preference and the principal method, dynamic-LCA, which follows the ISO 14040 LCA framework. Choice-based conjoint analysis (CBCA) is chosen as the stated preference tool to measure consumer preference based on SE alternatives, attributes, and attribute levels. CBCA integrates discrete choice experiments (DCE) and conjoint analysis features. Random utility theory is selected to interpret the CBCA results by employing multinomial logistics as the estimation procedure to derive the utilities. Derived utilities are connected in iterative modelling in the SD and LCA. Dynamic-LCA results are determined based on dynamic process inventory and DCE outcomes and then interpreted aligned with the SD policy scenarios.

**Results and Discussion:** The C-DLCA framework is applied to assess the GHG changes of the transition to car-based shared mobility in roundtrips to work in the USA. Carpooling and ridesourcing are selected as the shared mobility alternatives based on different occupancy behaviours. Powertrain system and body style are employed as the fleet technology attributes and the latter as an endogenous variable. Dynamic-LCA results are generated considering the high battery electrical vehicle (BEV) adoption as the policy scenario, and results are measured against a service-based functional unit, passenger-kilometre. The model outcomes show a significant reduction in aggregated personal mobility-related dynamic-GHG emissions by transitioning to car-based shared mobility. In contrast to the use phase GHG emissions, the production phase emissions show an increase. The results highlight the importance of integrating consumer preference and temporality in the SE environmental assessments.

**Conclusions:** The proposed C-DLCA framework is the first approach to combine consumer preferences, SD and LCA in a single formulation. The structured and practical integration of conjoint analysis, SD and LCA methods added some standardisation to the dynamic-LCAs of the SE systems, and the applicability is demonstrated. The C-DLCA framework is a fundamental structure to connect consumer preferences and temporal effects in LCAs that is expandable based on research scope.

**Subject Areas:** Dynamic life cycle assessment; Consumer preference; Sharing economy; System dynamics; Consumer preferences

**Availability:** Fernando, C., Buttriss, G., Yoon, H.-J., Soo, V.K., Compston, P., and Doolan, M. (2023). “Integration of Consumer Preferences into Dynamic Life Cycle Assessment for the Sharing Economy: Methodology and Case Study for Shared Mobility.” *The International Journal of Life Cycle Assessment*, 28, pp. 429–461. <https://doi.org/10.1007/s11367-023-02148-y>

## Chapter 4. Health

### 4.1. Title: Analyzing the Spatial Equity of Walking-Based Chronic Disease Pharmacies: A Case Study in Wuhan, China

**Author(s):** Liu, Y., Su, Y., and Li, X.

**Abstract:** Chronic diseases place a substantial financial burden on both the patient and the state. As chronic diseases become increasingly prevalent with urbanization and aging, primary chronic disease pharmacies should be planned to ensure that patients receive an equitable distribution of resources. Here, the spatial equity of chronic disease pharmacies is investigated. In this study, planning radiuses and Web mapping are used to assess the walkability and accessibility of planned chronic disease pharmacies; Lorenz curves are used to evaluate the match between the service area of the pharmacies and population; location quotients are used to identify the spatial differences of the allocation of chronic disease pharmacies based on residents. Results show that chronic disease pharmacies have a planned service coverage of 38.09%, an overlap rate of 58.34%, and actual service coverage of 28.05% in Wuhan. Specifically, chronic disease pharmacies are spatially dispersed inconsistently with the population, especially the elderly. The allocation of chronic disease pharmacies is directly related to the standard of patients' livelihood. Despite this, urban development does not adequately address this group's equity in access to medication. Based on a case study in Wuhan, China, this study aims to fill this gap by investigating the spatial equity of chronic disease medication purchases.

**Subject Areas:** Spatial equity; Primary healthcare; Walking accessibility; 15-min city

**Availability:** Liu, Y., Su, Y., and Li, X. (2023). "Analyzing the Spatial Equity of Walking-Based Chronic Disease Pharmacies: A Case Study in Wuhan, China." *International Journal of Environmental Research and Public Health*, 20(1). <https://doi.org/10.3390/ijerph20010278>

#### 4.2. Title: Modeling Virus Transmission Risks in Commuting with Emerging Mobility Services: A Case Study of COVID-19

**Author(s):** Mo, B., Noursalehi, P., Koutsopoulos, H.N., and Zhao, J.

**Abstract:** Commuting is an important part of daily life. With the gradual recovery from COVID-19 and more people returning to work from the office, the transmission of COVID-19 during commuting becomes a concern. Recent emerging mobility services (such as ride-hailing and bike-sharing) further deteriorate the infection risks due to shared vehicles or spaces during travel. Hence, it is important to quantify the infection risks in commuting. This paper proposes a probabilistic framework to estimate the risk of infection during an individual's commute considering different travel modes, including public transit, ride-share, bike, and walking. The objective is to evaluate the probability of infection as well as the estimation errors (i.e., uncertainty quantification) given the origin-destination (OD), departure time, and travel mode. We first define a general trip planning function to generate trip trajectories and probabilities of choosing different paths according to the OD, departure time, and travel mode. Then, we consider two channels of infections: 1) infection by close contact and 2) infection by touching surfaces. The infection risks are calculated on a trip segment basis. Different sources of data (such as smart card data, travel surveys, and population data) are used to estimate the potential interactions between the individual and the infectious environment. A first-order approximation is used to simplify the computational complexity. We also derive the closed-form formulation for the estimation errors, enabling us to quantify the uncertainty of the estimation results. The model is implemented in the MIT community as a case study. We evaluate the commute infection risks for employees and students. Results show that most of the individuals have an infection probability close to zero. The maximum infection probability is around 0.8%, implying that the probability of getting infected during the commuting process is low. Individuals with larger travel distances, traveling in transit, and traveling during peak hours are more likely to get infected. Practical implementations of the model are also discussed.

**Subject Areas:** COVID-19; Infection risk; Emerging mobility

**Availability:** Mo, B., Noursalehi, P., Koutsopoulos, H.N., and Zhao, J. (2023). *Modeling Virus Transmission Risks in Commuting with Emerging Mobility Services: A Case Study of COVID-19*. arXiv preprint, arXiv:2301.02594v1 [stat.AP]. <https://doi.org/10.48550/arXiv.2301.02594>

#### 4.3. Title: COVID and Cities, Thus Far

**Author(s):** Duranton, G. and Handbury, J.

**Abstract:** A key reason for the existence of cities are the externalities created when people cluster together in proximity. During COVID, such interactions became with health risks and people found other ways to interact. We document how cities changed during COVID and consider how the persistence of these new ways of interacting—particularly remote work—will shape the development of cities in the future. We first summarize evidence showing how residential and commercial prices and activity adjusted at different distances from dense city centers during and since the pandemic. We use a textbook monocentric city model to demonstrate that two adjustments associated with remote work—reduced commuting times and increased housing demand—generate the patterns observed in the data. We then consider how these effects might be magnified by changes in urban amenities and agglomeration forces and what such forces might mean for the future of cities.

**Subject Areas:** Cities; Covid; Monocentric model; Endogenous amenities; Agglomeration effects

**Availability:** Duranton, G. and Handbury, J. (2023). *COVID and Cities, Thus Far*. Authors' Manuscript, University of Pennsylvania, Philadelphia, PA.  
[http://www.jessiehandbury.com/papers/Cities\\_and\\_covid.pdf](http://www.jessiehandbury.com/papers/Cities_and_covid.pdf)

#### 4.4. Title: Factors Associated with Delaying Medical Care: Cross-Sectional Study of Nebraska Adults

**Author(s):** Ratnapradipa, K.L., Jadhav, S., Kabayundo, J., Wang, H., and Smith, L.C.

**Abstract: Background:** Delayed medical care may result in adverse health outcomes and increased cost. Our purpose was to identify factors associated with delayed medical care in a primarily rural state.

**Methods:** Using a stratified random sample of 5,300 Nebraska households, we conducted a cross-sectional mailed survey with online response option (27 October 2020 to 8 March 2021) in English and Spanish. Multiple logistic regression models calculated adjusted odds ratios (aORs) and 95% confidence intervals.

**Results:** The overall response rate was 20.8% ( $n = 1,101$ ). Approximately 37.8% of Nebraskans ever delayed healthcare (cost-related 29.7%, transportation-related 3.7%), with 22.7% delaying care in the past year (10.1% cost-related). Cost-related ever delay was associated with younger age [ $< 45$  years aOR 6.17 (3.24–11.76); 45–64 years aOR 2.36 (1.29–4.32)], low- and middle-income [ $< \$50,000$  aOR 2.85 (1.32–6.11);  $\$50,000$ – $\$74,999$  aOR 3.06 (1.50–6.23)], and no health insurance [aOR 3.56 (1.21–10.49)]. Transportation delays were associated with being non-White [aOR 8.07 (1.54–42.20)], no bachelor's degree [ $\leq$  high school aOR 3.06 (1.02–9.18); some college aOR 4.16 (1.32–13.12)], and income  $< \$50,000$  [aOR 8.44 (2.18–32.63)]. Those who did not have a primary care provider were 80% less likely to have transportation delays [aOR 0.20 (0.05–0.80)].

**Conclusions:** Delayed care affects more than one-third of Nebraskans, primarily due to financial concerns, and impacting low- and middle-income families. Transportation-related delays are associated with more indicators of low socio-economic status. Policies targeting minorities and those with low- and middle-income, such as Medicaid expansion, would contribute to addressing disparities resulting from delayed care.

**Subject Areas:** Health care costs; Transportation; Healthcare utilization; Healthcare delays; Access to care; Rural setting; COVID

**Availability:** Ratnapradipa, K.L., Jadhav, S., Kabayundo, J., Wang, H., and Smith, L.C. (2023). "Factors Associated with Delaying Medical Care: Cross-Sectional Study of Nebraska Adults." *BMC Health Services Research*, 23. <https://doi.org/10.1186/s12913-023-09140-0>

#### 4.5. Title: Evaluating Spatial and Temporal Patterns of Tick Exposure in the United States Using Community Science Data Submitted Through a Smartphone Application

**Author(s):** Kache, P.A. et al.

**Abstract:** Research initiatives that engage the public (i.e., community science or citizen science) increasingly provide insights into tick exposures in the United States. However, these data have important caveats, particularly with respect to reported travel history and tick identification. Here, we assessed whether a smartphone application, The Tick App, provides reliable and novel insights into tick exposures across three domains—travel history, broad spatial and temporal patterns of species-specific encounters, and tick identification. During 2019–2021, we received 11,424 tick encounter submissions from across the United States, with nearly all generated in the Midwest and Northeast regions. Encounters were predominantly with human hosts (71%), although one-fourth of ticks were found on animals. Half of the encounters (51%) consisted of self-reported peri-domestic exposures, while 37% consisted of self-reported recreational exposures. Using phone-based location services, we detected differences in travel history outside of the users' county of residence along an urbanicity gradient. Approximately 75% of users from large metropolitan and rural counties had traveled out of county in the four days prior to tick detection, whereas an estimated 50–60% of users from smaller metropolitan areas did. Furthermore, we generated tick encounter maps for *Dermacentor variabilis* and *Ixodes scapularis* that partially accounted for travel history and overall mirrored previously published species distributions. Finally, we evaluated whether a streamlined three-question sequence (on tick size, feeding status, and color) would inform a simple algorithm to optimize image-based tick identification. Visual aids of tick coloration and size engaged and guided users toward species and life stage classification moderately well, with 56% of one-time submitters correctly selecting photos of *D. variabilis* adults and 76% of frequent-submitters correctly selecting photos of *D. variabilis* adults. Together, these results indicate the importance of bolstering the use of smartphone applications to engage community scientists and complement other active and passive tick surveillance systems.

**Subject Areas:** Ticks; Tick encounters; Tick surveillance; Community science; Citizen science; Mobile app

**Availability:** Kache, P.A. et al. (2023). "Evaluating Spatial and Temporal Patterns of Tick Exposure in the United States Using Community Science Data Submitted Through a Smartphone Application." *Ticks and Tick-Borne Diseases*, 14(4). <https://doi.org/10.1016/j.ttbdis.2023.102163>

#### 4.6. Title: Associating, Understanding, and Measuring Environment and Physical Activity with Youth Health

**Author(s):** Yang, J.

**Abstract:** With the development of the economy, technology, and urbanization, the level of physical inactivity increased among people. Especially for the youth, the heavy schoolwork and the lack of awareness and investment in physical activity opportunities could affect their growth and health literacy for long-lasting healthy and active lifestyles. Access to a safe and enabling environment could bring diverse opportunities for youth to be physically active. To better understand the influence of the physical activity (PA) environment on youth, this dissertation will associate, understand, and measure the relationship in environments, PA, and youth health using GIScience, statistical and text mining methods.

The dissertation was conducted in three separate but related studies. We first integrated school surrounding environments and youth health study to investigate the spatial correlation between environmental factors and school youth's fitness outcome based on the elementary school attendance zone (ESAZ). The finding indicates that the inside-school PA environment is highly associated with youth health outcomes; also, the park and terrain indicate strong local geographic variation in youth health. The second study highlights the park-based variables to further understand the outside school and outdoor activity for the youth. We collected online review data to quantify how public perception and expectations change in various environments toward youth play in parks using GIS methods and text mining analysis. The results show that overall neutral public perception and expectation of the youth activity in the park. Also, the results demonstrate that the popularity of the discussion topic varies in the environmental settings. Lastly, a Physical activity Access Disparity (PAD) index was proposed to measure and map environments and PA for youth. We adopted five dimensions of "access" from healthcare to design and construct the youth PAD index. These five dimensions are Accessibility, Availability, Accommodation, Affordability, and Acceptability (5 A's). The result identifies "play oases" and "play deserts" in the US and Georgia by diverse 5 A's combinations.

The results from this dissertation bring diverse aspects to analyzing the environment and youth physical activity research using GIScience methods. Future researchers and policymakers could follow and customize the framework by incorporating their preferences and specific scenarios.

**Subject Areas:** GIScience; Youth; Physical activity; Environment; Disparity

**Availability:** Yang, J. (2023). *Associating, Understanding, and Measuring Environment and Physical Activity with Youth Health*. Doctoral Dissertation, The University of Georgia, Athens, GA. [https://esploro.lib.uga.edu/esploro/fulltext/doctoral/ASSOCIATING-UNDERSTANDING-AND-MEASURING-ENVIRONMENT-AND/9949558728502959?repId=12718425170002959&mId=13718425160002959&institution=01GALI\\_UGA](https://esploro.lib.uga.edu/esploro/fulltext/doctoral/ASSOCIATING-UNDERSTANDING-AND-MEASURING-ENVIRONMENT-AND/9949558728502959?repId=12718425170002959&mId=13718425160002959&institution=01GALI_UGA)



#### 4.7. Title: Travel for Medical or Dental Care by Race/Ethnicity and Rurality in the U.S.: Findings from the 2001, 2009 and 2017 National Household Surveys

**Author(s):** Akinlotan, M., Khodakarami, N., Primm, K., Bolin, J., and Ferdinand, A.O.

**Abstract:** The travel burden for medical or dental care is a well-documented barrier to healthcare access, particularly in rural areas. There is limited research providing national estimates of the travel trends for medical/dental care, particularly among racial/ethnic groups, and among rural and urban populations. We analyzed data from the 2001, 2009, and 2017 National Household Travel Surveys. Main outcomes were the average travel distance (in miles), average travel time (in minutes), and travel burden, characterized as the percentage of trips lasting  $\geq 30$  miles or minutes for medical/dental care. We used ordinary least squares and multivariable logistic regressions to examine trends in the travel time/distance and travel burden, controlling for socio-demographic and travel dynamics. Among rural residents, the average travel distance for medical/dental care increased by 17.8% between 2001 and 2017, while no increase was observed among urban residents. Thirty-six percent of trips among rural residents lasted  $\geq 30$  minutes in 2001 but increased to 47.4% in 2017. Logistic regression estimates show that though Blacks experienced higher odds of a travel time burden compared to Whites, the burden lessened over time. In 2017, urban Blacks (OR = 0.41; [95% CI: (0.26, 0.66)]), and rural Blacks (OR = 0.16; [95% CI: (0.05, 0.55)]) were less likely to spend  $\geq 30$  minutes traveling for medical/dental care compared to Whites, using the year 2001 as the baseline. The travel distance and time for medical/dental care have increased in rural areas. However, the travel burden among rural and urban Black residents has decreased. Continuing to alleviate excess burdens of transportation may be beneficial.

**Subject Areas:** Travel; Rural Health Services; Rural Population; Hispanic or Latino; African American; Urban Population

**Availability:** Akinlotan, M., Khodakarami, N., Primm, K., Bolin, J., and Ferdinand, A.O. (2023). "Travel for Medical or Dental Care by Race/Ethnicity and Rurality in the U.S.: Findings from the 2001, 2009 and 2017 National Household Surveys." *Preventive Medicine Reports*. <https://doi.org/10.1016/j.pmedr.2023.102297>

## Chapter 5. Policy and Mobility

### 5.1. Title: Understanding Mobility Change in Response to COVID-19: A Los Angeles Case Study

**Author(s):** Lu, Y. and Giuliano, G.

**Abstract:** The COVID-19 pandemic has affected people's lives throughout the world. Governments have imposed restrictions on business and social activities to reduce the spread of the virus. In the US, the pandemic response has been largely left to state and local governments, resulting in a patchwork of policies that frequently changed. We examine travel behavior across income and race/ethnic groups in Los Angeles County over several stages of the pandemic. We use a difference-in-difference model based on mobile device data to compare mobility patterns before and during the various stages of the pandemic. We find a strong relationship between income/ethnicity and mobility. Residents of low-income and ethnic minority neighborhoods reduced travel less than residents of middle- and high-income neighborhoods during the shelter-in-place order, consistent with having to travel for work or other essential purposes. As public health rules were relaxed and COVID vaccines became available, residents of high-income and White neighborhoods increased travel more than other groups, suggesting more discretionary travel. Our trip purpose model results show that residents of low-income and ethnic minority neighborhoods reduced work and shopping travel less than those of White and high-income neighborhoods during the shelter-in-place order. Results are consistent with higher-income workers more likely being able to work at home than lower-income workers. In contrast, low-income/minorities apparently have more constraints associated with work or household care. The consequence is less capacity to avoid virus risk. Race and socioeconomic disparities are revealed in mobility patterns observed during the COVID-19 pandemic.

**Subject Areas:** COVID-19; Mobility; Race/ethnicity; Income

**Availability:** Lu, Y. and Giuliano, G. (2023). "Understanding Mobility Change in Response to COVID-19: A Los Angeles Case Study." *Travel Behaviour and Society*, 31, pp. 189–201.

<https://doi.org/10.1016/j.tbs.2022.11.011>

## 5.2. Title: **Mobility Justice in Rural California: Examining Transportation Barriers and Adaptations in Carless Households**

**Author(s):** Barajas, J.M. and Wang, W.

**Abstract:** This report describes the scope and scale of car access in rural areas, identifies barriers that rural zero-car and car-deficit households face in their mobility and access, and proposes personal and policy-level adaptations that would help these households achieve their mobility and access needs using descriptive analysis from US census microdata and interviews with 22 residents of California’s Central Valley. Results indicate that 5% of rural residents are fully carless and 18% live in a car-deficit household with less than one vehicle per adult. Both zero-car and car-deficit households tend to be in the Central Valley. Zero-car and car-deficit households in rural areas tend to be more socioeconomically disadvantaged than in nonrural areas. Both groups earn lower household incomes; are more likely to be Black, Latino, or Asian; have lower educational attainment; have more disabilities; have higher housing-cost burdens; and are more likely to be unemployed than their counterparts in nonrural areas. Almost half of workers in rural zero-car households drive alone to work compared to about a quarter in nonrural zero-car households, while mode shares are similar for car-deficit and car fully equipped households. Rural zero-car households are more likely to carpool and far less likely to take public transit. Three major themes emerged from the interviews. First, a commonality uniting the interview participants was the practice of relying on their social networks to get rides or obtain vehicle access. Second, the cost of car ownership and operation was high, placing vehicles out of reach for many. Third, alternatives to car access included public transit, medical transportation services, and car sharing, but poor availability often caused individuals to forgo trips. Interview participants shared a variety of options they saw as solutions to overcoming their barriers to lack of car access. While obtaining a vehicle was not absent from their preferred solutions, most preferred better personal access to transportation without the burden of private car ownership. The findings demonstrate some of the complexities to consider when addressing transportation barriers in rural areas, where carlessness is less prevalent but solutions may be harder to implement than in urban areas.

**Subject Areas:** Rural transportation; Mobility justice; Zero-car households; Vehicle access

**Availability:** Barajas, J.M. and Wang, W. (2023). *Mobility Justice in Rural California: Examining Transportation Barriers and Adaptations in Carless Households*. Final Report, UCD-ITS-RR-22-116, University of California, Davis, CA. <https://doi.org/10.7922/G2X928NC>

**5.3. Title: Assessing Impacts of the Built Environment on Mobility: A Joint Choice Model of Travel Mode and Duration**

**Author(s):** Yang, Y., Samaranayake, S., and Dogan, T.

**Abstract:** This paper introduces a joint choice model for travel mode and duration to quantify the mobility impacts of urban design changes on the built environment. The model is formulated as a Random Forest classifier that predicts the mode-duration probabilities of a given trip. A novel series of predictor features are proposed that measure the urban form, demographics, and service densities on different scales of the transportation network. Through a sensitivity analysis and a proof-of-concept case study, we find that a dense, mixed-use environment with good coverage of a multi-modal mobility network can significantly promote active transportation and public transit use. However, we also find that ultra-dense, centralized developments can lead to increased travel time and increased vehicle use in the urban periphery. Our modeling and analysis method provides a simplified and effective way to assess urban design and planning scenarios from different mobility perspectives and facilitates data-driven, mobility-aware urban design and planning that can help identify better solutions more quickly.

**Subject Areas:** Joint choice model; Mobility; Urban design; Built environment; Random Forest; Travel mode; Trip duration

**Availability:** Yang, Y., Samaranayake, S., and Dogan, T. (2023). “Assessing Impacts of the Built Environment on Mobility: A Joint Choice Model of Travel Mode and Duration.” *Environment and Planning B: Urban Analytics and City Science*. <https://doi.org/10.1177/23998083231154263>

#### 5.4. Title: Modelling the Variation in the Mobility Pattern of Households in the Urban and Rural Areas of Nigeria

**Author(s):** Aderibigbe, O.-O. and Gumbo, T.

**Abstract:** There is evidence that rural areas are disadvantaged in mobility compared to urban areas. Hence, this study examined spatial variation in the travel pattern of households in urban and rural areas of Nigeria. This study used primary data obtained through questionnaire administration on household heads in the residential zones of both urban and rural areas studied, using the multi-stage sampling technique. Findings revealed that variations exist for age, education level, income level, and occupation in urban and rural areas, and household's average daily mean trip frequency showed a level of fewer trips being generated in the rural area than those in the urban area. Furthermore, the result of the stepwise multiple regression analysis showed that transport mode, household size, number of workers in the house, and occupation of household head were significant variables influencing trip making in urban areas while age, household size, the income of household head and number of employed people were significant in the rural areas. This study concludes that differences exist in the mobility pattern of urban and rural households, and as such, equal consideration and attention should be given to them in policy formulations.

**Subject Areas:** Trip generation; Socio-economic characteristics; Mobility; Urban; Rural

**Availability:** Aderibigbe, O.-O. and Gumbo, T. (2022). "Modelling the Variation in the Mobility Pattern of Households in the Urban and Rural Areas of Nigeria." *Scientific Journal of Silesian University of Technology. Series Transport*, 117, pp. 5–21.  
<https://doi.org/10.20858/sjsutst.2022.117.1>

**5.5. Title: Opinion: Induced Travel Demand Induces Media Attention**

**Author(s):** Polzin, S.

**Abstract:** Blog.

**Subject Areas:** Mobility; Congestion; Travel growth; Roadway capacity; Public transit; Induced demand; Road expansion; Planning

**Availability:** Polzin, S. (2023). "Opinion: Induced Travel Demand Induces Media Attention." *Planetizen*. <https://www.planetizen.com/blogs/121801-opinion-induced-travel-demand-induces-media-attention>

**5.6. Title: A Clustering-Based Approach to Quantifying Socio-Demographic Impacts on Urban Mobility Patterns**

**Author(s):** Yang, Y., Samaranayake, S., and Dogan, T.

**Abstract:** This paper uses a generalizable clustering approach to investigate the effects of socio-demographic features on aggregate urban mobility patterns, including activity distribution and travel modal split. We use K-means via principal component analysis to identify eight representative traveler clusters from the 2017 U.S. National Household Travel Survey. Based on the cluster centroids and the cluster percentages within a neighborhood, we can estimate a Temporal Mobility Choice Matrix (TM) that describes the neighborhood-level aggregate mobility choice pattern. The estimation accuracy is assessed in a case study in LA City. It is found that the neighborhood-level temporal mobility patterns are well-replicated, with an average  $R^2$  of 65.47%, 53.15%, and 72.04% among all analyzed neighborhoods in the city. However, we find a moderate- to -low accuracy in estimating the spatial differences in the mobility patterns across neighborhoods. This could be because factors other than socio-demographics, such as physical and built environment factors like terrain, street quality, or amenity densities, are contributing to the spatial differences but have not been considered in this study. Overall, we show that socio-demographic features alone can approximate the average temporal mobility choice patterns of a given population. Our method and result can serve as the baseline and benchmark for future mobility studies that take the socio-demographics of the traveler population into consideration in modeling.

**Subject Areas:** Urban mobility patterns; Temporal Mobility Choice Matrix; Socio-demographics

**Availability:** Yang, Y., Samaranayake, S., and Dogan, T. (2023). “A Clustering-Based Approach to Quantifying Socio-Demographic Impacts on Urban Mobility Patterns.” *Environment and Planning B: Urban Analytics and City Science*. <https://doi.org/10.1177/23998083231159909>

**5.7. Title: Can Shared Micromobility Replace Auto Travel? Evidence from the U.S. Urbanized Areas Between 2012 and 2019**

**Author(s):** Choi, K., Park, H.J., and Griffin, G.P.

**Abstract:** Previous literature has shown mixed findings on whether bike or E-scooter share programs, collectively called shared micromobility, play a role in reducing vehicle travel. In this study, we focused on two types of shared micromobility (i.e., bikes—both regular and e-bikes—and E-scooters). We examined their impact on vehicle travel in urbanized areas in the United States between 2012 and 2019. Employing the difference-in-differences (DID) approach, we quantified the collective effect of shared micromobility on daily vehicle miles of traveled (VMT) per capita at the urbanized area level. Our findings suggest that bike shares could reduce VMT while E-scooter share alone might not have a significant impact on lowering vehicle travel. Our results also indicate that there may be a synergistic effect of bike and scooter shares in VMT reduction when both types of shared micromobility are available in an urbanized area. Our findings also demonstrate regional variations in the impact of shared micromobility on vehicle travel.

**Subject Areas:** Bikeshare; Difference-in-differences; E-scooter; Shared micromobility; Urbanized areas; Vehicle miles of travel

**Availability:** Choi, K., Park, H.J., and Griffin, G.P. (2023). “Can Shared Micromobility Replace Auto Travel? Evidence from the U.S. Urbanized Areas Between 2012 and 2019.” *International Journal of Sustainable Transportation*. <https://doi.org/10.1080/15568318.2023.2179444>



**5.8. Title: Driver License Renewal Requirements Predict Driving Mobility Among Older Drivers with Health-Related Travel Difficulties**

**Author(s):** Freed, S., Ross, L., Mogle, J., Gamaldo, A., and Zhang, Y.

**Abstract:** Given the importance of driving mobility for older adults in the United States, it is important to examine how license renewal policies are related to driving mobility and whether the driving mobility of older adults with health limitations may be especially affected by such policies. The present study examined the association between license renewal requirements and driving mobility in a national sample of 89,757 older adults aged 62 and older in the United States ( $M$  age = 71.57, standard deviation age = 7.48). Using generalized estimating equations, the associations between two driver licensing requirements (in-person renewal and length of renewal cycle) and two indicators of driving mobility (driving status and annual driving mileage) were examined. Results indicated that in-person license renewal was significantly associated with lower driving mileage but not driving status. The association between in-person license renewal and lower driving mileage was greater for people who reported a health-related travel difficulty: in states requiring in-person license renewal, drivers with a health-related travel difficulty had driven 590 fewer miles in the previous year compared with drivers without such difficulties. Among people who experienced in-person license renewal requirements, a longer time between renewals was not significantly associated with driving status or annual mileage. The findings of the current study, combined with previous work showing a lack of safety benefits of in-person license renewal, suggest that in-person license renewal requirements may unnecessarily restrict the driving mobility of some older adults.

**Subject Areas:** License renewal policies; Driving mobility; Older adults; Health limitations

**Availability:** Freed, S., Ross, L., Mogle, J., Gamaldo, A., and Zhang, Y. (2023). "Driver License Renewal Requirements Predict Driving Mobility Among Older Drivers with Health-Related Travel Difficulties." *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981231155903>

## 5.9. Title: Planning for Electric Vehicles Coupled with Urban Mobility

**Author(s):** Xu, Y., Colak, S., Kara, E.C., Moura, S.J., and Gonzalez, M.C.

**Abstract:** The rising adoption of plug-in electric vehicles (PEVs) leads to the alignment of their electricity and their mobility demands. Therefore, transportation and power infrastructures are becoming increasingly interdependent. In this work, we uncover patterns of PEV mobility by integrating for the first time two unique data sets: (i) mobile phone activity of 1.39 million Bay Area residents and (ii) charging activity of PEVs in 580,000 sessions obtained in the same region. We present a method to estimate individual mobility of PEV drivers at fine temporal and spatial resolution integrating survey data with mobile phone data and income information obtained from census. Thereupon, we recommend changes in PEVs charging times of commuters at their work stations that take into account individual travel needs and shave the pronounced peak in power demand. Informed by the tariff of electricity, we calculate the 12 monetary gains to incentivize the adoption of the recommendations. These results open avenues for planning for the future of coupled transportation and electricity needs using personalized data.

**Subject Areas:** Plug-in electric vehicles; Mobility; Mobile phone data; Charging activity; Power infrastructures

**Availability:** Xu, Y., Colak, S., Kara, E.C., Moura, S.J., and Gonzalez, M.C. (2023). *Planning for Electric Vehicles Coupled with Urban Mobility*. arXiv preprint, arXiv:2303.15578v1 [physics.soc-ph]. <https://doi.org/10.48550/arXiv.2303.15578>

### **5.10. Title: Does Bike-Share Enhance Transport Equity? Evidence from the Sacramento, California Region**

**Author(s):** Mohiuddin, H., Fitch-Polse, D.T., and Handy, S.L.

**Abstract:** As bike-share systems proliferate across the US, their potential as a way of expanding opportunities for those most underserved by the transportation system merits a deeper understanding of its current users. In this study, we examine the rate of bike-share adoption by individuals from different socio-demographic groups and living in different bicycling contexts. We explore how individuals incorporate bike-share service into their travel patterns for different travel purposes and change their use of other modes. Data are from a two-wave survey of bike-share users and a parallel household survey of residents in the Sacramento region. Our modeling results for bike-share adoption and use frequency show that low-income individuals are less likely to adopt bike-share but use the service more frequently than other income groups when they do adopt. Low-income users, people of color, and non-auto owners are more likely than other groups to use bike-share frequently for many trip purposes. Individuals living in areas with a stronger biking culture and surrounded by bike infrastructure are less likely to adopt the service and less likely to use it for purposes other than commuting. All users change their use of other modes when they incorporate bike-share into their travel patterns, but low-income individuals, people of color, and non-auto owners would be more severely impacted if the service were to stop. Our results add new insights into the use of bike-share, a service that can enhance social equity while also addressing sustainability.

**Subject Areas:** Electric bike-share; Equity; Bike-share use purpose; Transport-disadvantaged groups; Statistical modeling

**Availability:** Mohiuddin, H., Fitch-Polse, D.T., and Handy, S.L. (2023). "Does Bike-Share Enhance Transport Equity? Evidence from the Sacramento, California Region." *Journal of Transport Geography*, 109. <https://doi.org/10.1016/j.jtrangeo.2023.103588>

### **5.11. Title: Ventura County CEQA Vehicle Miles Traveled Adaptive Mitigation Program**

**Author(s):** Not available.

**Abstract:** The California Environmental Quality Act (CEQA) Guidelines were updated in 2018 to change transportation impact analysis from vehicle operations level of service (LOS) to vehicle miles traveled (VMT) as required by Senate Bill (SB) 743. This changes environmental analysis from how a project affects congestion to the distance traveled by vehicle trips associated with a project. The change supports the GHG reduction goals of the California Global Warming Solutions Act of 2006 (Assembly Bill 32), as implemented.

The most effective means of reducing VMT is by providing convenient, safe, and accessible bicycle, pedestrian, and transit network improvements, providing a mix of land use types in proximity, and providing a range of housing options near places of work. This program will focus on providing a CEQA VMT Adaptive Mitigation Program that includes a simplified mitigation program to reduce residual significant VMT impacts with a focus on affordable housing development.

VMT impacts may be difficult for projects to mitigate without off-site improvements. This voluntary program will provide a mechanism to apply VMT mitigation measures to reduce VMT impacts to below a level of significance.

This program was developed with the assistance of REAP funds to assist CEQA lead agencies in Ventura County to streamline CEQA-required review of potential significant transportation impact as measured by VMT as opposed before 2020 when CEQA transportation impact analysis involved assessment of vehicle operations. Vehicle operations analysis and performance standards may still be required by non-CEQA review and entitlement requirements of jurisdictions.

**Subject Areas:** Vehicle Miles Traveled; Vehicle trips; Transportation impact analysis; Environmental analysis; Affordable housing development

**Availability:** Not available. (2023). *Ventura County CEQA Vehicle Miles Traveled Adaptive Mitigation Program*. Draft Report, Ventura County Transportation Commission, Camarillo, CA. [https://www.goventura.org/wp-content/uploads/2023/05/ATTACHMENT-ITEM-14\\_VENTURA-COUNTY-AMP-AADMIN-DRAFT-REPORT-VCTC\\_FINAL-FOR-COMMISSION-APPROVAL\\_05.12-1.pdf#page=121](https://www.goventura.org/wp-content/uploads/2023/05/ATTACHMENT-ITEM-14_VENTURA-COUNTY-AMP-AADMIN-DRAFT-REPORT-VCTC_FINAL-FOR-COMMISSION-APPROVAL_05.12-1.pdf#page=121)

**5.12. Title: A New Windshield Calibration Law Is Coming to Maryland**

**Author(s):** Thompson, M.

**Abstract:** Blogs.

**Subject Areas:** Windshield calibration; Vehicle age

**Availability:** Thompson, M. (2023). "A New Windshield Calibration Law Is Coming to Maryland." *Repair Driven News, DRIVEN COMMUNICATIONS Inc.*  
<https://www.repairerdrivennews.com/2023/05/17/a-new-windshield-calibration-law-is-coming-to-maryland/>

### **5.13. Title: SB 743 Implementation by Local Governments for Land Use Projects**

**Author(s):** Volker, J.M.B., Hosseinzade, R., and Handy, S.L.

**Abstract:** In 2018, pursuant to Senate Bill (SB) 743 (2013), the Governor’s Office of Planning and Research (OPR) and the California Natural Resources Agency promulgated regulations and technical guidance that eliminated automobile level of service (LOS) as a transportation impact metric for land development projects under the California Environmental Quality Act (CEQA), and replaced it with Vehicle Miles Traveled (VMT). The authors investigated how local governments have been implementing the LOS-to-VMT shift for land development projects, and how that differs from past practice. They also explored whether local governments monitor the actual VMT impacts from completed land use developments and what methods are available to do so. Their findings indicate that all responding jurisdictions acknowledged the mandatory LOS-to-VMT shift, but were in varying stages of implementing the shift. For those jurisdictions that had adopted VMT impact significance thresholds, most adhered closely to OPR’s recommendations. They also mostly tried to use apples-to-apples methods of calculating baseline VMT levels (for setting thresholds) and estimating project-level VMT, often relying on travel demand model outputs for both. However, most jurisdictions gave short shrift to VMT monitoring. Another important aspect of SB 743 implementation is how LOS will continue to be used outside of CEQA. The authors found that jurisdictions uniformly continue to employ LOS outside of CEQA. However, those LOS analyses are not necessarily as comprehensive and expensive as they would have been for CEQA purposes. The authors found a consensus among their interviewees that swapping LOS for VMT could streamline development in urban areas.

**Subject Areas:** Vehicle miles traveled (VMT); VMT estimation; VMT mitigation; VMT monitoring; Level of service; California Environmental Quality Act; Environmental review

**Availability:** Volker, J.M.B., Hosseinzade, R., and Handy, S.L. (2023). *SB 743 Implementation by Local Governments for Land Use Projects*. Final Research Report, UCD-ITS-RR-23-25, University of California, Davis, CA. <https://doi.org/10.7922/G2MP51M5>

#### **5.14. Title: The Business Case for Regional Air Mobility at Scale**

**Author(s):** Villa, I., Ramirez, L.A.M., and Moore, M.

**Abstract:** In the United States, there is limited access to safe, affordable, and sustainable air transport connecting urban, suburban, and regional communities. Passengers seeking intraregional travel are often left with few, tedious, and costly options, while regional air carriers operating low-demand routes struggle with high operating costs, impeding network expansion. Despite these challenges, the overall demand for regional travel is large, and the extensive network of regional airports in the US presents an opportunity to realize the vision of Regional Air Mobility (RAM) on a large scale. In this paper, we examine the current landscape of regional air travel, identify the obstacles that have hindered its expansion, and analyze the networks, fleets, and economics of three regional operators. Furthermore, we outline the feasibility needs that must be met for the successful deployment of the RAM vision, including the development of cost- and energy-efficient next-generation aircraft with reduced passenger capacity, capable of operating at high load factors and frequencies, as well as updates to operating models, improvements to the passenger experience, and community buy-in. With these advancements, RAM has the potential to revolutionize regional travel within the next decade, offering increased productivity and connectivity to communities, and the potential for significant profits to operators that embrace it.

**Subject Areas:** Regional air mobility; Network expansion; Feasibility

**Availability:** Villa, I., Ramirez, L.A.M., and Moore, M. (2023). *The Business Case for Regional Air Mobility at Scale*. Conference Presentation, AIAA 2023-3295, AIAA AVIATION 2023 Forum, San Diego, CA, and online. <https://doi.org/10.2514/6.2023-3295>

### **5.15. Title: A Comparative Study of Operational Limits for Urban and Regional Passenger-Carrying Missions across Metropolitans**

**Author(s):** Sells, B.E., Gunady, N., Wright, E., Iyengar, K., Patel, S.R., DeLaurentis, D.A., Kim, B., and Crossley, W.A.

**Abstract:** To realize the vision of large-scale Urban and Regional Air Mobility (UAM, RAM) operations within Advanced Air Mobility (AAM), it is important to understand and quantify the impact of various operational limits and their interdependence with potential new technologies. This paper presents a comparative assessment of active operational limits that could inhibit large-scale UAM and RAM operations for a choice set of metropolitan areas. The assessment deploys prior work to perform economic, aerodrome throughput, weather, and emissions analyses for the San Francisco, Orlando, New York City, Denver, Dallas, Cleveland, and Chicago metropolitan areas. In this work, daily commute trips and income information are generated for each metropolitan area to estimate the number of expected passenger-carrying trips for various network sizes and operational scenarios. Operational limits are assessed for specific aerodrome infrastructure, and operating conditions to inform which are more prevalent in a given metropolitan. A summary of key operational limits for each metropolitan in rank order by the number of impacted trips is provided to assist the AAM community in realizing what technology and innovation is necessary to sustain this emerging system-of-systems.

**Subject Areas:** Large-scale urban and regional air mobility; Advanced air mobility; Active operational limits; Metropolitans

**Availability:** Sells, B.E., Gunady, N., Wright, E., Iyengar, K., Patel, S.R., DeLaurentis, D.A., Kim, B., and Crossley, W.A. (2023). *A Comparative Study of Operational Limits for Urban and Regional Passenger-Carrying Missions across Metropolitans*. Conference Presentation, AIAA 2023-3410, AIAA AVIATION 2023 Forum, San Diego, CA, and online.  
<https://doi.org/10.2514/6.2023-3410>



### 5.16. Title: Mobility Gaps between Low-Income and Not Low-Income Households: A Case Study in New York State

**Author(s):** Liu, Y. and Uddin, M.

**Abstract:** Understanding the travel challenges faced by low-income residents has always been and continues to be one of the most important transportation equity topics. This study aims to explore the mobility gaps between low-income households (HHs) and not low-income HHs and how the gaps vary within different socio-demographic population groups in New York State (NYS). The latest National Household Travel Survey data were used as the primary data source for the analysis. The study first employed the K-prototype clustering algorithm to categorize the HHs in NYS based on their socio-demographic attributes. Five population groups were identified based on nine different household (HH) features, such as HH size, vehicle ownership, and elderly status of its members. Then, the mobility differences, measured by trip frequency, trip distance, travel time, and person miles traveled, were examined among the five population groups. Results suggest that the individuals in low-income HHs consistently took fewer trips and made shorter trips compared to their not low-income counterparts in NYS. The travel distance gaps were most obvious among white HHs with more vehicles than drivers. In addition, while the population from low-income HHs made shorter trips on average (2.7 mi shorter per trip), they experienced longer travel time than those from not low-income HHs (1.8 min longer per trip). These key findings provide a deeper understanding of the travel behavior disparities between low-income and not low-income households. The findings could also support policymakers and transportation planners in addressing the critical needs of residents in low-income households in NYS and provide inputs for designing a more equitable transportation system.

**Subject Areas:** Mobility gaps; Household income; New York State; Trip characteristics; K-prototype clustering algorithm

**Availability:** Liu, Y. and Uddin, M. (2023). "Mobility Gaps between Low-Income and Not Low-Income Households: A Case Study in New York State." In: Wei, H. (Ed.), *International Conference on Transportation and Development 2023*, pp. 663–673. American Society of Civil Engineers, Reston, VA. <https://ascelibrary.org/doi/abs/10.1061/9780784484883.057>

**5.17. Title: Planning for Smart Safe Routes to School: Learning Case of Georgian Acres Community Hub for Smart Mobility, Austin, Texas**

**Author(s):** Nelson, N.A.

**Abstract:** Transit Deserts are places where there is a gap between the level of transit service (supply) and the transit needs of a particular population (demand) (Jiao, 2013). The relative lack of transit service in such places can be especially troubling for school-aged children because students should not navigate high-speed environments, poor crossings, and a lack of complete streets to get to school. Safe Routes to School (SRTS) planning offers a national framework to address the missing infrastructure in these underserved communities. SRTS is part of the solution to increase physical activity and improve unsafe walking and bicycling conditions for students, simultaneously reducing the number of cars on the road. Walking and bicycling to and from school can contribute to developing lifelong health, social skills, and community-wide norms of incorporating physical activity into daily routines. Children’s safety and commutes to school should be funded by the Department of Transportation, metropolitan planning organizations, local government, school districts, or even a school in historically underserved areas. This PR will examine the potential of using technology to aid SRTS planning. Specifically, robots with cameras can be used to collect existing sidewalk conditions data and video maps and perform route testing. Planners can program technology to go into any Transit Desert to assess pedestrian conditions, collect missing data, and identify safe routes efficiently, improving walkability on the neighborhood community level. This innovation can be used as a tool for cities to maintain street-level assessments of infrastructure, replace walking audits, and improve the collection, usability, and access of data. Within the current SRTS framework, all schools provide maps showing safe routes for students to walk and bike to and from school, and these can evolve into video maps for additional educational benefit. This PR will use a pilot project in the Georgian Acres neighborhood in Austin, Texas, to test the Community Hub for Smart Mobility’s capacity to host SRTS programming and participatory mapping aimed to foster school-aged children’s use of shared alternative transportation.

**Subject Areas:** Smart technology; Participatory planning; Safe Routes to School planning; Audit methodology; Sidewalk existing conditions methodology

**Availability:** Nelson, N.A. (2023). *Planning for Smart Safe Routes to School: Learning Case of Georgian Acres Community Hub for Smart Mobility, Austin, Texas*. Master’s Thesis, University of Texas at Austin, Austin, TX. <http://dx.doi.org/10.26153/tsw/46176>

## 5.18. Title: Evaluating Impacts of Shared E-Scooters from the Lens of Sustainable Transportation

**Author(s):** Shah, N.

**Abstract:** As the popularity of shared micromobility is increasing worldwide, city governments are struggling to regulate and manage these innovative travel technologies that have several benefits, including increasing accessibility, reducing emissions, and providing affordable travel options. This dissertation evaluates the impacts of shared micromobility from the perspective of sustainable transportation to provide recommendations to decision-makers, planners, and engineers for improving these emerging travel technologies.

The dissertation focuses on four core aspects of shared micromobility as follows: 1) Safety: I evaluated police crash reports of motor vehicle involving E-scooter and bicycle crashes using the most recent PBCAT crash typology to provide a comprehensive picture of demographics of riders crashing and crash characteristics, as well as mechanism of crash and crash risk, 2) Economics: I estimated the demand elasticity of E-scooters deployed, segmented by weekday type, land use, category of service providers based on fleet size using negative binomial fixed-effect regression model and K-means clustering, 3) Expanding micromobility to emerging economies: Using dynamic stated preference pivoting survey and panel data mixed logit model, I assessed the intentions to adopt shared micromobility in mid-sized cities of developing countries where these innovative technology could be the first wave of decarbonizing transportation sector, and 4) Micromobility data application: I identified five usagemclusters of shared E-scooter trips using a combination of principal component analysis (PCA) and K-means clustering to propose a novel framework for using micromobility data to inform data-driven decisions on broader policy goals.

Based on the key findings of the research, I provide five recommendations as follows: 1) Decision-makers should be proactive in incorporating new travel technologies such as shared micromobility, 2) city governments should leverage shared micromobility usage and operation data to empower the decision-making process, 3) each shared micromobility vehicle should be approached uniquely for improving road safety, 4) city governments should consider regulating the number of service providers and their fleet sizes, and 5) decision-makers should prioritize expanding shared micromobility in emerging economies as one of the first efforts to the decarbonizing transportation sector.

**Subject Areas:** Shared micromobility; Sustainable transportation; E-scooters; Safety; Demand-supply; Sustainability; Transportation in emerging economies

**Availability:** Shah, N. (2022). *Evaluating Impacts of Shared E-Scooters from the Lens of Sustainable Transportation*. Doctoral Dissertation, University of Tennessee, Knoxville, TN. [https://trace.tennessee.edu/utk\\_graddiss/7616](https://trace.tennessee.edu/utk_graddiss/7616)

## Chapter 6. Special Population Groups

### 6.1. Title: Who Takes the School Bus?: The Roles of Location, Race, and Parents in Choosing Travel-to-School Mode in Georgia

**Author(s):** Speroni, S.

**Abstract:** In the United States, roughly one-third of students in public and private K–12 schools ride a school bus to school; in Georgia, that share is even higher (46%). But policy differences between and within states complicate explanations of school trip mode choice. To address this and create a consistent choice set, this article uses the 2017 National Household Travel Survey Georgia Add-on to construct a statewide analysis of school trip mode choice among school bus–eligible students, as Georgia state law requires students to receive bus service if they live more than 1.5 miles from school, creating a consistent choice set. I use a binary logistic regression model and marginal effects to determine factors predicting school bus use on morning trips to school in Georgia among a suite of trip, individual, household, and environmental characteristics. I find that Black students, older students, and students in greater Atlanta are more likely to use a school bus, while students who live farther from school, girls, students who have at least one parent with a college degree, and students who have at least one parent with a flexible work schedule are less likely to do so. Additionally, for those who are age-eligible, possessing a driver’s license strongly predicts not using a school bus. Notably, neither family income nor family structure are significant predictors of school bus use. Ultimately, these findings have implications for state school bus policy in Georgia and help elucidate who uses this important service so that resources can be directed appropriately.

**Subject Areas:** K-12 schools; School bus; School trip mode choice; School bus policy; Binary logistic regression model; Marginal effects; Demographics

**Availability:** Speroni, S. (2023). “Who Takes the School Bus? The Roles of Location, Race, and Parents in Choosing Travel-to-School Mode in Georgia.” *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981231164388>

## 6.2. Title: Racial Disparities in the Auto Loan Market

**Author(s):** Butler, A.W., Mayer, E.J., and Weston, J.P.

**Abstract:** We document racial disparities in auto lending. Combining credit bureau records with borrower characteristics, we find that Black and Hispanic applicants' approval rates are 1.5 percentage points lower, even after controlling for creditworthiness. In aggregate, this effect crowds out 80,000 minority loans each year. Results are stronger where racial biases are more prevalent and lending competition is lower. Minority borrowers pay 70 basis points higher interest rates, but default less ceteris paribus, consistent with racial bias rather than statistical discrimination. A major antidiscrimination enforcement policy initiated in 2013, but halted in 2018, reduced unexplained racial differences in interest rates by 60 percent.

**Subject Areas:** Racial disparities; Race; Ethnicity; Minority; Auto loan

**Availability:** Butler, A.W., Mayer, E.J., and Weston, J.P. (2023). "Racial Disparities in the Auto Loan Market." *The Review of Financial Studies*, 36(1), pp. 1–41.  
<https://doi.org/10.1093/rfs/hhac029>

**6.3. Title: Approaching Accessibility: Four Opportunities to Address the Needs of Disabled People in Transportation Planning in the United States**

**Author(s):** Levine, K. and Karner, A.

**Abstract:** In common transportation planning practice and research, disability is largely mistreated and oversimplified. This review essay identifies four shortcomings in U.S. transportation planning that perpetuate oversight, exclusion, and inadequate transportation systems for disabled people. Compliance-based agendas are used by public agencies to implement accessibility accommodations based on minimum requirements, failing to consider the everyday experiences of disabled people. Data gaps and access to opportunity assumptions reveal how transportation planning and analysis approaches are inadequate when considering the disability community. Lastly, the narrow focus on mobility disability in the transportation field ignores the diversity of human conditions. These existing challenges are defined in detail with examples of how disability justice ideas and inclusive public engagement practices can address each shortcoming. Meaningful public engagement with the disability community would improve how transportation planning, policy, and practice address the needs and lived experiences of this critical population group.

**Subject Areas:** Disability; Accessibility; Public engagement

**Availability:** Levine, K. and Karner, A. (2023). “Approaching Accessibility: Four Opportunities to Address the Needs of Disabled People in Transportation Planning in the United States.” *Transport Policy*, 131, pp. 66–74. <https://doi.org/10.1016/j.tranpol.2022.12.012>

#### **6.4. Title: Disabled Travel and Urban Environment: A Literature Review**

**Author(s):** Shen, X., Zheng, S., Wang, R., Li, Q., Xu, Z., Wang, X., and Wu, J.

**Abstract:** The relationship between urban environment and the travel of people with disabilities has received scholarly attention. Studies have analyzed disabled travel from multiple perspectives. However, there lacks a systematic review of the variety of existing research methods and results. This paper identifies and examines 66 studies to understand the state of knowledge on the relationship between urban environment and the travel of people with disabilities. Adapting the classic travel demand model to the mobility characteristics of people with disabilities, we interpret the existing literature, point out the missing links, and suggest directions of future research.

**Subject Areas:** Disability; Travel; Built environment; Social environment; Demand model

**Availability:** Shen, X., Zheng, S., Wang, R., Li, Q., Xu, Z., Wang, X., and Wu, J. (2023). "Disabled Travel and Urban Environment: A Literature Review." *Transportation Research Part D: Transport and Environment*, 115. <https://doi.org/10.1016/j.trd.2022.103589>

## 6.5. Title: The Enduring Price of Place: Revisiting the Rural Cost of Living

**Author(s):** Zimmerman, J.N., Rignall, K., and McAlister, C.

**Abstract:** Even as the 2016 elections brought increased public attention to rural life, stereotypes and misconceptions abound. One of these misperceptions is the generalization that prices are lower in rural areas. This article is a restudy of Zimmerman, Ham, and Frank (2008) research on geographic differences in the costs of living. Asking the same fundamental question—If someone bought the same thing in a rural and urban area, would they pay the same price?—and using the same methodology, the results 10 years later indicate that, contrary to popular perception, there was again no consistent pattern of lower prices in rural counties and no consistent pattern of a lower rural cost of living in all of the rural areas. While prices are only one piece of the larger picture of how rural households meet their needs, in addition to price differences, the results highlight how differences in rural life create additional costs that extend beyond prices.

**Subject Areas:** Rural life; Geographic differences; Living costs; Price differences

**Availability:** Zimmerman, J.N., Rignall, K., and McAlister, C. (2023). “The Enduring Price of Place: Revisiting the Rural Cost of Living.” *Rural Sociology*, 88(1), pp. 252–280.  
<https://doi.org/10.1111/ruso.12475>



**6.6. Title: U.S. Physical Activity Para Report Card for Children and Adolescents with Disabilities**

**Author(s):** Stanish, H., Ross, S.M., Lai, B., Haegele, J.A., Yun, J., and Healy, S.

**Abstract:** The U.S. Report Card on Physical Activity for Children and Youth has tracked 10 physical activity (PA) indicators common to the Active Healthy Kids Global Matrix since 2014. This article expands on the U.S. report cards by presenting PA indicator assessments among children and adolescents with disabilities. Grades for indicators were assigned based on a search of peer-reviewed articles presenting nationally representative data. The Global Matrix 3.0 benchmarks and grading framework guided the process. Grades for overall PA, sedentary behaviors, organized sports, and school were F, D+, D+, and D, respectively. Insufficient evidence existed to assign grades to the remaining six indicators. There is a need in the United States for targeted PA promotion strategies that are specific to children and adolescents with disabilities. Without a commitment to this effort across sectors and settings, the low grades identified in this para report card are expected to remain.

**Subject Areas:** Sports; Sedentary behavior; Physical fitness; National surveillance

**Availability:** Stanish, H., Ross, S.M., Lai, B., Haegele, J.A., Yun, J., and Healy, S. (2023). "U.S. Physical Activity Para Report Card for Children and Adolescents with Disabilities." *Adapted Physical Activity Quarterly*, 40(3), pp. 560–567. <https://doi.org/10.1123/apaq.2022-0054>

**6.7. Title: How Far Are We From Transportation Equity? Measuring the Effect of Wheelchair Use on Daily Activity Patterns**

**Author(s):** Macfarlane, G.S. and Lant, N.

**Abstract:** The mobility needs of individuals with travel-limiting disabilities has been a transportation policy priority in the United States for more than thirty years, but efforts to model the behavioral implications of disability on travel have been limited. In this research, we present a daily activity pattern choice model for multiple person type segments, including an individual's wheelchair use as an explanatory variable. The model results show a strong negative impact of wheelchair use on out-of-home travel, exceeding the impact of other variables commonly considered in such models. We then apply the estimated model within an activity-based model for the Wasatch Front region in Utah; the results suggest a shift in tour making of sufficient scale—among both wheelchair users and those in their households—to warrant further scrutiny and analysis.

**Subject Areas:** Transportation equity; Travel behavior; Transportation equity; Travel behavior

**Availability:** Macfarlane, G.S. and Lant, N. (2023). “How Far Are We From Transportation Equity? Measuring the Effect of Wheelchair Use on Daily Activity Patterns.” In: Antoniou, C., Busch, F., Rau, A., and Hariharan, M. (Eds.), *Proceedings of the 12th International Scientific Conference on Mobility and Transport. Lecture Notes in Mobility*, pp. 141–155. Springer, Singapore. [https://doi.org/10.1007/978-981-19-8361-0\\_10](https://doi.org/10.1007/978-981-19-8361-0_10)

**6.8. Title: Disability, Transportation, Activity Performance, and Neighborhood Features in California: Conducting a Focus Group and Designing a Survey**

**Author(s):** Flynn, J.A., Circella, G., and Venkataram, P.S.

**Abstract:** People with disabilities often encounter more and different problems with transportation compared to their socioeconomic peers without disabilities, but their desires for transportation mode choices, usage frequencies, activity frequencies, and neighborhood features have been poorly understood. The authors have begun to rectify those deficiencies with this study, developed in close cooperation with disability advocacy organizations (DAOs). The authors conducted a focus group in 2021 November involving 20 adults with various disabilities across California, including rural, suburban, and urban parts of the major coastal metropolitan areas as well as areas in the interior of the state. Focus group participants' comments evinced a broad theme of problems for people with disabilities arising from car-oriented land use patterns, as they asked for more street lighting, seating, and shade; more frequent public transit service with more geographic coverage; and similar support for infrequent yet critical longer-distance trips. Based on focus group participants' suggestions and pre-testing as well as feedback from DAOs, the authors developed a survey of adults across California to capture how disability affects the choices and desires that people make for transportation mode frequencies, activity frequencies, and neighborhood features. The survey collected nearly 2,000 cleaned responses, reflecting the diversity in disability, geography, and socioeconomic conditions in California.

**Subject Areas:** Disability; Transportation; Focus group; Survey; Mix

**Availability:** Flynn, J.A., Circella, G., and Venkataram, P.S. (2023). *Disability, Transportation, Activity Performance, and Neighborhood Features in California: Conducting a Focus Group and Designing a Survey*. Final Research Report, UCD-ITS-RR-22-119, University of California, Davis, CA. <https://doi.org/10.7922/G29K48JZ>

**6.9. Title: Are Older Adults Living in Compact Development More Active?—Evidence from 36 Diverse Regions of the United States**

**Author(s):** Tian, G., Kalantari, H.A., and Ewing, R.

**Abstract:** With the population of older adults growing globally, this study asks the question: Are older adults living in compact developments more active than those living in sprawling developments? Older adults can be deemed more active if they travel more in total or travel more by non-auto travel modes (such as walking, transit). By analyzing disaggregated data from 36 regions of the United States, this study finds that older adults living in compact neighborhoods do not travel more in total but travel more by walking and public transportation than those living in sprawling neighborhoods. In addition, older adults travel less, are more auto-dependent, and make more home-based–non-work trips compared to younger adults. Older adults with lower income travel less than those with higher income. Older adults living in compact neighborhoods with the lowest income level generate the highest number of transit trips. It is important for planners and policymakers to not only create built environments that support older adults’ travel needs, but also to avoid social inequity.

**Subject Areas:** Travel behavior; Older adults; Active; Mobility; Compact development; Social inequity

**Availability:** Tian, G., Kalantari, H.A., and Ewing, R. (2023). “Are Older Adults Living in Compact Development More Active?—Evidence from 36 Diverse Regions of the United States.” *Computational Urban Science*, 3. <https://doi.org/10.1007/s43762-023-00086-x>

**6.10. Title: What New Tech Is Best for Students?**

**Author(s):** Chapmant, R.

**Abstract:** Blog.

**Subject Areas:** Students; Biking; Technology and applications

**Availability:** Chapmant, R. (2023). "What New Tech Is Best for Students?." *Midgard Times*.  
<https://moviesr.net/p-what-new-tech-is-best-for-students>

**6.11. Title: Choosing the Right Car for Teens and New Drivers**

**Author(s):** Serhan, A.

**Abstract:** Blog.

**Subject Areas:** Teenage Driving; Teenage drivers; Safety

**Availability:** Serhan, A. (2023). "Choosing the Right Car for Teens and New Drivers."  
*Engineerine*. <https://engineerine.com/car-for-teens-new-drivers/>

**6.12. Title: Challenges Faced by People with Disabilities in Public and Active Transportation Systems in the United States of America**

**Author(s):** Venkataram, P.S., Flynn, J.A., Circella, G., and Sperling, D.

**Abstract:** A significant fraction of people with disabilities in the United States of America (USA) do not drive, and these people disproportionately use public transit and paratransit services compared to drivers with disabilities. Substantial research exists regarding not only the ease for people with disabilities to use public transit and paratransit services but also the availability of such services and the availability of nearby pedestrian infrastructure. However, much less research exists regarding the effects of shared micromobility services, car-free areas, and consolidation of public transit services on the mobility of people with disabilities. This systems-level thinking about not only first-order effects but also second- and higher-order effects is critical for the development of policies that more effectively address the mobility needs of people with disabilities.

**Subject Areas:** People with disabilities; Public transit; Paratransit services; Pedestrian infrastructure; Mobility

**Availability:** Venkataram, P.S., Flynn, J.A., Circella, G., and Sperling, D. (2023). *Challenges Faced by People with Disabilities in Public and Active Transportation Systems in the United States of America*. Research Report, University of California, Davis, CA.  
<http://dx.doi.org/10.7922/G2HX1B17>

### **6.13. Title: Measuring and Mapping Physical Activity Disparity (PAD) Index Based on Physical Activity Environment for Children**

**Author(s):** Yang, J., Mu, L., and Rajbhandari-Thapa, J.

**Abstract:** Physical activity (PA) plays a vital role in children’s physical and mental health. The built, natural, and socio-demographic environmental variables affect children’s PA behaviors in various ways. However, few studies focus on systematically measuring the environmental spatiality to enhance PA research. We propose a Physical activity Access Disparity (PAD) index for children. This study aims to design, test, and apply an integrated approach to the children’s PAD index. We adopt five dimensions of “access” to healthcare to measure the children’s PAD index for the United States (US) and the state of Georgia at the county level. The PAD index sorts 18 environmental measures with 23 variables into accessibility, availability, accommodation, affordability, and acceptability (5 A’s) for children’s PA. We use the self-organizing map (SOM) method to measure how the 5 A’s affect the PAD index values. According to the result, the children’s PAD index ranking normalizes from 0 to 1 and identifies “play oases” to “play deserts” in the US and Georgia using diverse 5 A’s combinations. The children’s PAD index shows low disparity in the north and coastal region and high disparity in Deep South states in the US. Moreover, the PAD index shows low disparity and high disparity in the north and south of Georgia. The PAD index provides a valuable tool for researchers and policymakers to analyze disparity in children’s “access” to the PA environment. The flexible parameters and the weighing scheme also extend the method’s generality and allow users to customize the PAD index based on local preferences and conditions.

**Subject Areas:** Children; Physical activity environment; Physical Activity Disparity (PAD) index; Geographic information system; Self-organizing map

**Availability:** Yang, J., Mu, L., and Rajbhandari-Thapa, J. (2023). “Measuring and Mapping Physical Activity Disparity (PAD) Index Based on Physical Activity Environment for Children.” *ISPRS International Journal of Geo-Information*, 12(3). <https://doi.org/10.3390/ijgi12030134>



**6.14. Title: Revisiting the Relationship Between Information and Communication Technologies and Travel Behavior: An Investigation of Older Americans**

**Author(s):** Li, S

**Abstract:** In the digital era, information and communication technologies (ICTs) have provided inexpensive ways for older people to access daily activities; however, the relationship between ICTs and travel among older people has been insufficiently studied. Drawing on an online survey of 2,510 older Americans, this study used a series of structural equation models to examine the relationship between ICTs and travel among older people. The results show that ICT usage and daily travel for shopping, social and recreational, and healthcare purposes among older Americans are positively related. Of all the predictors, the difficulty of using the Internet is one of the most critical for lower ICT usage for all purposes, all else being equal. The study also provides user profiles for different ICT applications. For example, older people who were still relatively young used social media more. E-health applications were more widely used by people of color. The study also demonstrates racial disparities in e-shopping: African Americans tended to use e-shopping applications less frequently and also generated fewer in-store shopping trips compared to non-Hispanic Whites. The study implies that there is significant potential in using ICTs to reduce travel difficulties for disadvantaged older people, and it is important to improve older people's technology literacy.

**Subject Areas:** Older adults; Information and communication technologies (ICTs); Equity; Digital divide; United States

**Availability:** Li, S. (2023). "Revisiting the Relationship Between Information and Communication Technologies and Travel Behavior: An Investigation of Older Americans." *Transportation Research Part A: Policy and Practice*, 172. <https://doi.org/10.1016/j.tra.2023.103689>

**6.15. Title: Transitions into and out of Car Ownership among Low-Income Households in the United States**

**Author(s):** Klein, N.J., Basu, R., and Smart, M.J.

**Abstract:** We examine transitions into and out of car ownership among low-income households. We use a novel online survey of U.S. residents to investigate why households lose access to a car, how long they are without a car, why they regain a car, and how these transitions affect their quality of life. We find that car ownership transitions are primarily motivated by economic security and insecurity. The median length of a carless episode is 1.7 years, while Black and Hispanic respondents experienced longer carless episodes. Despite their precarious grasp on car ownership, respondents felt that owning a car was worth it.

**Subject Areas:** Car ownership transitions; Household income; Quality of life; Demographics

**Availability:** Klein, N.J., Basu, R., and Smart, M.J. (2023). "Transitions into and out of Car Ownership among Low-Income Households in the United States." *Journal of Planning Education and Research*. <https://doi.org/10.1177/0739456X231163755>

## 6.16. Title: Travel Burdens in Rural US Households

**Author(s):** Espeland, S.E.-L.

**Abstract:** Transportation accessibility, the ease of reaching valued destinations, is critical to satisfying a person's fundamental needs. Travel burdens, such as high transportation costs, long travel times, or unmet needs, can decrease accessibility and adversely affect one's well-being. Travel burdens can be induced by both individual and environmental factors. Prior research establishes the inverse relationship between travel burdens and access to transportation options, such as public transit or a personal vehicle, financial resources, and proximity to destinations. Although travel behavior is understood to differ in rural versus nonrural contexts, few studies have evaluated the nature of travel burdens in rural communities. Using the 2017 National Household Travel Survey, this study evaluates differences in travel burdens and the factors that drive them in rural and nonrural communities in the United States. We evaluate i) the magnitude of travel burdens, ii) who experiences travel burdens, and iii) the individual and environmental factors that are associated with travel burdens. We find higher rates of burdensome travel among rural and low-income residents. People who live in rural areas are more likely to report longer medical trip durations, burdensome travel costs, and unmet travel needs due to a lack of transportation options compared to people living in nonrural areas, and these differences are exacerbated for people earning a low income and those without car access. Our results highlight the need for context-specific strategies to ensure that travel needs are met in rural communities.

**Subject Areas:** Transportation accessibility; Travel burdens; Transportation options; Rural communities; Household income

**Availability:** Espeland, S.E.-L. (2023). *Travel Burdens in Rural US Households*. Master's Thesis, University of Vermont, Burlington, VT. <https://scholarworks.uvm.edu/graddis/1686>

### 6.17. Title: On the Road Again: Factors Associated with Family/Friend Caregiver-Provided Transportation

**Author(s):** Koumoutzis, A. and Vivoda, J.M.

**Abstract: Introduction:** Many older adults rely on family/friend caregivers to provide transportation following decreasing and/or ceasing driving. Because caregiving is related to negative mental and physical health outcomes, providing consistent transportation could be challenging. However, we need to first understand the predictors of providing transportation before we can begin assessing its implications. Therefore, the aim of this study was to add to the literature that is beginning to examine family/friend caregiver-provided transportation and its associations.

**Methods:** Data came from Round 7 of the National Health and Aging Trends Study (NHATS) and the linked National Survey of Caregiving (NSOC;  $n = 1103$  dyads). Ordinal regression analyses assessed how care recipient transportation, disability, and demographic factors were associated with the frequency of family/friend caregiver-provided transportation.

**Results:** Less frequent care recipient driving; assisting with shopping, mobility, and bills/banking needs; coresidence; and not being homebound were associated with higher odds of more family/friend caregiver-provided transportation. Caregivers also expected lower odds of providing transportation to care recipients with greater ADL difficulties and with a high school degree or less or a bachelor's degree compared to those with some graduate school or higher.

**Conclusions:** Results of this study suggest that various determinants are related to the odds of family/friend caregiver-provided transportation. This can provide direction for needed targeted interventions, such as services and supports. More research is necessary to help maintain and/or improve mobility in older adulthood and decrease reliance on family/friend caregivers.

**Subject Areas:** Driving; Driving reduction; Driving cessation; Caregiving; National Health and Aging Trends Study; National Survey of Caregiving

**Availability:** Koumoutzis, A. and Vivoda, J.M. (2023). "On the Road Again: Factors Associated with Family/Friend Caregiver-Provided Transportation." *Journal of Transport & Health*, 31. <https://doi.org/10.1016/j.jth.2023.101633>

## Chapter 7. Survey, Data Synthesis, and Other Applications

### 7.1. Title: Exploring the Impact of Bike Lanes on Transportation Mode Choice: A Simulation-Based, Route-Level Impact Analysis

**Author(s):** Hwang, U. and Guhathakurta, S.

**Abstract:** Many U.S. cities are investing in making a more bike-friendly environment in hopes of reducing auto dependency. Studies have shown that improving bike lanes enhance bike users' perceived safety and comfort, but whether it also shifts mode choice toward more biking remains largely unaddressed. This study proposes a model to examine whether and how bike lanes shift the mode choice toward various non-automobile modes. With the help of more than 110,000 sample trips from travel surveys, hypothetical bike routes are obtained to assess each route's level of bike friendliness. A mode choice model with four modes—walking, biking, driving, and transit—is developed using this data. The model results suggest that bike lanes increase not only biking trips but also walking and public transit trips. However, the impact on biking trips alone was marginal, suggesting that a more comprehensive strategy may be necessary to make a significant transition toward non-auto trips. When the data are segmented by poverty level, model results show that the mode choice of the low-income population is as significantly affected by bike lanes as the general population. In addition, the study results indicate that frequent transit users can greatly benefit from bike infrastructure since walking, biking, and public transit trips are closely associated with each other.

**Subject Areas:** Bike lanes; Active mobility; Mode choice; Bike Route Simulation

**Availability:** Hwang, U. and Guhathakurta, S. (2023). "Exploring the Impact of Bike Lanes on Transportation Mode Choice: A Simulation-Based, Route-Level Impact Analysis." *Sustainable Cities and Society*, 89. <https://doi.org/10.1016/j.scs.2022.104318>

## 7.2. Title: Definition of the E-Scooter Sharing Stations Number and Location Under a Lack of Data: A Case Study of the City District in Dnipro

**Author(s):** Svichynska, O., Serhiienko, K., Svichynskyi, S., and Chyzhyk, V.

**Abstract:** In Ukrainian cities, the number of users of bicycles, usual and electric scooters, and e-unicycles increased in recent years. All these vehicles are a direct alternative to walking trips or short-distance transport trips. During the COVID-19 pandemic, the micromobility has become a safe option to travel in the open air, which ensured the possibility to keep social distance and reduce the number of contacts in comparison with public transport. This paper presents the approach to defining the rational number and location of E-scooter sharing stations under limited data. To estimate the number of the sharing stations, the station capacity, potential daily demand for E-scooter trips, and the locations of available E-scooters were used. The locations of sharing stations were defined concerning walking accessibility, demand coverage, and remoteness from the shortest path of the vehicle commissioned to collect the scooters for recharging or replace the scooter batteries on-site. The research was conducted by the example of the Sobornyi district in Dnipro, Ukraine. Apart from the number and location of sharing stations, the potential flows of E-scooter riders were modeled. These findings are relevant because they can provide local authorities and sharing operators with the information for well-grounded decisions on public space and street design, micromobility infrastructure extension, as well as planning of the sharing system performance indicators.

**Subject Areas:** e-Scooter; Micromobility; Sharing station; Micro-vehicle infrastructure; Shared mobility

**Availability:** Svichynska, O., Serhiienko, K., Svichynskyi, S., and Chyzhyk, V. (2023). “Definition of the E-Scooter Sharing Stations Number and Location Under a Lack of Data: A Case Study of the City District in Dnipro.” In: Arsenyeva, O., Romanova, T., Sukhonos, M., Tsegelnyk, Y. (Eds.), *Smart Technologies in Urban Engineering. STUE 2022. Lecture Notes in Networks and Systems*, 536, pp. 669–680. Springer, Cham [https://doi.org/10.1007/978-3-031-20141-7\\_60](https://doi.org/10.1007/978-3-031-20141-7_60)

### 7.3. Title: UrbanPop: A Spatial Microsimulation Framework for Exploring Demographic Influences on Human Dynamics

**Author(s):** Tuccillo, J., Stewart, R., Rose, A., Trombley, N., Moehl, J., Nagle, N., and Bhaduri, B.

**Abstract:** Ensuring the social equity of planning measures in social systems requires an understanding of human dynamics, particularly how individual relationships, activities, and interactions intersect with individual needs. Spatial microsimulation models (SMSMs) support planning for human security goals by representing human dynamics through realistic, georeferenced synthetic populations that a) provide a complete representation of social systems while b) also protecting individual privacy. In this paper, we present UrbanPop, an open and reproducible SMSM framework for analysis of human dynamics with high spatial, temporal, and demographic resolution. UrbanPop creates synthetic populations of demographically detailed worker and student agents, positioning them first at probable nighttime locations (home), then moving them to probable daytime locations (work/school). Summary aggregations of these populations match the granular detail available at the census block group level in the American Community Survey Summary File (SF), providing realistic approximations of the actual population. UrbanPop users can select particular demographic traits important in their application, resulting in a highly tailored agent population. We first lay out UrbanPop’s baseline methodology, including population synthesis, activity modeling, and diagnostics, and then demonstrate these capabilities by developing case studies of shifting population distributions and high-risk populations in Knox County, TN, during the global COVID-19 pandemic.

**Subject Areas:** Spatial microsimulation; Synthetic population; Human dynamics; Planning; Resilience; COVID-19 pandemic

**Availability:** Tuccillo, J., Stewart, R., Rose, A., Trombley, N., Moehl, J., Nagle, N., and Bhaduri, B. (2023). “UrbanPop: A Spatial Microsimulation Framework for Exploring Demographic Influences on Human Dynamics.” *Applied Geography*, 151. <https://doi.org/10.1016/j.apgeog.2022.102844>

**7.4. Title: Simulation Study of Passing Drivers' Responses to the Autonomous Truck-Mounted Attenuator System in Road Maintenance**

**Author(s):** Li, Y., Wang, B., Li, W., and Qin, R.

**Abstract:** The autonomous truck-mounted attenuator (ATMA) system is a lead–follower vehicle system based on autonomous driving and connected vehicle technologies. The lead truck performs maintenance tasks on the road, and the unmanned follower truck alerts passing vehicles about the moving work zone and protects workers and the equipment. While the ATMA has been under testing by transportation maintenance and operations agencies recently, a simulator-based testing capability is a supplement, especially if human subjects are involved. This paper aims to discover how passing drivers perceive, understand, and react to the ATMA system in road maintenance. With the driving simulator developed for this ATMA study, the paper performed a simulation study wherein a screen-based eye tracker collected 16 subjects' gaze points and pupil diameters. Data analysis evidenced the change in subjects' visual attention patterns while passing the ATMA. On average, the ATMA starts to attract subjects' attention from 500 ft behind the follower truck. Most (87.50%) understood the follower truck's protection purpose, and many (60%) reasoned the association between the two trucks. Nevertheless, nearly half of the participants (43.75%) did not recognize that the ATMA is a connected autonomous vehicle system. While all subjects safely changed lanes and attempted to pass the slow-moving ATMA, their inadequate understanding of the ATMA is a potential risk for issues such as cutting into the ATMA. The results implied that transportation maintenance and operations agencies should consider this in establishing the deployment guidance.

**Subject Areas:** Autonomous truck-mounted attenuator; Road maintenance; Passing drivers

**Availability:** Li, Y., Wang, B., Li, W., and Qin, R. (2023). "Simulation Study of Passing Drivers' Responses to the Autonomous Truck-Mounted Attenuator System in Road Maintenance." *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981221144281>



## 7.5. Title: Development of Guidance for a Vehicle Occupancy Rate Data Collection Program

**Author(s):** Xu, Y., Dougald, L.E., and Miller, J.S.

**Abstract:** Transportation planning practices increasingly require knowing the number of occupants per vehicle. Except for manual observations, Virginia has two data sources for obtaining occupancy: the American Community Survey and the National Household Travel Survey, neither of which provides corridor-specific values. This study developed an approach for estimating occupancy based on crash records data—now feasible because Virginia routinely collects, for each crash, the total number of occupants regardless of injury status. This occupancy is not widely available because of privacy concerns but can be obtained through a special tabulation performed by VDOT’s Traffic Engineering Division.

Having crash data is not a panacea: As the area of interest shrinks from a district to a roadway segment, the likelihood that crashes alone provide a biased estimate of occupancy increases. Accordingly, the recommended approach for detecting occupancy contains two additional steps beyond extracting crash data: (1) At the jurisdiction level, test whether this bias exists by performing an eta-squared test; if appropriate, perform Type 1 bias correction by ensuring all occupancy groups (e.g., three occupants per vehicle) are synthesized in the crash data set; and (2) at the corridor level, perform Type 2 bias correction by building a correction model incorporating field observations. Yet bias is not necessarily a fatal flaw. At the corridor level, the mean average absolute difference between occupancy based on uncorrected crash data and occupancy collected from field observations was 0.06; use of the Type 2 bias correction model showed a difference of 0.05 between field observations and corrected data when the model was used on a set of data not used to build the model. At the jurisdiction level, the difference between uncorrected occupancies and Type 1 bias correction was never above 0.02 as long as at least 200 vehicles are observed in crashes.

This method allows Virginia to estimate occupancies by time period, day type, and functional class. Crash data for VDOT’s Hampton Roads District showed statistically significant differences in occupancies ranging from 1.18 to 1.30 (midweek vs. weekend); 1.15 to 1.22 (a.m. peak vs. off-peak); and 1.16 to 1.26 (variation among seven functional classes).

The study recommends that VDOT establish an occupancy data collection program in one district based on two elements: (1) the extraction of occupancies from crash reports, and (2) an adjustment of these occupancies based on the two bias correction methods studied. These two recommendations need not preclude the possibility of using new technologies, some of which were examined in this study, but the approaches highlighted in this report have been successfully tested on a case study basis in Virginia.

**Subject Areas:** Scenario planning; Forecasting; Strategic planning; Problem solving

**Availability:** Xu, Y., Dougald, L.E., and Miller, J.S. (2022). *Development of Guidance for a Vehicle Occupancy Rate Data Collection Program*. Final Report, FHWA/VTRC 23-R5, Virginia

Transportation Research Council, Charlottesville, VA.  
[http://www.virginiadot.org/vtrc/main/online\\_reports/pdf/23-r5.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/23-r5.pdf)

## 7.6. Title: The Value of Better Vehicle Occupancy Estimates for Project Prioritization

**Author(s):** Xu, Y., Dougald, L.E., and Miller, J.S.

**Abstract:** Transportation projects are increasingly evaluated based on how they improve person throughput, which requires knowing the passenger car occupancy. Yet obtaining occupancies is labor-intensive, leading agencies to rely on statewide values. How useful are locality-specific vehicle occupancies? A case study of 38 candidate Virginia highway investments showed an occupancy change of 0.15 randomly applied to one-half of the projects affects 24–42% of project rankings if locality-specific occupancies are used. Occupancy is not the only data element affecting project prioritization, but it is an underlooked one. The study showed that an occupancy uncertainty of 0.15 is equivalent to an uncertainty of 3.90% in the discount rate or 13.2% in assigned traffic volume. As these investments had a mean value of \$17 million, this study demonstrated that when project prioritization metrics are based on person throughput, city- or county-specific occupancies are an integral component of a data-driven prioritization process.

**Subject Areas:** Project prioritization; Locality-specific vehicle occupancies; Virginia highway investments; Traffic volume

**Availability:** Xu, Y., Dougald, L.E., and Miller, J.S. (2023). “The Value of Better Vehicle Occupancy Estimates for Project Prioritization.” *Public Works Management & Policy*. <https://doi.org/10.1177/1087724X231184404>

### 7.7. Title: Prediction of Automobiles Prices Using Exploratory Data Analysis Based on Improved Machine Learning Techniques

**Author(s):** Basysyar, F.M., Ferisanti, Wulandari, M., Sucitra, I., Kurnia, D.A., and Solikin.

**Abstract:** The fast development of on-demand ridesharing services, especially those that incorporate driving technologies, has the potential to revolutionize mobility provision. Nonetheless, a worrying disparity exists between vehicle availability and trip demand over space and time. Researchers and professionals in the transportation industry are renewing their focus on automobiles and mobility in an effort to identify the elements that affect the cost of pre-owned vehicles. Standard machine learning algorithms are used to provide cost predictions in several articles. However, people rarely think about the efficiency of individual models and instead disregard the less well-known but more intricate ones. A multi-period theoretical model for dynamic pricing is presented here. In this analysis, we will examine several state-of-the-art models by utilizing both traditional and state-of-the-art machine learning techniques to assess the impact of features on prediction strategies. As an added bonus, this research will provide robust validation for numerous regression model implementation strategies, offering promise for future price forecasting of automobiles.

**Subject Areas:** Automobiles; Prices; Prediction; Machine learning

**Availability:** Basysyar, F.M., Ferisanti, Wulandari, M., Sucitra, I., Kurnia, D.A., and Solikin. (2022). "Prediction of Automobiles Prices Using Exploratory Data Analysis Based on Improved Machine Learning Techniques." *2022 Seventh International Conference on Informatics and Computing (ICIC)*, Denpasar, Bali, Indonesia, pp. 1–6.  
<https://doi.org/10.1109/ICIC56845.2022.10006925>

**7.8. Title: Who Drops Off Web-Based Travel Surveys? Investigating the Implications of Respondents Dropping Out of Travel Diaries During Online Travel Surveys**

**Author(s):** Wang, K., Liu, Y., Hossain, S., and Habib, K.N.

**Abstract:** Household travel surveys collect core datasets for modelling passenger travel demand. However, decline in survey completion rate is becoming a concern in recent years. One major cause is the transition from computer-assisted telephone interviews (CATIs) to computer-assisted web interview (CAWI) surveys, where respondents need to self-complete the surveys without any active help from an interviewer. Among all components, the travel diaries are the most challenging part of CAWI travel surveys and suffer significant dropouts of participation. Therefore, an investigation is necessary to understand the implications of such participation dropouts in CAWI-based household travel surveys on travel survey data quality. This study reports two travel diary designs developed to ease response burdens in travel surveys. Empirical investigations are conducted to understand survey participation drop-off behaviour while filling out travel diaries. In proxy household travel surveys, diary designs with stable repetitions outperform sophisticated diary designs. In a survey deployed with supposedly advanced diary designs, respondents with higher travel demand are more likely to drop out. Estimated using a generalizable analysis framework proposed by this study, the travel demand reflected in the final dataset collected using the sophisticated travel diary design might be underestimated by 10.2%. This study also proposes strategies and recommendations for future travel surveys.

**Subject Areas:** Travel surveys; Travel diary; Survey completion rate; Non-response bias

**Availability:** Wang, K., Liu, Y., Hossain, S., and Habib, K.N. (2023). *Who Drops Off Web-Based Travel Surveys? Investigating the Implications of Respondents Dropping Out of Travel Diaries During Online Travel Surveys*. Research Article, Research Square, Durham, NC.  
<https://doi.org/10.21203/rs.3.rs-2512597/v1>

## 7.9. Title: Two-Stage Stochastic One-to-Many Driver Matching for Ridesharing

**Author(s):** Homsy, G., Gendron, B., and Jena, S.D.

**Abstract:** We introduce a modeling framework for stochastic rider-driver matching in many-to-one ridesharing systems, in which drivers have to be selected before the exact rider demand is known. The modeling framework allows for the use of driver booking fees and penalties for unmatched drivers, therefore supporting different system operating modes. We model this problem as a two-stage stochastic set packing problem. To tackle the intractability of the stochastic problem, we introduce three model approximations and evaluate them on a large set of benchmark instances for three different system operating modes. Our computational experiments show the superiority of some model approximations over others and provide valuable insights on the impact of penalties and booking fees on the system's profitability and user satisfaction.

**Subject Areas:** Two-stage stochastic programming; Ridesharing matching; Mixed-integer programming

**Availability:** Homsy, G., Gendron, B., and Jena, S.D. (2022). *Two-Stage Stochastic One-to-Many Driver Matching for Ridesharing*. Research Report, Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT), Montreal, Quebec, Canada.  
<https://www.cirrelt.ca/documentstravail/cirrelt-2022-36.pdf>

### 7.10. Title: Non-Linear Associations Between the Urban Built Environment and Commuting Modal Split: A Random Forest Approach and SHAP Evaluation

**Author(s):** Hatami, F., Rahman, M.M., Nikparvar, B., and Thill, J.-C.

**Abstract:** The study of commuting mode choice is crucial since driving, with all its associated environmental and economic consequences, is the United States' most popular mode of transportation due to urban sprawl, priority to road construction, and America's love affair with the automobile. More attention needs to be paid to sustainable modes such as public transit and walking. The built environment is expected to have an impact on commuting mode choice. Built environments with higher density, diversity, intentional design, destination accessibility, and shorter distance to transit (collectively known as the 5 D's of the built environment) are hypothesized to lead to more sustainable mode choices, including public transit and walking. In this paper, we evaluate the impact of built environment variables on commuting modal split, including the four modes of public transit—bus, public transit-rail, walking, and driving. The study is conducted in Mecklenburg County, North Carolina, at the geographic level of census block groups in year 2015. Given the complexity of relationships in the built environment-travel behavior subject, the random forest method is used to predict aggregated commuting mode choice. Random forest is employed as it is capable of capturing nonlinear relationships and is not constrained by limitations in other widely used methods, such as multinomial logistic regression. After predicting the commuting mode shares, SHAP values (SHapley Additive exPlanations) are used to evaluate the impact of the built environment on commuting mode choices. As an advanced machine learning method, SHAP values add explainability to the model. This method resolves the known limitation of machine learning methods as being “black boxes” and converts them to “white boxes” by providing interpretability. They provide insights into both the direction and magnitude of the relationships. Thanks to its rigorous ML-based design, our study helps to solidify the state of knowledge with strong evidence that block groups with higher degrees of the 5 D's lead to more choices of public transit and walking modes. We discuss urban policy implications of this study.

**Subject Areas:** The built environment; Commuting mode choice; Modal split; Random forest; SHAP values; Feature importance

**Availability:** Hatami, F., Rahman, M.M., Nikparvar, B., and Thill, J.-C. (2023). “Non-Linear Associations Between the Urban Built Environment and Commuting Modal Split: A Random Forest Approach and SHAP Evaluation.” *IEEE Access*, 11, pp. 12649–12662.  
<https://doi.org/10.1109/ACCESS.2023.3241627>

### **7.11. Title: On-Street Parking for Freight, Services, and E-Commerce Traffic in US Cities: A Simulation Model Incorporating Demand and Duration**

**Author(s):** Ramirez-Rios, D.G., Kalahasthi, L.K., and Holguín-Veras, J.

**Abstract:** This paper develops a modeling framework to estimate the on-street parking demand for urban commercial traffic in the US using publicly available data. The commercial traffic includes the freight trip generation (pick-ups and deliveries), service trip attraction (service visits to establishments), and E-commerce deliveries, altogether referred to as freight and service activities (FSAs) in this study. The methodology includes a simulation model incorporating FSA demand estimation, probability distributions for FSA duration, and industry sectors at the 2-digit North American Industry Classification System (NAICS) level. The authors validated the model through a case study of the SoHo commercial complex's parking demand in New York City (NYC) (Campbell et al., 2018). In addition, the study analyzes the magnitude of the parking issue in NYC comparing five ZIP codes in Midtown Manhattan, which generate the highest commercial demand in the city. The study extends the analysis to the busiest ZIP codes in six cities in the US (Austin, TX; Columbus, OH; San Jose, CA; Seattle, WA; Washington DC; Boston, MA). The results show that the parking spaces required during peak hours at the denser areas (i.e., ZIP codes in Manhattan) cannot be accommodated by the available on-street parking capacities. The authors tested four demand management initiatives to reduce the peak-hour needs. The off-hours strategy, which indicates 30 percent of freight pick-ups and deliveries and 51 percent of service visits shifting to the off-hours, is the most effective one, with the potential to reduce daytime parking needs by 30 percent. Results also show the need to dedicate curb space for FSA vehicle parking to satisfy time-of-day requirements.

**Subject Areas:** Freight and service activity; On-street parking; Duration data; Freight trip generation; Service trip attraction

**Availability:** Ramirez-Rios, D.G., Kalahasthi, L.K., and Holguín-Veras, J. (2023). "On-Street Parking for Freight, Services, and E-Commerce Traffic in US Cities: A Simulation Model Incorporating Demand and Duration." *Transportation Research Part A: Policy and Practice*, 169. <https://doi.org/10.1016/j.tr.2023.103590>



**7.12. Title: Forecast Performance of Metropolitan Trip Generation Models Statistically Updated with US National Household Travel Survey Data**

**Author(s):** Johnson, L.K. and Badoe, D.A.

**Abstract:** An investigation is conducted into whether trip generation models, estimated on travel survey data collected in the 1998 Nashville household travel behavior survey, can be enhanced in forecast performance by combining the 1998 Nashville survey data with data collected in metropolitan regions in either the 2009 National Household Travel Survey (NHTS) or in the 2009 State of Tennessee Add-On NHTS. Data for assessing the forecast performance of the alternative developed models were collected in the 2012 Nashville transportation and health survey. Linear regression analysis and Bayesian statistics were used to develop alternative trip generation models whose performances in forecasting travel were assessed. Major findings of the study include the following: (a) Metropolitan trip generation models for the mandatory purposes of work and school did not benefit from update with national- or state-level data for these trip purposes; (b) metropolitan trip generation models for nonwork non-school purposes (discretionary purposes) and for trips across all travel purposes improved in forecast performance with update with national-level data collected in the 2009 NHTS only. This finding suggests that metro-level data collected in the regular NHTS rather than data collected in a specific US state's Add-On Survey should be the data source for updating metropolitan models of discretionary travel in medium-range forecasting; and (c) development of updated models by Bayesian updating, though relatively simple, had the best forecast performance of the tested models and hence is recommended as the preferred method for model updating in planning practice in the state.

**Subject Areas:** Travel demand; Statistics; Urban areas; Travel patterns; Forecasting; Data collection; Bayesian analysis; Surveys (non-geomatic); Tennessee; United States

**Availability:** Johnson, L.K. and Badoe, D.A. (2023). "Forecast Performance of Metropolitan Trip Generation Models Statistically Updated with US National Household Travel Survey Data." *Journal of Urban Planning and Development*, 149(2). <https://doi.org/10.1061/JUPDDM.UPENG-4099>

### 7.13. Title: On Hyperparameter Optimization of Machine Learning Methods Using a Bayesian Optimization Algorithm to Predict Work Travel Mode Choice

**Author(s):** Aghaabbasi, M., Ali, M., Jasiński, M., Leonowicz, Z., and Novák, T.

**Abstract:** Prediction of work travel mode choice is one of the most important parts of travel demand forecasting. Planners can achieve sustainability goals by accurately forecasting how people will get to and from work. In the prediction of travel mode selection, machine learning methods are commonly employed. To fit a machine-learning model to various challenges, the hyperparameters must be tweaked. Choosing the optimal hyperparameter configuration for machine learning models has an immediate effect on the performance of the model. In this paper, optimizing the hyperparameters of common machine learning models, including support vector machines, k-nearest neighbor, single decision trees, ensemble decision trees, and Naive Bayes, is studied using the Bayesian Optimization algorithm. These models were developed and optimized using two datasets from the 2017 National Household Travel Survey. Using several criteria, including average accuracy (%), average area under the receiver operating characteristics, and a simple ranking system, the performance of the optimized models was investigated. The findings of this study show that the BO is an effective model for improving the performance of the k-nearest neighbor model more than other models. This research lays the groundwork for using optimized machine learning methods to mitigate the negative consequences of automobile use.

**Subject Areas:** Bayesian optimization algorithm; Hyperparameters; Sustainable mode choice decision; Work travel mode choice

**Availability:** Aghaabbasi, M., Ali, M., Jasiński, M., Leonowicz, Z., and Novák, T. (2023). “On Hyperparameter Optimization of Machine Learning Methods Using a Bayesian Optimization Algorithm to Predict Work Travel Mode Choice.” *IEEE Access*, 11, pp. 19762–19774. <https://doi.org/10.1109/ACCESS.2023.3247448>

#### **7.14. Title: A Survey to Investigate Transport Conditions in Depopulating Cities in Illinois**

**Author(s):** Sutradhar, U., Badhrudeen, M., Chauhan, R.S., and Derrible, S.

**Abstract:** Despite the global population increase, many cities in the world are depopulating. While the literature focuses heavily on the challenges brought by an increasing population, depopulating cities face many challenges as well. In particular, the management and maintenance of infrastructure often becomes challenging in depopulating areas. To identify the challenges related to transport, this study conducts a survey on depopulating cities in Illinois. Asking questions about the availability of travel modes, the challenges faced by users of each mode, commonly/possible implemented solutions to facilitate mobility, and investment and funding in transport, this study provides an analysis of transport conditions in depopulating cities from an administrative standpoint. A descriptive analysis of the survey responses is presented to provide aggregated results and to exhibit how responses vary with city size and location. This study also highlights the importance of evaluating existing conditions to implement tailored solutions to local contexts instead of applying blanket solutions that often fail to benefit the residents.

**Subject Areas:** Disability; Aging; Transport; Depopulation; Survey

**Availability:** Sutradhar, U., Badhrudeen, M., Chauhan, R.S., and Derrible, S. (2023). *A Survey to Investigate Transport Conditions in Depopulating Cities in Illinois*. engrXiv preprint, Open Engineering, Menomonie, WI. <https://doi.org/10.31224/2842>

**7.15. Title: Use of Mobile Sensing Data for Assessing Vibration Impact of E-Scooters with Different Wheel Sizes**

**Author(s):** Ma, Q., Yang, H., and Yan, Z.

**Abstract:** With the growing demand of shared electric scooters (E-scooters) for short-distance trips in urban areas, their safety issues have received significant attention from various stakeholders. In general, E-scooter riders encounter more vibrations compared with users of other transportation modes such as bicycles that typically have larger wheels and better suspension systems. Such riding experience may lead to discomfort, affect riders' health, and increase riding risk. Intuitively, increasing E-scooters' wheel sizes may provide a safer and more comfortable riding experience. However, this assumption has not been well tested. The main objective of this paper is to curtail this gap by quantitatively assessing the impacts riders experienced, through the use of mobile sensing data. Specifically, a mobile sensing platform was deployed on E-scooters with different wheel sizes to continuously measure encountered vibrations. Then, the instrumented E-scooters were ridden on routes with different pavement materials. Finally, the collected data were further processed and analyzed to evaluate various riding issues in each riding scenario. The comparative results suggest that E-scooters with larger wheels can efficiently alleviate vibrations during a ride compared with those with smaller wheels. To improve riding experience and safety, it is beneficial to use larger-wheel E-scooters, given other similar riding conditions.

**Subject Areas:** Shared electric scooters; Safety; Vibration impact; Wheel sizes; Mobile sensing data

**Availability:** Ma, Q., Yang, H., and Yan, Z. (2023). "Use of Mobile Sensing Data for Assessing Vibration Impact of E-Scooters with Different Wheel Sizes." *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981231156586>

## 7.16. Title: Are Inflationary Shocks Regressive? A Feasible Set Approach

**Author(s):** Del Canto, F., Grigsby, J., Qian, E., and Walsh, C.

**Abstract:** We develop a framework to measure the welfare impact of inflationary shocks throughout the distribution. The first-order impact of a shock is summarized by the induced movements in agents' feasible sets: their budget constraint and borrowing constraints. To measure this impact, we combine estimated impulse response functions with micro-data on household consumption bundles, asset holdings, and labor income for different US households. We find that inflationary oil shocks are regressive, but monetary expansions are progressive, and there is substantial heterogeneity throughout the life cycle. In both cases, the dominant channel is the effect of the shock on asset accumulation, not movements in goods' prices or labor income.

**Subject Areas:** Welfare; Impact of inflationary shocks; U.S. households; Household consumption bundles; Asset holdings; Labor income

**Availability:** Del Canto, F., Grigsby, J., Qian, E., and Walsh, C. (2023). *Are Inflationary Shocks Regressive? A Feasible Set Approach*. Authors' Manuscript, Princeton University, Princeton, NJ. <https://static1.squarespace.com/static/5b4b997eda02bc592b5131cd/t/642c4505a38e184e80e6b302/1680622862445/Inflation.pdf>

### 7.17. Title: System Dynamics Models of Automated Vehicle Impacts

**Author(s):** Smith, S., Rakoff, H.E., Eilbert, A., Shaw, J., and Berg, I.

**Abstract:** The many potentially transformative changes to the transportation system, such as automated vehicles, electric vehicle adoption, increased telework, and new travel modes, are creating increasing uncertainties for the future. These uncertainties call for fast, flexible models.

System dynamics (SD) is emerging as a research modeling focus area for changes to the transportation system that may have transformative impacts, including those from vehicles using automated driving systems (ADS). System dynamics provides both qualitative methods to bring diverse stakeholders to a common understanding of the problem and quantitative methods for modeling complex systems that consider feedback effects and changes over time. Qualitative methods include those for representing systems, such as causal loop diagrams, and for collecting information to determine that representation, such as working with stakeholders via group model building techniques. This project developed causal loop diagrams for several “building blocks” (archetypes) that affect how automated vehicles might be used. These building blocks include new product adoption, sustainability of business model, mode choice, scale effects, congestion, and residential relocation.

This report then summarizes our use of group model building in several settings and, finally, presents a quantitative model of a shared mobility service, with initial calibration results and sensitivity results for urban, suburban, and rural areas. The results showed that higher trip densities would lead to lower wait times and a greater return on investment. While this result is not surprising, the CLD is a research contribution by demonstrating the causal mechanisms that lead to this result, as well as providing a way to test the effects of possible policy levers.

**Subject Areas:** Automation; Automated vehicles; Automated driving systems; System dynamics; Group model building; Shared mobility

**Availability:** Smith, S., Rakoff, H.E., Eilbert, A., Shaw, J., and Berg, I. (2023). *System Dynamics Models of Automated Vehicle Impacts*. Final Report, FHWA-JPO-22-985, John A. Volpe National Transportation Systems Center, Cambridge, MA.

[https://rosap.ntl.bts.gov/view/dot/66972/dot\\_66972\\_DS1.pdf](https://rosap.ntl.bts.gov/view/dot/66972/dot_66972_DS1.pdf)

**7.18. Title: A Method for Evaluating Accessibility in Transportation Problems Considering Social Vulnerability**

**Author(s):** Sullivan, J.L. and Novak, D.C.

**Abstract:** In this paper, we introduce a methodological approach for evaluating transportation-based access via the public roadway network referred to as edge accessibility, which is derived from the graph theory measure of closeness. EA evaluates each edge in the roadway network based on its system-wide contribution in facilitating access between all origin-destination (OD) pairs in the roadway network and includes an edge disruption component in the calculation. The measure also includes an importance weighting approach that can be applied to both origins and destinations to address concerns related to equity and criticality and can be readily incorporated into existing transportation planning models. The measure is demonstrated via a case study that examines food accessibility by socially vulnerable populations in a rural setting to support the expansion of a fixed-route public transit service. As part of the case study, we use a statewide network of all public roadways in a GIS-based transportation planning platform called TransCAD™, a customizable off-the-shelf software for transportation network applications.

**Subject Areas:** Transportation planning; Public sector; Food accessibility; Transportation network design problem (TNDP); Social vulnerability

**Availability:** Sullivan, J.L. and Novak, D.C. (2023). “A Method for Evaluating Accessibility in Transportation Problems Considering Social Vulnerability.” *European Journal of Operational Research*. <https://doi.org/10.1016/j.ejor.2023.04.015>

### **7.19. Title: Comparisons of Observed and Unobserved Parameter Heterogeneity in Modeling Vehicle-Miles Driven**

**Author(s):** Kim, S.H. and Mokhtarian, P.L.

**Abstract:** This study examines potential observed and unobserved parameter heterogeneity in modeling vehicle-miles driven (VMD). This application is both important in its own right and a vehicle for exploring conceptual, mathematical, and empirical differences among three finite-segmentation ways of addressing such heterogeneity: deterministic segmentation and (endogenous) switching for observed heterogeneity and latent class models for unobserved heterogeneity. Based on empirical data from about 3,000 Georgia residents, we model weekly VMD and identify key explanatory variables as well as the different sensitivities to those variables exhibited by various population segments. The study posits that people have different sensitivities to explanatory variables by residence type (urban versus “less urban”), and supporting evidence was found in the deterministic segmentation and endogenous switching models. The switching regression model characterized those who are more likely to live in urban areas, e.g., workers, pro-environmental, and those who are less favorable to driving. In addition, the estimated error correlations in the endogenous switching model corroborated that there are unobserved factors common to the joint decisions of residential choice and VMD generation. The latent class model identified lower and higher VMD-inclined segments and had a better goodness of fit than the other two models. The results confirm that (1) there is notable heterogeneity in the population with respect to the weight given to relevant factors that influence VMD, and (2) accounting for both observed and unobserved heterogeneities is useful in modeling VMD.

**Subject Areas:** Mixture modeling; Latent class model; Switching regression; Heterogeneity; Market segmentation; Vehicle-miles driven

**Availability:** Kim, S.H. and Mokhtarian, P.L. (2023). “Comparisons of Observed and Unobserved Parameter Heterogeneity in Modeling Vehicle-Miles Driven.” *Transportation Research Part A: Policy and Practice*, 172. <https://doi.org/10.1016/j.tra.2023.103614>



## 7.20. Title: Proposed Typology for Ridesourcing Using Survey Data from Tennessee

**Author(s):** Crossland, C., Brakewood, C., Guo, J., and Cherry, C.

**Abstract:** Although ridesourcing users have been studied in literature, it is unlikely that everyone uses ridesourcing homogenously. Identifying a ridesourcing user typology could help to further understand how ridesourcing is used, to better plan and manage these services. This study employed survey data collected in 2019 from residents of three heavily auto-oriented metro areas in Tennessee to generate a ridesourcing user typology based on demographic, socioeconomic, and preference variables. We identified four ridesourcing user and nonuser types: “young urban local users,” “wealthy travelers,” “tagalong users,” and “nonusers.” The young urban local users made up about 20% of the sample and included those who used ridesourcing locally. They tended to use ridesourcing for social purposes, were younger, and had higher incomes. These findings aligned with prior research. The wealthy traveler type comprised those who used ridesourcing primarily when traveling. Wealthy travelers were older and had higher incomes than other user types. Tagalong users typically rode with friends/family; they tended to be younger, female, and/or Black. Prior research has largely excluded the tagalong user type. The nonuser was the fourth and largest (53%) type. Nonusers were usually older, had lower incomes, and were located in rural areas. Their most common reasons for not using ridesourcing included car ownership, safety concerns, and cost. Understanding the differences between these user types could help practitioners and policymakers better plan for ridesourcing services and integrate them into the operations of local transportation systems, particularly in more auto-centric metropolitan areas.

**Subject Areas:** Ridesourcing; Metro areas; Tennessee; Demographics; User types

**Availability:** Crossland, C., Brakewood, C., Guo, J., and Cherry, C. (2023). “Proposed Typology for Ridesourcing Using Survey Data from Tennessee.” *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981231161356>

**7.21. Title: A Note on the Sample Selection (Switching Regression) Model and Treatment Effects for a Log-Transformed Outcome Variable, in the Context of Residential Self-Selection**

**Author(s):** Kim, S.H. and Mokhtarian, P.L.

**Abstract:** This study examines the residential self-selection issue from conceptual and methodological aspects, with an empirical application. The study was motivated by the challenge of interpreting the results of an endogenous switching model and the lack of convenient/proper equations for calculating treatment effects when the dependent variable is log-transformed. We classify expected returns from living in a certain kind of area (urban vs. non-urban) into location-related versus transportation-related, and economic versus lifestyle, aspects. From that, we note that the outcome variable of interest to this study among many others—vehicle-miles driven (VMD)—may not correspond to the returns an individual is seeking to optimize when choosing where to live. Previous studies tend to expect negative error correlations between selection and outcome equations, on the presumption that urbanite people would desire to drive less (so, unobserved traits *increasing* the utility of an urban neighborhood should also tend to *decrease* VMD). However, given the variety of possible expected returns, we argue that error correlations (and thus the directions of selection corrections) could be either positive or negative. As an empirical application, we apply the endogenous switching model to modeling VMD, where the treatment is living in an urban area (vs. living in a less urban area). In addition, the paper provides conceptual and graphical illustrations to improve the understanding of treatment effects and their mathematical mechanisms.

**Subject Areas:** Self-selection; Sample selection model; Endogenous switching model; Treatment effects; Vehicle-miles driven; Log-transformation

**Availability:** Kim, S.H. and Mokhtarian, P.L. (2023). “A Note on the Sample Selection (Switching Regression) Model and Treatment Effects for a Log-Transformed Outcome Variable, in the Context of Residential Self-Selection.” *Transportation*. <https://doi.org/10.1007/s11116-023-10384-2>

## 7.22. Title: Incorporating Social Vulnerability Variables in Measures to Quantify Access to Opportunities

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

**Abstract:** This study quantifies access to travel opportunities to understand what societal factors are linked with local access and to identify communities with reduced access. We introduce a method to compare accessibility across all census tracts in the United States that can be used across geographically diverse communities ranging from sparsely to densely populated areas. This study considers six key opportunities that we consider essential for all communities (grocery stores, public schools, daycares, primary care doctors, pharmacies, and parks), and six additional destinations that can be viewed as a social safety net (homeless shelters, women’s shelters, food pantries, libraries, vocational schools, and banks). We quantify accessibility to these opportunities within a 15 min walk, transit trip, bicycle ride, and automobile drive for every census tract in the United States and observe a decrease in vehicle miles traveled and vehicle ownership in tracts with increased walkability. Through analysis at the census tract level, this study incorporates variables of social vulnerability with these cumulative opportunity metrics to better understand diminished accessibility as attributed to social and racial inequities. As example findings, we find decreased access to financial services in communities with high minority and limited English-speaking populations, no apparent change in access for childcare in communities with high percentages of single-parent families, and potentially increased or decreased access to women’s healthcare resources for Black women depending on the travel mode.

**Subject Areas:** Self-selection; Sample selection model; Endogenous switching model; Treatment effects; Vehicle-miles driven; Log-transformation

**Availability:** Sansone, M., Gohlke, D., and Zhou, Y. (2023). “Incorporating Social Vulnerability Variables in Measures to Quantify Access to Opportunities.” *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981231168861>

**7.23. Title: Can Good Microscale Pedestrian Streetscapes Enhance the Benefits of Macroscale Accessible Urban Form? An Automated Audit Approach Using Google Street View Images**

**Author(s):** Koo, B.W., Guhathakurta, S., Botchwey, N., and Hipp, A.

**Abstract:** While pedestrian accessibility measures have been widely used interchangeably with walkability, walkability is not just about accessibility. Microscale streetscape factors can provide qualities that pedestrians seek, including safety from crime, traffic safety, and pleurability. These qualities can encourage walking through direct contributions or by enhancing the benefits of macroscale accessibility measures, or both. This study examines the main and interaction effects of microscale streetscape factors measured from street view images using computer vision in Atlanta, Georgia, USA. The correlation analysis showed that many microscale factors have moderate to strong correlations with the pedestrian accessibility measure. Binary logistic regressions demonstrated that safety from crime, pleurability, and composite microscale index have direct contributions to walking mode choice. Regarding moderating effects, traffic safety, safety from crime, and composite microscale index enhanced the benefits of pedestrian accessibility measure. Policies designed to encourage walking can focus on streetscape features for short-term efforts. Important caveats for policymakers in using machine-driven data collection are discussed.

**Subject Areas:** Walkability; Accessibility; Streetscapes; Google Street View; Computer vision; Interaction effects

**Availability:** Koo, B.W., Guhathakurta, S., Botchwey, N., and Hipp, A. (2023). "Can Good Microscale Pedestrian Streetscapes Enhance the Benefits of Macroscale Accessible Urban Form? An Automated Audit Approach Using Google Street View Images." *Landscape and Urban Planning*, 237. <https://doi.org/10.1016/j.landurbplan.2023.104816>

## 7.24. Title: Independent Data Validation to Detect Biases in Synthetic Populations

**Author(s):** Embury, J.

**Abstract:** Increasing access to mobility microdata drives agent-based modeling innovations. Agent-based models are broadly applicable to academic, industry, and municipal projects because they can test scenarios that are not easily assessed using other means. Agent-based activity models inform decisions related to public health, emergency management, transportation management, and urban planning. Amid ethical concerns about mobility microdata usage and calls for improved utility from agent-based activity models, it is crucial to verify that the models accurately simulate the behaviors of the study population.

Increasing an agent-based model's behavioral realism starts with assessing whether the model's synthetic population is representative of its real-world counterpart. Validation of a synthetic population can detect biases that have the potential to harm marginalized individuals and groups. The recent increase in the availability of mobility microdata provides opportunities to introduce methods of independent data validation for synthetic populations. This study uses a common population synthesis technique to generate synthetic populations at two spatial granularities and introduces an independent data validation method to identify and characterize biases.

Validation methods using independent data detected biases in the synthetic populations that were not apparent from the other evaluation measures. Spatial clusters exposed the locations of underrepresented and overrepresented communities. In addition, this study identified socio-demographic attributes that may play an important role in determining synthetic population validity. This information can be used to guide bias mitigation efforts that will generate a more representative synthetic population. These findings demonstrate the value of adding independent data validation to existing synthetic population evaluation methods.

**Subject Areas:** Agent-based models; Population synthesis; Data validation; Bias detection and mitigation; Mobility microdata

**Availability:** Embury, J. (2023). *Independent Data Validation to Detect Biases in Synthetic Populations*. Master's Thesis, San Diego State University, San Diego, CA.

<https://www.proquest.com/openview/d7eca16bbc8044ae1c12992e58aa3106/1?pq-origsite=gscholar&cbl=18750&diss=y>

## 7.25. Title: **Sharing In and Sharing Out: The Equity Implications of Informal Vehicle-Sharing**

**Author(s):** Paul, J.

**Abstract:** U.S. residents travel in cars for the vast majority of their trips. Yet car travel imposes costs on the individual (in terms of out-of-pocket costs) and society (via air pollution, congestion, and collision rates). Urban planners, policymakers, and elected officials have enacted many policies to subsidize and promote shared-vehicle travel, including via public transit, to mitigate these costs. Yet despite the billions of public dollars poured into public transportation, most shared travel in the U.S. occurs in private cars. And by extending mobility to people with limited car access, informal automobile sharing—with household members, friends, coworkers, and strangers—also offers benefits to disadvantaged travelers. But due to data limitations and policy emphases on public forms of shared travel, few researchers have systematically examined the relationship between transportation disadvantage and informal sharing.

In this dissertation, I use mixed methods to answer different aspects of a single question: What utility does informal vehicle-sharing offer U.S. travelers? In the first essay, I use quantitative methods to explore the factors that determine whether a traveler chooses to share. In particular, I emphasize how disadvantage (in the form of medical conditions, poverty, and vehicle access) influences informal automobile sharing. Using data from the 2017 National Household Travel Survey (NHTS), I model automobile sharing as an expression of rational choice and thus a proxy for the utility it offers travelers. I find that while transportation disadvantage is associated with certain sharing behaviors (including borrowing cars and receiving rides from people living in other households), trip purposes—particularly non-work-related ones—best predict the likelihood of sharing a private vehicle.

In the latter two essays, I analyze data from the Craigslist rideshare board to examine the opportunities and challenges people face in ridesharing with strangers. In the second essay, I use mixed methods to analyze web-scraped data. I examine the physical qualities of trips desired and offered on Craigslist and how they varied across California regions. I also measure the frequency and types of compensation that posters mentioned. In the third essay, I use qualitative methods to analyze information from surveys of and interviews with people who posted on the Craigslist rideshare board. I evaluate how often they successfully rideshared and how they balanced the risks and rewards of interacting with strangers.

Findings from the three essays highlight the potential of informal vehicle-sharing to address social and environmental challenges in the U.S. Millions of empty seats fill streets and highways every day, while many disadvantaged people struggle to meet their daily travel needs. Based on my findings, I recommend policies that provide automobile-based assistance, such as subsidized carshare programs, to low-income families. To facilitate ridesharing between strangers, I recommend that public agencies create digital applications to help people match with other travelers. I also recommend that agencies consider pricing road travel by distance to make non-sharing—and particularly driving alone across long distances—costlier. Doing so will help increase opportunities to share for all travelers.

**Subject Areas:** Shared-vehicle travel; Informal automobile sharing; Transportation disadvantage; Ridesharing

**Availability:** Paul, J. (2023). *Sharing In and Sharing Out: The Equity Implications of Informal Vehicle-Sharing*. Doctoral Dissertation, University of California, Los Angeles, CA.  
<https://escholarship.org/uc/item/6bt0d169>

## 7.26. Title: Chapter 1: The Challenges of Freight Transport in Cities

**Author(s):** Giuliano, G.

**Abstract:** Large cities are the economic engines of the global economy. They serve as logistics hubs in the global freight network, as well as the producers and consumers of most of the world's goods and services. Urban freight activity is growing and will continue to grow as a result of continued globalization and urbanization, rising per capita income, and the growth of E-commerce. Cities are increasingly challenged to effectively manage freight demand and reduce its negative impacts. This chapter presents an overview of urban freight and its challenges. It describes the growth of urban freight and explains its causal factors. It discusses the state of knowledge regarding the major negative externalities associated with urban freight: congestion, air pollution, traffic safety, noise, and environmental justice. Urban freight is addressed as being of two types: last-mile activity serving local supply and demand, and trade node activity serving global trade and supply chains. The main driver of last-mile urban freight is the rise of E-commerce and its impacts on the structure of supply chains and delivery patterns. Global trade determines the volume and geographic distribution of international trade and metropolitan areas that serve as major nodes experience an additional layer of freight traffic. The chapter ends with some concluding observations.

**Subject Areas:** Freight demand; Freight externalities; E-commerce; Urban freight policy

**Availability:** Giuliano, G. (2023). "Chapter 1: The Challenges of Freight Transport in Cities." In: Marcucci, E., Gatta, V., and Le Pira, M. (Eds.), *Handbook on City Logistics and Urban Freight*, pp. 11–34. Edward Elgar Publishing, Cheltenham, UK.  
<https://doi.org/10.4337/9781800370173.00008>



### 7.27. Title: Evidence for Modal Inertia in Multimodal Tours: An Integrated Choice and Latent Variable Modeling Approach

**Author(s):** Jabbari, P., Khan, N.A., and MacKenzie, D.

**Abstract:** In this paper, we aim to answer two main questions in the context of multimodal travel and new modes of transportation, such as autonomous vehicles: Firstly, as travelers gain the ability to readily compare modes side by side for each trip, will they become more willing to select the option that best meets their needs in the moment, or will they continue to prefer using a single mode for a whole tour? Secondly, we compare two approaches to estimating mode choice models in the context of a typical workday tour: one in which we enumerate each possible sequence of modes, and one in which we calculate the expected utility given all modes available for each trip separately, and sum over all trips in the tour. We find that the latter approach returns similar estimation results to the former, but is much faster and easier to compute, an advantage that would only grow with more mode alternatives or more trips in the tour. In addition, we discovered a substantial “mode inertia” in our sample: The utility of the mode used for the previous trip is significantly higher for the present trip. This finding indicates that respondents in our sample are more likely to stick with unimodal tours than multimodal ones.

**Subject Areas:** Multimodal travel; Mode choice; Mode alternatives; Mode inertia; Workday travel

**Availability:** Jabbari, P., Khan, N.A., and MacKenzie, D. (2023). “Evidence for Modal Inertia in Multimodal Tours: An Integrated Choice and Latent Variable Modeling Approach.” *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981231170185>

**7.28. Title: Exploring Heterogeneous Structural Relationships Between E-Shopping, Local Accessibility, and Car-Based Travel: An Application of Enriched National Household Travel Survey Add-On Data**

**Author(s):** Kim, S.H., Mokhtarian, P.L., Choo, S., and Circella, G.

**Abstract:** This study analyzes structural relationships between information and communication technology (ICT), e-shopping, local accessibility, and travel intensity in the U.S. state of Georgia. Beginning with the 2017 National Household Travel Survey (NHTS), we enriched the data by exploiting the add-on program. After obtaining contact information for the Georgia NHTS participants who expressed willingness to take a follow-up survey, we conducted another survey with those participants. In addition, we appended land use characteristics associated with respondents' home locations. To test the hypothesis of possible heterogeneity in structural relationships, we applied a mixed structural equation model. We corroborated our hypotheses that the use of ICT has a positive impact on e-shopping frequency, whereas local accessibility reduces e-shopping frequency. In addition, we identified two meaningful segments exhibiting different structural relationships. The smaller segment (12.7%) showed complementary effects of e-shopping on car-based travel intensity, but local accessibility did not have a significant impact on car-based travel intensity. The dominant segment (87.3%) presented a negative impact of local accessibility but no meaningful effect of e-shopping frequency on car-based travel intensity. A post hoc analysis revealed meaningful differences in demographics between the two classes. The study suggests that an assumption of homogeneous structural relationships between e-shopping and car-based travel intensity and between local accessibility and car-based travel intensity may not hold. The paper discusses benefits and practical issues concerning fusion of the NHTS data with other data sources. In addition, it stresses the potential of the NHTS add-on program and notes some recommendations.

**Subject Areas:** Economics; Highways; Vehicles and equipment; Accessibility; Automobiles; Electronic commerce; Heterogeneity; Telecommunications; Travel

**Availability:** Kim, S.H., Mokhtarian, P.L., Choo, S., and Circella, G. (2023). "Exploring Heterogeneous Structural Relationships Between E-Shopping, Local Accessibility, and Car-Based Travel: An Application of Enriched National Household Travel Survey Add-On Data." *Transportation Research Record: Journal of the Transportation Research Board*, 2677(5), pp. 463–480. <https://doi.org/10.1177/03611981221132854>

### 7.29. Title: Evaluating Segment-Level Active Mode Shift Potential Using Desire Lines

**Author(s):** Young, G., Wasserman, D., Foster, D., Singleton, P.A., and Tomlin, S.

**Abstract:** Understanding which active transportation facilities have a high potential for shifting car trips to active modes is a potent metric of success for funders seeking to make high-impact transportation investments. This paper documents the development and validation of a traveler alignment analysis tool that evaluates the orientation, proximity, and magnitude of trips by distance in origin–destination (OD) desire line data to evaluate mode shift potential at the segment level. This alignment analysis operates by using line features created by a Utah statewide OD matrix of vehicle trips taken from the Replica Places activity-based modeling data platform. Additionally, the research tests the implementation of jittering, a previously proposed method for OD line disaggregation, and the impact on traveler alignment performance. To tune parameters related to proximity, angle, and trip distance, a sensitivity analysis was conducted comparing similar mode shift potential trips generated by the proposed Traveler Alignment tool and 25 StreetLight Data pass-through zone analyses. This sensitivity analysis used a mean absolute error metric to minimize estimation error and understand how altering parameters and applying jittering affected tool performance. A Pearson correlation test indicates a significant, positive linear relationship ( $p < 0.01$ ) between Traveler Alignment tool outputs and results of the select-link analysis, indicating that this method produces reasonable results that may be used to evaluate different projects comparatively for their active mode shift potential.

**Subject Areas:** Active transportation; Mode shift potential; Segment level; StreetLight Data; Replica Places

**Availability:** Young, G., Wasserman, D., Foster, D., Singleton, P.A., and Tomlin, S. (2023). “Evaluating Segment-Level Active Mode Shift Potential Using Desire Lines.” *Transportation Research Record: Journal of the Transportation Research Board*.  
<https://doi.org/10.1177/03611981231175155>

### 7.30. Title: Emerging Trends in Household Travel Survey Programs

**Author(s):** Lawson, C.T., Krans, E., Rentz, E., and Lynch, J.

**Abstract:** Transportation planners use household travel surveys to understand travel behavior, whether to develop forecasts of travel activity using travel demand or simulation models, to analyze personal motivations that drive the decision to travel, to identify users of existing transportation infrastructure and services, or to determine responsiveness to available or future travel options. Large urban area transportation planning organizations are faced with making decisions on their next household travel surveying effort to meet growing data needs. The New York Metropolitan Transportation Planning Council (NYMTC) has focused attention on surveying options, including conducting a pilot study to evaluate the ability to collect household travel data using a smartphone app. This research reviews current travel surveying strategies aimed at improving timeliness and accuracy, while reducing participant burden (e.g., using smartphone technologies). It also includes a vision for a long-term data program, facilitated by the establishment of a regional Community of Practice (CoP) to support multi-agency data collection efforts.

**Subject Areas:** Household travel survey; Smartphone travel survey; Travel behavior data; Community of Practice; Long-term data collection program; Deployment strategy; Survey frequency

**Availability:** Lawson, C.T., Krans, E., Rentz, E., and Lynch, J. (2023). “Emerging Trends in Household Travel Survey Programs.” *Social Sciences & Humanities Open*, 7(1).  
<https://doi.org/10.1016/j.ssaho.2023.100466>

## Chapter 8. Traffic Safety

### 8.1. Title: Zone-Level Traffic Crash Analysis with Incorporated Multi-Sourced Traffic Exposure Variables Using Bayesian Spatial Model

**Author(s):** Zhang, H., Bao, J., Hong, Q., Chang, L., and Yin, W.

**Abstract:** The primary objective of this study is to discover traffic exposure variables from some new data sources and explore how these new data sources and their combination affects the performance of zone-level crash models. Seven types of check-in activities and five types of taxi trips are inferred from Twitter and taxi GPS records, respectively. Then, Bayesian spatial models are employed to conduct zone-level traffic crash analysis. The results suggest that some specific check-in activities and inferred taxi trips are closely related with zone-level crash counts and thereby confirms the benefits of incorporating new data sources into zone-level crash models. The comparative analyses further indicate that Twitter check-in activities perform better than inferred taxi trips as a proxy for traffic exposures on spatial analyses of traffic crashes, and detailed trip purpose information hidden in new data sources greatly benefits zone-level crash models than simply aggregating location points in each zone. The results of this study reveal that each big data source has its prominent coverage of user groups and spatial areas, and their combination can serve as effective supplementary information to traditional exposure variables to improve the performance of zone-level crash models and better reveal the spatial impacts of human activities on traffic crashes. The findings of this study can help transportation authorities develop more targeted traffic demand adjustment strategies to effectively reduce zone-level crash risks.

**Subject Areas:** Spatial analyses; Bayesian spatial model; Traffic exposure; Crash

**Availability:** Zhang, H., Bao, J., Hong, Q., Chang, L., and Yin, W. (2023). "Zone-Level Traffic Crash Analysis with Incorporated Multi-Sourced Traffic Exposure Variables Using Bayesian Spatial Model." *Journal of Transportation Safety & Security*.  
<https://doi.org/10.1080/19439962.2022.2164815>

## 8.2. Title: Impact of Driver's Age and Gender, Built Environment, and Road Conditions on Crash Severity: A Logit Modeling Approach

**Author(s):** Lee, D., Guldmann, J.-M., and von Rabenau, B.

**Abstract:** The purpose of this research is (1) to investigate the relationship between crash severity and the age and gender of the at-fault driver, the socio-economic characteristics of the surrounding environment, and road conditions, and (2) to explain the probability of a bodily injury crash, including fatality, with the alternative being a property damage-only crash. In contrast to earlier research that has focused on young and old drivers, age is considered here on its lifetime continuum. A logit model is adopted and the gender and age of the at-fault drivers are part of the independent explanatory variables. The unit of analysis is the individual crash. Since age is a continuous variable, this analysis shows more precisely how age impacts accident severity and identifies when age has little effect. According to the results, the type of vehicle, timing of the crash, type of road and intersection, road condition, regional and locational factors, and socio-economic characteristic have a significant impact on crashes. Regarding the effect of age, when an accident occurs, the probability of bodily injury or fatality is 0.703 for female drivers and 0.718 for male drivers at 15 years of age. These probabilities decline very slightly to 0.696 and 0.711, respectively, around 33 years of age, and then very slightly increase to 0.697 and 0.712, respectively, around 47.5 years of age. The results show that age affects crash severity following a polynomial curve. While the overall pattern is one of a downward trend with age, this trend is weak until the senior years. The policy implications of the results are discussed.

**Subject Areas:** Crash severity; At-fault drivers; Age and gender; Socio-economic factors; Built environment; Road conditions; Logit model

**Availability:** Lee, D., Guldmann, J.-M., and von Rabenau, B. (2023). "Impact of Driver's Age and Gender, Built Environment, and Road Conditions on Crash Severity: A Logit Modeling Approach." *International Journal of Environmental Research and Public Health*, 20(3). <https://doi.org/10.3390/ijerph20032338>

### 8.3. Title: Variation in Drivers' Seat Belt Use by Indicators of Community-Level Vulnerability

**Author(s):** Sartin, E.B., Lombardi, L.R., Metzger, K.B., Myers, R.K., Pfeiffer, M.R., and Curry, A.E.

**Abstract: Introduction:** Examining crash reports with linked community-level indicators may optimize efforts aimed at improving traffic safety behaviors, such as seat belt use. To examine this, quasi-induced exposure (QIE) methods and linked data were used to (a) estimate trip-level seat belt non-use of New Jersey (NJ) drivers and (b) determine the degree to which seat belt non-use is associated with community-level indicators of vulnerability.

**Method:** Driver-specific characteristics were identified from crash reports (age, sex, number of passengers, vehicle type) and licensing data (license status at the time of the crash). Geocoded residential addresses were leveraged within the NJ Safety and Health Outcomes warehouse to create quintiles of community-level vulnerability. QIE methods were applied to estimate trip-level prevalence of seat belt non-use in non-responsible, crash-involved drivers between 2010 and 2017 (n = 986,837). Generalized linear mixed models were then conducted to calculate adjusted prevalence ratios and 95% confidence intervals for being unbelted for driver-specific variables and community-level indicators of vulnerability.

**Results:** Drivers were unbelted during 1.2 percent of trips. Males, those with suspended licenses, and those without passengers had higher rates of being unbelted than their counterparts. An increase was observed in traveling unbelted with increasing quintiles of vulnerability, such that drivers in the most vulnerable communities were 121 percent more likely to be unbelted than those in the least vulnerable communities.

**Conclusions:** Prevalence of driver seat belt non-use may be lower than previously estimated. Additionally, communities with the highest amount of the population living with three or more indicators of vulnerability have higher rates of seat belt non-use; this may be a particularly useful metric to inform future translational efforts improving seat belt use.

**Practical Applications:** As evidenced by the findings that risk of being unbelted increased as drivers' community vulnerability increased, novel communication efforts tailored to drivers from vulnerable neighborhoods may optimize efforts.

**Subject Areas:** Health behaviors; Motor vehicles; Traffic injury; Risk factors; Community Resilience Estimates

**Availability:** Sartin, E.B., Lombardi, L.R., Metzger, K.B., Myers, R.K., Pfeiffer, M.R., and Curry, A.E. (2023). "Variation in Drivers' Seat Belt Use by Indicators of Community-Level Vulnerability." *Journal of Safety Research*, 85, pp. 140–146.  
<https://doi.org/10.1016/j.jsr.2023.01.013>

#### 8.4. Title: What Factors Contribute to E-Scooter Crashes: A First Look Using a Naturalistic Riding Approach

**Author(s):** White, E. et al.

**Abstract: Introduction:** Shared dockless electric scooters (E-scooters) are a popular shared mobility service providing an accessible last-mile transportation option in urban and campus environments. However, city and campus stakeholders may hesitate to introduce these scooters due to safety concerns. While prior E-scooter safety studies have collected injury data from hospitals or riding data under controlled or naturalistic conditions, these datasets are limited and did not identify risk factors associated with E-scooter riding safety. To address this gap in E-scooter safety research, this study collected the largest naturalistic E-scooter dataset to date and quantified the safety risks associated with behavioral, infrastructure, and environmental factors.

**Method:** A fleet of 200 E-scooters was deployed on Virginia Tech’s campus in Blacksburg, VA, for a 6-month period. Fifty were equipped with a unique onboard data acquisition system using sensors and video to capture E-scooter trips in their entirety. The resulting dataset consisted of 3,500 hours of data spanning over 8,500 trips. Algorithms were developed to identify safety critical events (SCEs) in the dataset, and analyses were conducted to determine the prevalence of various SCE risk factors and associated odds ratios.

**Results:** Results from this study indicate that infrastructure-related factors, behavior of E-scooter riders and other actors, and environmental factors all contributed to the SCE risk for E-scooter riders in Virginia Tech’s pedestrian-dense campus environment.

**Conclusions:** To help mitigate unsafe rider behavior, educational outreach programs should quantify the significant risks associated with infrastructure, behavioral, and environmental risk factors and provide clear recommendations to riders. Improved infrastructure maintenance and design may also improve safety for E-scooter riders.

**Practical Applications:** The infrastructure, behavioral, and environmental risk factors quantified in this study can be applied by E-scooter service providers, municipalities, and campus administrators to develop mitigation strategies to reduce the safety risks associated with E-scooter deployments in the future.

**Subject Areas:** Safety; Last-mile transportation; Mobility as a service; Crash severity; Crash risk

**Availability:** White, E. et al. (2023). “What Factors Contribute to E-Scooter Crashes: A First Look Using a Naturalistic Riding Approach.” *Journal of Safety Research*, 85, pp. 182–191. <https://doi.org/10.1016/j.jsr.2023.02.002>



**8.5. Title: Bicycle Helmet Influence in the New Millennium on United States Head, Traumatic Brain Injury, Upper and Lower Body Injury Rates**

**Author(s):** Gillham, C.

**Abstract:** This study compares cycling participation and helmet wearing survey results with bicycle-related total injuries, head injuries, traumatic brain injuries, and upper-/lower-body injuries for all ages—youth and adults—who presented to emergency departments or were hospitalized in the United States from 2001 to 2020. Demographic increases/decreases in bicycle-related total injuries concur with participation survey trends, and this is reflected through injury trends for body parts not influenced by helmet wearing. The decrease in 0–17yo total ED presentations from 2001–2010 to 2011–2020 was greater than the decrease in head injuries, but the decrease in total hospital admissions was less than the decrease in hospitalized head injuries. The TBI proportion of 0-17yo head injury ED presentations increased significantly, and to a lesser extent among hospitalized head injuries. 18yo+ head injury ED presentations increased at a significantly greater rate than total injuries from 2001–2010 to 2011–2020. 18yo+ hospital admissions more than doubled and head injuries increased 81.6%. The TBI proportion among 18yo+ ED head injuries increased by 9%, while the hospitalized head injury TBI proportion increased from 84.2% to 86.8%. Future studies should examine the relationship between cycling participation and head injuries to determine why total youth injuries, including head injury declines, were commensurate with participation declines; why adult total injuries, including head injuries increased at rates above estimated participation trends; and why the TBI proportion of head injuries has increased despite a greater number of cyclists wearing helmets since 2001.

**Subject Areas:** Cyclist hospital admissions; Cyclist emergency department presentations; Cyclist head injuries; Cyclist traumatic brain injuries; Bicycle helmet injuries

**Availability:** Gillham, C. (2023). *Bicycle Helmet Influence in the New Millennium on United States Head, Traumatic Brain Injury, Upper and Lower Body Injury Rates*. medRxiv preprint, Cold Spring Harbor Laboratory Press, Long Island, NY.  
<https://doi.org/10.1101/2023.02.12.23285812>

**8.6. Title: Characteristics of Fatal, Pedestrian-Involved, Motor Vehicle Crashes in West Virginia: A Cross-Sectional and Spatial Analysis**

**Author(s):** Rudisill, T.M., Barbee, L.O., and Hendricks, B.

**Abstract:** Fatal, pedestrian-involved, motor vehicle collisions are increasing in the United States yet remain lower in rural states such as West Virginia. This study's purpose was to investigate the overall risk factors of pedestrian fatalities by rurality and sex in West Virginia. Data were obtained from the Fatality Analysis Reporting System. The fatality had to occur within West Virginia between 1 January 2009 and 31 December 2019. Risk factors of rural vs. urban and male vs. female crashes were determined using multivariable logistic regression models. Clustering of crash locations was analyzed using kernel density estimation and Ripley's K. Among the 254 fatalities, most victims were male (70%). Most crashes occurred at night (76%), on highways (73%), on level (71%), non-curved (84%), dry (82%) roads during fair weather conditions (82%). Nearly 34% of the victims tested positive for alcohol. Men were 2.5 times as likely to be hit in a rural area (OR = 2.5; [95% CI: (1.2, 5.4)]), on curved roads, and 57% less likely (OR = 0.43; [95% CI: (0.2, 0.9)]) to test positive for drugs compared to women. Crash characteristics, including location, were similar between the sexes. As many risk factors were modifiable behaviors, public health interventions to ensure pedestrian safety may be necessary.

**Subject Areas:** Pedestrian; Fatal; Motor vehicle; Rural

**Availability:** Rudisill, T.M., Barbee, L.O., and Hendricks, B. (2023). "Characteristics of Fatal, Pedestrian-Involved, Motor Vehicle Crashes in West Virginia: A Cross-Sectional and Spatial Analysis." *International Journal of Environmental Research and Public Health*, 20(7). <https://doi.org/10.3390/ijerph20075251>

**8.7. Title: Overview of Walking Rates, Walking Safety, and Government Policies to Encourage More and Safer Walking in Europe and North America**

**Author(s):** Buehler, R. and Pucher, J.

**Abstract:** Walking is the most sustainable means of daily travel for short trip distances and is a key component of the overall transport system. This paper documents variation in walking rates among countries, cities in the same country, and in different parts of the same city. Our international analysis of official government statistics shows that walking rates are highest for short trips, higher for women than for men, decline with increasing income, and remain constant as age increases. Walking fatality rates are much higher in the USA compared with the other countries we examined, both per capita and per km walked. Government policies that would increase walking rates while improving pedestrian safety include integrated networks of safe and convenient walking infrastructure; roadways and intersections designed for the needs of pedestrians; land-use regulations that encourage mixed uses and short trip distances; lower city-wide speed limits and traffic calming in residential neighborhoods; reduced supply and increased price of parking; traffic laws that give priority to pedestrians; improved traffic education for motorists and non-motorists; tax surcharges on large personal vehicles; and strict enforcement of laws against drink and distracted driving. Five decades of success with these policies in many European cities provide practical examples for car-oriented cities to follow, especially in North America.

**Subject Areas:** Walking; Pedestrian; Safety; International comparison; Time trends; Modal share distribution; Trip distance; Demographics; Government policies

**Availability:** Buehler, R. and Pucher, J. (2023). "Overview of Walking Rates, Walking Safety, and Government Policies to Encourage More and Safer Walking in Europe and North America." *Sustainability*, 15(7). <https://doi.org/10.3390/su15075719>

## 8.8. Title: Resources and Tools to Improve Pedestrian Safety

**Author(s):** Arpin, J., Finley, K., and Hamre, A.

**Abstract:** Pedestrian fatalities have increased at an alarming rate. “According to the Fatality Analysis Reporting System (FARS), pedestrian fatalities increased by 53 percent from 2009 to 2018, while other traffic deaths increased by only 2 percent” (U.S.DOT, 2020, p. 6). Pedestrian fatalities account for a growing percentage of all roadway fatalities. Transportation stakeholders are uniquely positioned to lead efforts to improve pedestrian safety. However, whether stakeholders engage in appropriate strategies to improve pedestrian safety is influenced by their traffic safety culture—their shared values and beliefs.

While pedestrian safety is found in many strategic highway safety plans across the country, there may be potentially competing values and beliefs that influence the deployment of effective pedestrian safety strategies. Values such as innovation or efficiency may influence planning, prioritization of transportation projects, and design efforts. Further, beliefs about support (or lack of support) for pedestrian strategies and implementation of such strategies may be influencing the deployment of effective strategies to improve pedestrian safety.

Therefore, understanding shared values and beliefs among transportation stakeholders about pedestrian safety is critical to growing a positive traffic safety culture, deploying effective strategies to improve pedestrian safety, and ultimately achieving our nation’s goal of zero deaths on our roadways. This project seeks to improve pedestrian safety by developing resources to assess and grow beliefs among transportation stakeholders to support deployment of effective pedestrian safety strategies.

**Subject Areas:** Pedestrian fatalities; Pedestrian safety strategies; Literature review; Interviews; Traffic safety stakeholders

**Availability:** Arpin, J., Finley, K., and Hamre, A. (2023). *Resources and Tools to Improve Pedestrian Safety*. Task 1 Report, Montana State University, Bozeman, MT.  
<https://www.mdt.mt.gov/research/projects/trafficsafety-ips.aspx>

### 8.9. Title: Usability and Vibration Analysis of a Low-Profile Automatic Powered Wheelchair to Motor Vehicle Docking System

**Author(s):** Lee, C.D. et al.

**Abstract:** The QLX is a low-profile automatic powered wheelchair docking system (WDS) prototype developed to improve the securement and discomfort of wheelchair users when riding in vehicles. The study evaluates the whole-body vibration effects between the proposed QLX and another WDS (4-point tiedown system) following ISO 2631-1 standards and a systematic usability evaluation. Whole-body vibration analysis was evaluated in wheelchairs using both WDS to dock in a vehicle while riding on real-world surfaces. Also, participants rated the usability of each WDS while driving a wheelchair and while riding in a vehicle in driving tasks. Both WDSs showed similar vibration results within the vibration health-risk margins but shock values below health-risk margins. Fifteen powered wheelchair users reported low task load demand to operate both WDS but better performance to dock in vehicles with the QLX ( $p = 0.03$ ). Also, the QLX showed better usability ( $p < 0.01$ ), less discomfort ( $p$ 's  $< 0.05$ ), and greater security compared to the 4-point tiedown while riding in a vehicle ( $p$ 's  $< 0.05$ ). Study findings indicate that both WDS maintain low shock exposure for wheelchair users while riding vehicles but a better performance overall to operate the QLX compared to the 4-point tiedown system, hence enhancing users' autonomy to dock in vehicles independently.

**Subject Areas:** Accessible transportation; Wheelchair docking system; Assistive technology; Securement; Vehicle safety

**Availability:** Lee, C.D. et al. (2023). "Usability and Vibration Analysis of a Low-Profile Automatic Powered Wheelchair to Motor Vehicle Docking System." *Vibration*, 6(1), pp. 255–268. <https://doi.org/10.3390/vibration6010016>

## Chapter 9. Transit Planning

### 9.1. Title: Transit Access to Subsidized Food Stores in the U.S. Midwest

**Author(s):** DeJohn, A.D., Widener, M.J., and Shannon, J.

**Abstract:** In the United States, low-income individuals and some racial and ethnic minorities have higher rates of transit use and food insecurity. The Supplemental Nutrition Assistance Program (SNAP), which provides low-income households with money for groceries at authorized retailers, creates a unique food procurement environment for participants. In this article, transit networks' effect on access to SNAP retailers is assessed by calculating transit travel times to all transitable SNAP stores of census block groups (CBGs) in thirty-three metropolitan areas in the U.S. Midwest. Low transit access CBGs are identified and compared to U.S. Department of Agriculture (USDA) low-income, low-access (LILA) census tracts. Store type transit access ratios are analyzed to further specify disproportionate access to healthy food retailers. Findings indicate that low transit access is experienced in fringe-urban, majority White, car-dependent CBGs. However, approximately 24,380 people receiving public assistance, 145,636 Black people, 135,731 non-Black Hispanic people, and 108,325 low-income people live within these CBGs. The USDA's LILA census tracts are more expansive than this study's low-income, low-transit access (LILTA) tracts. Despite being classified as rural, LILTA-only tracts had sixty-eight households without a vehicle, on average. Future research and policy should engage populations in suburban and exurban regions to accommodate transportation needs of a nonnegligible portion of potentially food-insecure households.

**Subject Areas:** Food environments; Food insecurity; Supplemental Nutrition Assistance Program; Transit access; Transport poverty

**Availability:** DeJohn, A.D., Widener, M.J., and Shannon, J. (2023). "Transit Access to Subsidized Food Stores in the U.S. Midwest." *The Professional Geographer*, 75(1), pp. 76–89. <https://doi.org/10.1080/00330124.2022.2103720>

**9.2. Title: How to Save American Mass Transit**

**Author(s):** Scribner, M.

**Abstract:** Blog.

**Subject Areas:** Mass transit; Ridership; Fare-free transit; Policy

**Availability:** Scribner, M. (2023). "How to Save American Mass Transit." *Reason Foundation*.  
<https://reason.com/2023/03/03/how-to-save-american-mass-transit/>

**9.3. Title: Riders' Perceptions Toward Transit Bus Electrification: Evidence from Salt Lake City, Utah**

**Author(s):** Flaris, K., Gkritza, K., Singleton, P.A., Graul, A.R.H., and Song, Z.

**Abstract:** While battery electric buses (BEBs) can lead to energy savings and reduced emissions, BEB adoption is developing slowly. Although BEBs offer quieter operations, better acceleration, and no smell of diesel or gas fumes, little focus has been placed on the user's perspective. This study investigates bus riders' preferences toward BEBs. To achieve these objectives, a survey was designed and administered to solicit riders' typical travel behaviors and patterns as well as preferences and opinions about BEBs' performance in terms of emissions and noise. Statistical analysis showed that several factors influence rider perceptions toward transit bus electrification that include trip purpose, attitudes toward environmental issues and environmental impacts of BEBs, and certain non-instrumental ride factors, such as ride comfort and social image. A better understanding of the importance of electrification to transit riders can help transit service providers adjust their marketing decisions and their systemwide operations to accommodate preferences toward BEBs.

**Subject Areas:** Electric buses; User perceptions; Ride comfort; Multivariate probit model; Bivariate probit model; Transit electrification

**Availability:** Flaris, K., Gkritza, K., Singleton, P.A., Graul, A.R.H., and Song, Z. (2023). "Riders' Perceptions Toward Transit Bus Electrification: Evidence from Salt Lake City, Utah." *Transportation Research Part D: Transport and Environment*, 117. <https://doi.org/10.1016/j.trd.2023.103642>



#### 9.4. Title: Urban Transit Infrastructure and Inequality

**Author(s):** Lee, K.H. and Tan, B.J.

**Abstract:** How does transit expansion impact welfare and inequality? We exploit data covering the universe of transit farecard trips from Singapore, taken to a novel quantitative spatial model with heterogeneous worker groups incorporating travel to consume non-tradable goods and services. First, we establish that low- and high-income workers live in and travel to different places. Second, using gravity regressions, we find that low-income workers are more sensitive to changes in travel time than their high-income counterparts. Third, since low-income workers are overwhelmingly employed in non-tradable sectors, we find that changes in consumption travel induced a spatial re-organization of low-income jobs in the city, with important distributional implications. We show that the Downtown Line resulted in large welfare gains for high-income workers but near zero for low-income workers. All workers benefited from improved access to consumption opportunities, but low-income jobs in the non-tradable sector moved to less attractive workplaces. Abstracting from consumption travel underestimates the inequality effects five-fold.

**Subject Areas:** Transit expansion; Equality; Welfare

**Availability:** Lee, K.H. and Tan, B.J. (2023). *Urban Transit Infrastructure and Inequality*. Authors' Manuscript, Princeton University, Princeton, NJ. <https://kwokhao.io/papers/20230403-lee-tan-manuscript.pdf>

**9.5. Title: Evolution of Mode Use During the COVID-19 Pandemic in the United States: Implications for the Future of Transit**

**Author(s):** Magassy, T.B. et al.

**Abstract:** The COVID-19 pandemic has brought about transformative changes in human activity-travel patterns. These lifestyle changes were naturally accompanied by and associated with changes in transportation mode use and work modalities. In the United States, most transit agencies are still grappling with lower ridership levels, thus signifying the onset of a new normal for the future of transit. This paper addresses this challenge using a novel panel survey data set collected from a representative sample of individuals across the United States. The study involved the estimation of a panel multinomial probit model of mode choice to capture both socio-economic effects and period (pre-, during-, and post-COVID) effects that contribute to changes in mode choice. This paper provides rich insights into the evolution of commute mode use as a result of the pandemic, with a particular focus on public transit. Through a rigorous modeling approach, this paper provides a deep understanding of how transit use has evolved, how it is likely to evolve into the future, and the socio-economic and demographic characteristics that affect the evolution (and expected future use) of public transit. Results suggest that transit patronage is likely to remain depressed by about 30% for the foreseeable future, in the absence of substantial changes in service configurations. This study also shows that minority groups and those living in higher-density regions are more likely to exhibit a return to transit use in the post-pandemic period.

**Subject Areas:** COVID-19; Activity-travel patterns; Commute mode; Public transit; Transit ridership; Demographics; Population density

**Availability:** Magassy, T.B. et al. (2023). "Evolution of Mode Use During the COVID-19 Pandemic in the United States: Implications for the Future of Transit." *Transportation Research Record: Journal of the Transportation Research Board*.  
<https://doi.org/10.1177/03611981231166942>

**9.6. Title: The Quiet Revolution Revisited: Low-Information Voting and Ballot Box Support for Public Transportation in the United States**

**Author(s):** Manville, M.

**Abstract:** I use an original survey to examine support for a large, transit-oriented tax ballot in the United States. Support for increasing taxes to finance public transportation is associated with a positive effect for transit but not with a desire to drive less or concerns about congestion. Most respondents, even those who voted for the measure, knew relatively little about it; partisan affiliation was one of the strongest predictors of support. In combination, these results suggest devolving transit finance to local ballots. Votes cast with low levels of information may help explain why changes in travel behavior are often small after transit ballots win.

**Subject Areas:** Transit; Voting; Congestion; Travel behavior; Referenda

**Availability:** Manville, M. (2023). *The Quiet Revolution Revisited: Low-Information Voting and Ballot Box Support for Public Transportation in the United States*. Preprint Research Article, Research Square, Durham, NC. <https://doi.org/10.21203/rs.3.rs-3006154/v1>

## Chapter 10. Travel Behavior

### 10.1. Title: Household Family Dynamics and Telecommuting: Analysis of the 2017 National Household Travel Survey

**Author(s):** Menon, N. and Gawade, M.

**Abstract:** Over the past few years, telecommuting has rapidly gained in popularity and grown extensively in the United States. Using data from the 2017 National Household Travel Survey (NHTS), this paper investigates the socio-demographic (individual- and household-level), work attributes, health, and built environment/land-use land use factors that affect individuals' option and frequency of working from home across different types of U.S. households. Random Parameter Ordered Probit (RP-OP) models are estimated, and the results suggest the influence of individual-level attributes, such as gender, race and ethnicity, household income, and education on the adoption and frequency of telecommuting, with considerable levels of unobserved heterogeneity in behavior. As children grow in age, workplace flexibility seems to be increasing as well, pointing to the potential challenges faced by younger families. Additional health-level metrics investigated show the unequal distribution of workplace privileges among healthier individuals. Results also indicate how multi-vehicle ownership in households with dependent members is not always a determinant for greater workplace flexibility as more and more Americans are being forced into car ownership due to the sprawled nature of our cities, additional trip-making requirements, and the unreliability of the existing transportation systems. Lastly, there are important neighborhood/land-use effects that provide deeper insight into our understanding of the telecommuting options and frequencies.

**Subject Areas:** Telecommuting; Workplace flexibility; Socio-demographic; Work attributes; Health; Built environment/land-use

**Availability:** Menon, N. and Gawade, M. (2023). *Household Family Dynamics and Telecommuting: Analysis of the 2017 National Household Travel Survey*. Transportation Research Board 102nd Annual Meeting, Washington, D.C.  
<https://annualmeeting.mytrb.org/OnlineProgramArchive/Details/19320>

## 10.2. Title: How Regularly Do People Visit Service Places?

**Author(s):** Zhong, S. and Bian, L.

**Abstract:** It is often believed that regularities are embedded in mobile behaviors. Highly regular mobile behaviors, such as daily commutes between home and workplace, have been actively investigated in the context of health risks. Less regular mobile behaviors, such as visits to service places (e.g., supermarkets and healthcare facilities), have not received much attention. This study explores the regularity in service place visits using a deep learning method and the effect of place type on the stability of recurring visits using an entropy assessment.

Results reveal both periodic and bursty visit behaviors to service places. The periodic visits are prominent on the weekly and bi-weekly scales, and the bursty visits dominate the multi-day scales. Service place type indeed affects the stability of recurring visits, and certain place types have the strongest effect. The research findings substantially expand the knowledge of mobile behaviors and are valuable in informing both visitor-based and place-based health risks.

**Subject Areas:** Human mobility; Service place visits behaviors; Service place types

**Availability:** Zhong, S. and Bian, L. (2023). "How Regularly Do People Visit Service Places?" *Computers, Environment and Urban Systems*, 99.  
<https://doi.org/10.1016/j.compenvurbsys.2022.101896>

### 10.3. Title: Household Structure and Gender Disparities in Out-of-Home Time Use

**Author(s):** Hu, L.

**Abstract:** This paper examines how household structure affects gender differences in out-of-home time use, including time spent on travel and time spent at destinations, among full-time workers in America. The research revisits the topic of gendered travel behavior in the context of increasingly diversified American households, which had shifted family roles and imposed complex challenges in work-life balance for both working women and men. Results based on the 2017 U.S. National Household Travel Survey (NHTS) suggest that household effects on the total out-of-home time and work-related time concentrate on working women but not men; meanwhile, the household effects on time use on other, non-work activities affect both women and men. Intrinsic gender differences in time use exist between single childless women and men who tend to have minimum levels of household responsibilities. The presence of children directly impacts the time use of working women in two-adult households as well as single parents—women and men. Women’s relative economic status—whether they are the sole breadwinners or not—does not systematically affect time use. These nuanced findings call for improving the family and childcare support systems for both women and men in the U.S.

**Subject Areas:** Travel time; Stay time; Maintenance and care; Discretionary activities; Single parents; Dual-income

**Availability:** Hu, L. (2023). “Household Structure and Gender Disparities in Out-of-Home Time Use.” *Travel Behaviour and Society*, 31, pp. 106–119. <https://doi.org/10.1016/j.tbs.2022.11.008>

**10.4. Title: Factors Influencing the Types of Merchandise Purchased Online: Evidence From the 2018 California Survey of Emerging Transportation Trends**

**Author(s):** Yousefi, N., Wang, K., and Circella, G.

**Abstract:** Understanding consumer preferences has become increasingly important with the growth of E-commerce. This study leverages the 2018 California Panel Study of Emerging Transportation Trends to analyze the factors that influence consumer decisions to purchase different merchandise online. Diffusion of innovations theory and efficient market hypothesis guide the execution of our research. According to our findings, two hypotheses can explain the links between neighborhood characteristics and online shopping frequency for different types of merchandise: 1) physical books and DVDs, 2) e-books, digital movies, TV shows, 3) clothing, shoes, 4) groceries, fresh produce, flowers, and 5) electronics. People’s online purchasing behaviors are significantly influenced by sociodemographic traits. Online shopping is less popular among people who drive more frequently. The research results can provide valuable insights and help assess the impacts of e-shopping behaviors.

**Subject Areas:** E-commerce; Types of Merchandise; Spatial Attributes; Multivariate Ordered Probit Model

**Availability:** Yousefi, N., Wang, K., and Circella, G. (2023). “Factors Influencing the Types of Merchandise Purchased Online: Evidence From the 2018 California Survey of Emerging Transportation Trends” *Transportation Research Interdisciplinary Perspectives*, 17. <https://doi.org/10.1016/j.trip.2022.100734>

**10.5. Title: Growth in Commuting Patterns and Their Impacts on Rural Workforce and Economic Development**

**Author(s):** Kures, M. and Deller, S.C.

**Abstract:** Residential and employment locational decisions for working households are frequently commingled. Numerous economic and social factors, such as job accessibility, wage differentials, housing markets, travel time, trip-chaining opportunities, dual employment, and other quality-of-life considerations, influence where a household ultimately chooses to reside relative to places of employment. These choices in turn shape commuting patterns within a region. Using the U.S. Census Bureau’s LEHD Origin-Destination Employment Statistics (LODES), the authors explore longitudinal changes in the growth of commuting patterns based on commuters traveling 50 miles or more between their place of residence and place of employment for counties in Midwestern states from 2002 to 2019. The authors find that the rate of commuters traveling 50 miles or more appears to have increased in rural areas across several periods and regions. Thus, rural communities concerned about labor supply constraints must take into consideration more expansive geographic labor markets and approach labor force development in partnership across local economic development institutions. In essence, the growth in commuting sheds requires stronger regional partnerships to address the issue.

**Subject Areas:** Rural workforce; Commuting patterns; Economic and social factors; Commuting distance

**Availability:** Kures, M. and Deller, S.C. (2023). “Growth in Commuting Patterns and Their Impacts on Rural Workforce and Economic Development.” *Economic Development Quarterly*, 37(1), pp. 54–63. <https://doi.org/10.1177/08912424221145173>



**10.6. Title: Linking Travel Behavior and Tourism Literature: Investigating the Impacts of Travel Satisfaction on Destination Satisfaction and Revisit Intention**

**Author(s):** Acharya, S., Mekker, M., and De Vos, J.

**Abstract:** This study aims to link two closely related domains in literature—travel behavior and tourism. Travel behavior studies partly aim to improve travel satisfaction by exploring its relationships with overall and domain-specific life satisfaction. Tourism studies, on the other hand, focus on improving the attraction and sustainability of tourism destinations and often investigate the factors affecting destination satisfaction and revisit intention. The present study uncovers the interconnections between travel behavior and tourism by investigating the impacts of travel satisfaction on destination satisfaction and revisit intention. An online survey of 696 visitors to national parks in the US conducted in the summer of 2022 was analyzed using a structural equation modeling approach. Analysis results show that travel satisfaction has a direct impact on destination satisfaction and both direct and indirect (through destination satisfaction) impacts on revisit intention. Also, interestingly, results reveal that travel satisfaction has a stronger impact on revisit intention than destination satisfaction. These results offer an important implication to the tourism destination managers that investing in destination attributes alone might not be sufficient to attain the desired level of tourism for the destination. Thus, an area to be focused on is improving the satisfaction and experiences of travelers on the way to their destination. This could be achieved by investing in transportation infrastructures, networks, facilities, and services connecting major tourism destinations and city centers.

**Subject Areas:** Destination satisfaction; Revisit intention; Tourism; Travel behavior; Travel satisfaction; Satisfaction with travel scale; Structural equation modeling

**Availability:** Acharya, S., Mekker, M., and De Vos, J. (2023). “Linking Travel Behavior and Tourism Literature: Investigating the Impacts of Travel Satisfaction on Destination Satisfaction and Revisit Intention.” *Transportation Research Interdisciplinary Perspectives*, 17. <https://doi.org/10.1016/j.trip.2022.100745>

**10.7. Title: Analysis of Urban Travel Time and Travel Distance: A Fully Parametric Bivariate Hazard-Based Duration Modelling Approach with Correlated Grouped Random Parameters**

**Author(s):** Ahmed, S.S., Fountas, G., Anastasopoulos, P.C., and Peeta, S.

**Abstract:** Hazard-based duration models have been successfully implemented to study event durations across many disciplines. This paper focuses on integrating—for the first time, to the authors’ knowledge—the hazard-based duration modelling method into a novel bivariate framework while accounting for the cross-equation error correlation, endogeneity, unobserved heterogeneity, and unbalanced panel effects, by employing correlated grouped random parameters. The developed framework provides the flexibility of using appropriate, case-specific distribution of the hazard function for each duration. Greater explanatory power is achieved through estimation of panel-specific correlated random parameters, which can account for the interaction between the captured unobserved effects and their impact on durations. For demonstrative purposes, travel time and travel distance for trips in the year 2017 and made by household members from the Miami metropolitan area, FL, are modelled using the proposed method. The results show that using different distributions significantly affects the overall statistical fit, forecasting accuracy, and the interaction of error terms within the models.

**Subject Areas:** Bivariate hazard-based duration model; Correlated grouped random parameters; Spatio-temporal hazard modelling; Unobserved heterogeneity

**Availability:** Ahmed, S.S., Fountas, G., Anastasopoulos, P.C., and Peeta, S. (2023). “Analysis of Urban Travel Time and Travel Distance: A Fully Parametric Bivariate Hazard-Based Duration Modelling Approach with Correlated Grouped Random Parameters.” *Travel Behaviour and Society*, 31, pp. 271–283. <https://doi.org/10.1016/j.tbs.2022.12.004>

## 10.8. Title: Worker Age, Jobs-Housing Balance, and Commute Distance

**Author(s):** Blumenberg, E. and King, H.

**Abstract:** Anecdotal evidence suggests that the affordable housing crisis is forcing households to seek lower-cost housing in the outer reaches of major metropolitan areas, helping to explain recent increases in commute distance. In this study, we examine the location of young workers (under 30) and their jobs. We then test whether the relative availability of housing is associated with the commute distance of young workers, many of whom are relatively new to the labor market. To test this relationship, we use spatial regression to examine the relationship between the availability of housing in proximity to jobs (jobs-housing balance) and commute distance in two high-cost metropolitan areas in California: Los Angeles and the San Francisco Bay Area.

Controlling for other characteristics, commute distance is longer in neighborhoods with more jobs relative to housing. The effect size is stronger in San Francisco—where housing is most constrained—compared to Los Angeles. However, contrary to our hypothesis, jobs-housing balance is important to all workers regardless of age. Finally, while housing availability is associated with commute distance, its contribution is small relative to other factors. The findings suggest the importance of policies to greatly enhance housing availability in high-cost metropolitan areas. They also underscore the need to go beyond housing policy in efforts to significantly increase access to employment and reduce travel.

**Subject Areas:** Commute distance; Young workers; Jobs-housing balance; Residential location

**Availability:** Blumenberg, E. and King, H. (2022). *Worker Age, Jobs-Housing Balance, and Commute Distance*. Authors' Manuscript, University of California, Los Angeles, CA.  
<https://www.anderson.ucla.edu/sites/default/files/document/2023-01/2023-01WP.pdf>

**10.9. Title: Average Number of Miles Americans Drive Each Year**

**Author(s):** Beck, R.H.

**Abstract:** Blog.

**Subject Areas:** Annual miles driven; Driving mileage by individual state; Insurance rate; Accidents; Average commute distance

**Availability:** Beck, R.H. (2023). "Average Number of Miles Americans Drive Each Year." *Credible Operations, Inc.* <https://www.credible.com/blog/car-insurance/average-miles-driven-per-year/>

**10.10. Title: Understanding the Choice for Sustainable Modes of Transport in Commuting Trips with a Comparative Case Study**

**Author(s):** Yanar, T.

**Abstract:** This study aims to understand the reasons behind people's modal preferences in commuting trips, which contribute to transportation-related problems, and to develop and prioritize policies that increase the use of sustainable modes. For this reason, in this study, a comparative case study was conducted to evaluate the factors that lead to choosing or not choosing sustainable modes. Commuting trips in San Francisco, San Diego, Los Angeles, San Jose, and Sacramento, which are large cities with high automobile dependency and many potential alternatives to driving, were examined using the National Household Transportation Survey (NHTS) and spatial data. The factor classifications suggested in the literature were shaped according to the scope of the study and examined on four main headings. Proximity analyses were completed in the GIS environment to evaluate the environmental effects. The effects of all factor parameters on modal preferences were calculated for each mode of transport in the study with Binary Logistic Regression analyses. As a result of the comparative analysis, the barriers to using sustainable transportation modes in cities and the reasons for driving are determined. As a result, long-term policies were determined and prioritized with literature to manage these causes and barriers. The results show that modal choices are affected by many different parameters, the reasons differ locationally, and accordingly, the policy measures in each region should be different.

**Subject Areas:** Mode choices; Commuting trips; Sustainable transport; Comparative case study; National Household Travel Survey

**Availability:** Yanar, T. (2023). "Understanding the Choice for Sustainable Modes of Transport in Commuting Trips with a Comparative Case Study." *Case Studies on Transport Policy*, 11. <https://doi.org/10.1016/j.cstp.2023.100964>

### **10.11. Title: Spatial Implications of Telecommuting in the United States**

**Author(s):** Parkhomenko, A. and Delventhal, M.J.

**Abstract:** Telecommuting came roaring to the forefront of the American workplace in the spring of 2020. While no more than 8% of work was done remotely in 2019, shutdowns and social-distancing policies introduced at the onset of the COVID-19 pandemic pushed more than 1 out of every 3 American workers to telecommute. To reflect this shift, the research team aimed to update the spatial modeling toolbox to allow remote employment and develop a quantitative framework capable of analyzing the full range of reallocations, both within and across cities, which may result from its increasing popularity. The researchers build a quantitative spatial model in which some workers can substitute on-site effort with work done from home. The team quantifies their framework to match the distribution of jobs and residents across 4,502 U.S. locations. A permanent increase in the attractiveness of telework results in a rich non-monotonic pattern of reallocations within and across cities. Workers who can telecommute experience welfare gains, and those who cannot suffer losses. Additionally, broader access to jobs reduces inequality across residential locations. The framework robustly predicts changes in residents and housing prices observed in 2019–2021.

**Subject Areas:** Urban; Work from home; Commuting; Spatial equilibrium

**Availability:** Parkhomenko, A. and Delventhal, M.J. (2023). *Spatial Implications of Telecommuting in the United States*. Research Report, NCST-USC-RR-23-05, University of Southern California, Los Angeles, CA.

<https://escholarship.org/content/qt97q6c2rg/qt97q6c2rg.pdf>

**10.12. Title: How Much Are Electric Vehicles Driven? Depends on the EV**

**Author(s):** Doshi, S.S. and Metcalf, G.E.

**Abstract:** We use the 2017 National Household Travel Survey to investigate whether all-electric vehicles (EVs) are driven less than their counterfactual alternative in the US as hypothesized by Davis (2019). We find that selection effects reduce to a small degree the driving differential between EVs and gasoline- or diesel-powered vehicles. The dominant factor affecting annual miles driven is battery range. Once one limits the analysis to EVs with a range of 100 miles or more, the differences between EVs and internal combustion engine vehicles disappear. Given the rapidly increasing range of new EVs, we conclude that any difference in annual driving between EVs and other vehicles will be insignificant going forward. This has important implications for policy modeling, including such policies as a revenue neutral VMT-Gas Tax swap.

**Subject Areas:** Driving differential; Electric vehicles; Gasoline and diesel vehicles; Vehicle-miles-traveled tax

**Availability:** Doshi, S.S. and Metcalf, G.E. (2023). *How Much Are Electric Vehicles Driven? Depends on the EV*. Working Paper Series, CEEPR WP 2023-01, Center for Energy and Environmental Policy Research, Massachusetts Institute of Technology, Cambridge, MA. <https://ceepr.mit.edu/wp-content/uploads/2023/01/MIT-CEEPR-WP-2023-01.pdf>

### **10.13. Title: Understanding the Impact of Ridesharing Services on Traffic Congestion**

**Author(s):** Behroozi, M.

**Abstract:** Improving urban mobility systems has been one of the main engineering challenges, especially in large cities and metropolitan areas. Since their emergence, ridesharing services have had a promising outlook on disrupting the current urban transportation system and using technology to solve its problems. However, studies on their current and projected future accomplishments toward this goal are divided. Despite being supported by many well-designed studies, many recent studies point out the new problems caused by these services or the exacerbation of the old problems after their entry to the mobility services mix of a city. This chapter reviews the research from both sides and describes policy measures and research gaps that could help mitigate such potential negative impacts on traffic congestion and improve the overall efficiency and effectiveness of the urban mobility systems.

**Subject Areas:** Ridesharing; Traffic congestion; Reservations in advance; Policy design; Integrated mobility systems

**Availability:** Behroozi, M. (2023). “Understanding the Impact of Ridesharing Services on Traffic Congestion.” In: Heydari, B., Ergun, O., Dyal-Chand, R., and Bart, Y. (Eds.), *Reengineering the Sharing Economy: Design, Policy, and Regulation*, pp. 119–145. Cambridge University Press, Cambridge. <https://doi.org/10.1017/9781108865630.011>



#### 10.14. Title: Modeling Vehicle-Miles of Travel Accounting for Latent Heterogeneity

**Author(s):** Nazari, F. and Mohammadian, A.

**Abstract:** Vehicle use is associated with negative externalities, such as traffic congestion, air pollution, and greenhouse gas emissions. Particularly in the U.S. as a car-oriented country, vehicle use—in terms of vehicle-miles of travel (VMT)—has been on the rise and is projected to increase in the future. To curb the VMT growth and mitigate the associated externalities, policymakers can design informed strategies based on VMT predicted by vehicle use models. However, traditional vehicle use models capture merely the observed heterogeneity across vehicle decision-making units (e.g., individuals) and ignore the latent or taste heterogeneity sourced in individuals' attitudes and lifestyle preferences, which may cause biased and inconsistent results that mislead implications for policymakers. To address this research gap, the present study introduces a latent class regression model, where a probabilistic multinomial logit component endogenously classifies a sample of vehicle use observations so as to be homogeneous within and heterogeneous across the classes with respect to VMT. At the same time, a finite set of linear regression equations in the number of the latent classes yields class-specific VMT. The model is estimated on a sample dataset from the State of California identifying three latent classes, verifying the hypothesis of positing vehicle use on both observed and unobserved heterogeneity. The estimation results are analyzed to infer implications of potential policies aiming at reducing VMT through increasing fuel cost and switching to telework and to evaluate the efficiency of resource allocation to policies by targeting different classes with distinctive characteristics.

**Subject Areas:** Vehicle-miles of travel; Taste heterogeneity; Latent class regression; Fuel cost; Telework

**Availability:** Nazari, F. and Mohammadian, A. (2023). "Modeling Vehicle-Miles of Travel Accounting for Latent Heterogeneity." *Transport Policy*, 133, pp. 45–53.  
<https://doi.org/10.1016/j.tranpol.2023.01.005>

**10.15. Title: Socioeconomics of Urban Travel in the U.S.: Evidence from the 2017 NHTS**

**Author(s):** Wang, X. and Renne, J.L.

**Abstract:** Using the 2017 National Household Travel Survey (NHTS), this study analyzes America’s urban travel trends compared with earlier nationwide travel surveys and examines the variations in travel behaviors among a range of socioeconomic groups. The most noticeable trend for the 2017 NHTS is that, although private automobiles continue to be the dominant travel mode in American cities, the share of car trips has slightly and steadily decreased since its peak in 2001. In contrast, the share of transit, non-motorized, and taxicab (including ride-hailing) trips has steadily increased. Besides this overall trend, there are important variations in travel behaviors across income, home ownership, ethnicity, gender, age, and life-cycle stages. Although the trends in transit development, shared mobility, E-commerce, and lifestyle changes offer optimism about American cities becoming more multimodal, policymakers should consider these differences in socioeconomic factors and try to provide more equitable access to sustainable mobility across different socioeconomic groups.

**Subject Areas:** Vehicle-miles of travel; Transit; Socioeconomics; Demography; Mobility; Sustainable development

**Availability:** Wang, X. and Renne, J.L. (2023). “Socioeconomics of Urban Travel in the U.S.: Evidence from the 2017 NHTS.” *Transportation Research Part D: Transport and Environment*, 116. <https://doi.org/10.1016/j.trd.2023.103622>

**10.16. Title: COVID-19 and Teleworking: Lessons, Current Issues and Future Directions for Transport and Land-Use Planning**

**Author(s):** Anik, M.A.H., and Habib, M.A.

**Abstract:** Teleworking has been considered to be one of the emanating behaviors from the pandemic that may become long-lasting. Wider adoption of teleworking may fundamentally change urban mobility and spaces across cities. However, knowledge about the potential implications of teleworking on urban transport and land-use systems post-pandemic is limited. Through a comprehensive review of existing teleworking studies, this research identifies gaps in the literature, discusses major issues for exploration and suggests future research directions. It also explores ways to utilize teleworking as an effective travel demand management strategy. Analysis shows that teleworking has the potential to substantially change city landscapes and can assist in reducing traffic congestion, greenhouse gas emissions, and energy use. Priority areas for further research are identified, such as in-home activities, residential location choice, non-work trip patterns, and energy consumption decisions of teleworkers for a clearer understanding of the relationship between teleworking and urban systems. Analysis also reveals several planning and policy challenges surrounding teleworking, including digital divide, urban sprawling, and transformation of city centers, among others. To fully realize the benefits of teleworking, planners need to reconfigure community design principles to promote mixed-use, lively, and vibrant neighborhoods where people can both live and work. At the same time, governments should consider providing incentives to both organizations and employees with an aim to retain teleworking. Results of this paper will be highly beneficial to transport and land-use researchers, planners, and policymakers.

**Subject Areas:** Information and communications technology; Telecommuting; Travel behavior; Land-use; Traffic emission and energy use; Transportation and economic development

**Availability:** Anik, M.A.H., and Habib, M.A. (2023). "COVID-19 and Teleworking: Lessons, Current Issues and Future Directions for Transport and Land-Use Planning." *Transportation Research Record: Journal of the Transportation Research Board*.  
<https://doi.org/10.1177/03611981231166384>

**10.17. Title: How the Design of Complete Streets Affects Mode Choice: Understanding the Behavioral Responses to the Level of Traffic Stress**

**Author(s):** Bas, J., Al-Khasawneh, M.B., Erdoğan, S., and Cirillo, C.

**Abstract:** Following a federal policy statement in 2010 supporting bicycle and pedestrian accommodation in federal-aid transportation projects, many cities across the US have implemented Complete Streets principles and invested in developing better-planned infrastructure that can be safely accessed by a diversity of modes of transportation by all types of users in a mix of land uses. However, most of the travel demand forecasting models and planning tools used in practice are not sensitive to changes in demand for non-motorized modes, such as walking and cycling, in response to road infrastructure improvements. Hence, there is a need for models and tools that are capable of evaluating impacts of infrastructure changes that include Complete Streets implementations on the travel behavior and estimate shifts in mode choices from motorized to non-motorized modes. This paper proposes a specific data collection plan, a multi-modal choice model, and strategies to update traditional trip-based transportation models to forecast rates of non-motorized trips for evaluating Complete Streets plans at a higher level. Concretely, we estimate elasticities to Level of Traffic Stress, which defines the comfort or discomfort experienced by walkers and bikers, segmented by income levels and trip purposes. We then use them to compute the new non-motorized mode shares that would be achieved by improving CS attributes, leading to lower levels of traffic stress. The proposed modeling framework has been successfully applied to the Maryland Statewide Transportation Model, producing reliable non-motorized trip rates, and can be extended to other methodological frameworks used by public agencies.

**Subject Areas:** Complete Streets; Non-Motorized modes; Level of Traffic Stress; Travel Demand Forecasting; Elasticity; Transportation planning

**Availability:** Bas, J., Al-Khasawneh, M.B., Erdoğan, S., and Cirillo, C. (2023). “How the Design of Complete Streets Affects Mode Choice: Understanding the Behavioral Responses to the Level of Traffic Stress.” *Transportation Research Part A: Policy and Practice*, 173.

<https://doi.org/10.1016/j.tr.2023.103698>

**10.18. Title: Delineating Race-Specific Driving Patterns for Identifying Racial Segregation**

**Author(s):** Zhou, Y., Wei, R., Liu, X.C., Wallace, D., and Grubestic, T.

**Abstract:** Transportation equity is a substantial concern for planners. Segregation and exposure analysis provide a lens from which community stakeholders can better decipher transportation equity challenges. This paper aims to expand racial segregation analysis beyond residential places to a more holistic activity space, including commuter populations. We filled existing research gaps on validity by calibrating Information Maximization (IM) model and a distance decay function to estimate race-specific driving patterns iteratively. A unique index of intergroup exposure and potential for contact between residents, workers, and commuters is proposed to understand the varying exposures different racial groups have with each other. We further identified the most racially segregated road segments, residential and workplace areas, and how they become segregated based on the commuters' information. Given that exposure is a precursor to contact, understanding race-specific driving patterns is vital to understanding more extensive social mobility and segregation processes and their consequences for transport equity.

**Subject Areas:** Intergroup exposure; Racial segregation; Social equity; Race-specific driving pattern

**Availability:** Zhou, Y., Wei, R., Liu, X.C., Wallace, D., and Grubestic, T. (2023). "Delineating Race-Specific Driving Patterns for Identifying Racial Segregation." *Transportation Research Part D: Transport and Environment*, 119. <https://doi.org/10.1016/j.trd.2023.103769>

**10.19. Title: Explore Regional Variation in the Effects of Built Environment on Driving with High-Resolution U.S. Nationwide Data**

**Author(s):** Wang, L.

**Abstract:** There have been numerous studies on the relationship between travel behavior and built environment over the last few decades. Prior studies have mostly focused on producing point estimates of model coefficients and ended up with a wide range of estimates for the built environment elasticity of travel behavior, including household vehicle miles traveled. With few exceptions, previous studies use data from a single region or a small number of regions and thus are not able to sufficiently investigate the regional variation in built environment elasticity.

On the other hand, a few papers have addressed the heterogeneity of elasticity among different population groups and neighborhood types but so far have paid little attention to regional variation of elasticity. In his latest research project, Liming Wang uses the 2009 U.S. National Household Travel Survey and high-resolution built environment measures in the Smart Location Database to investigate the urbanized area-level variation in the effect of built environment with multi-level mixed effect models. He found that there exist regional variations in the relationship between built environment and household VMT, and, as a matter of fact, there is no significant fixed effect of major built environment factors on VMT after considering urbanized area-level random effect. This presentation will conclude with a discussion of the implications of this research.

**Subject Areas:** Built environment on driving; Regional variation; Mixed Effect Models; Reproducible research

**Availability:** Wang, L. (2023). *Explore Regional Variation in the Effects of Built Environment on Driving with High-Resolution U.S. Nationwide Data*. PSU Transportation Seminar, Portland State University, Portland, OR. [https://pdxscholar.library.pdx.edu/trec\\_seminar/240/](https://pdxscholar.library.pdx.edu/trec_seminar/240/)

**10.20. Title: Understanding Ride-Hailing Sharing and Matching in Chicago Using Travel Time, Cost, and Choice Models**

**Author(s):** Mucci, R. and Erhardt, G.D.

**Abstract:** Ride-hailing data are sparingly available throughout the U.S., which limits researchers' understanding of the mode. Chicago is one of a few cities that have mandated ride-hailing companies to submit detailed trip data to their local transportation agency. The dataset is one of the few to contain trip-level attributes, such as fare, travel time, and trip length. Most research using the Chicago dataset has focused on understanding why people use ride-hailing. This study focuses on why ride-hailing passengers choose shared over private trips and what influences the shared trips to be matched. Trips to/from airports are less likely to be shared. Trips to/from low-income areas are more likely to be shared. Longer shared trips are more likely to be matched, shared trips to/from dense areas are more likely to be matched, and shared trips between areas with a high number of shared trips are more likely to be matched. Matching an additional shared trip with another adds approximately 4 min to a trip. Ride-hailing users' value of time is found to be \$48.23 per hour. Understanding travel behavior is important for all modes of transportation, including ride-hailing. The results of this paper can be applied to guide policies aiming to promote more sustainable transportation modes.

**Subject Areas:** Ride-hailing; Chicago; Shared trips; Value of time; Travel behavior

**Availability:** Mucci, R. and Erhardt, G.D. (2023). "Understanding Ride-Hailing Sharing and Matching in Chicago Using Travel Time, Cost, and Choice Models." *Transportation Research Record: Journal of the Transportation Research Board*.  
<https://doi.org/10.1177/03611981231173636>

## Chapter 11. Trend Analysis and Market Segmentation

### 11.1. Title: Spatial Sorting within Cities

**Author(s):** Couture, V. and Handbury, J.

**Abstract:** We study changing trends in within-city sorting by education over the last 40 years. We show that neighborhoods closest to the centers of large U.S. cities rose from having the lowest levels of college attainment in 1980 to the highest in 2017. We discuss the determinants of changes in sorting patterns, focusing on the role of transportation technology and income growth. We outline various consequences of the recent urbanization of college graduates on neighborhood amenities, house prices, and segregation. We highlight the tendency of college graduates to cluster into select central neighborhoods, likely limiting opportunities for interactions across educational lines.

**Subject Areas:** Sorting patterns; Urbanization; College graduates; Transportation technology; Income growth

**Availability:** Couture, V. and Handbury, J. (2022). *Spatial Sorting within Cities*. Authors' Manuscript, University of British Columbia, Vancouver, BC, Canada, and University of Pennsylvania, Philadelphia, PA. [http://www.jessiehandbury.com/papers/CH\\_spatialsorting\\_2022.pdf](http://www.jessiehandbury.com/papers/CH_spatialsorting_2022.pdf)



**11.2. Title: How Can We Minimize the Accessibility Gap in the Travel Industry?**

**Author(s):** Sequeira, F.

**Abstract:** Blog.

**Subject Areas:** Accessibility gap; Tourism industry; TravelAbility; Social responsibility; Financial impacts

**Availability:** Sequeira, F. (2023). "How Can We Minimize the Accessibility Gap in the Travel Industry?" *Newstrail.com*. <https://www.newstrail.com/how-can-we-minimize-the-accessibility-gap-in-the-travel-industry/>

### 11.3. Title: **The Future of the Urban Street in the United States: Visions of Alternative Mobilities in the Twenty-First Century**

**Author(s):** Zipori, E.

**Abstract:** This dissertation is concerned with the present and future of urban streets in the United States. The goal is to document and analyze current visions, policies, and strategies related to the form and use of American urban streets. The dissertation examines current mobility trends and offers a framework for organizing visions of the future of urban streets, evaluating them through three lenses: safety, comfort, and delight—assessing physical conditions in accordance with livability standards toward sustainable development. At the same time, it demonstrates the way 12 scenarios (NACTO Blueprint for Autonomous Urbanism, Sidewalk Labs: Quayside Project, Public Square by FXCollaborative, AIANY Future Street, The National Complete Street Coalition, Vision Zero, Smart Columbus, Waymo by Alphabet, The Hyperloop, Tesla “Autopilot,” Ford City of Tomorrow, SOM City of Tomorrow) have intentionally or unintentionally influenced contemporary use of American urban streets. Ultimately, the study shows that while sustainable alternative mobilities continue to emerge, the dominance of the automobility system has led to a stagnation of sustainable urban street development in the United States.

**Subject Areas:** Bicycification; Pedestrianization; Urban streets; Mobility trends; Sustainable development; Alternative mobilities; Automobility system

**Availability:** Zipori, E. (2022). *The Future of the Urban Street in the United States: Visions of Alternative Mobilities in the Twenty-First Century*. Doctoral Dissertation, New Jersey Institute of Technology, Newark, NJ. <https://digitalcommons.njit.edu/dissertations/1646>

**11.4. Title: Gender Gap and Parenthood Penalties in Business Travel from 2001 to 2017: Occupational Variations and Associations with Technology Use**

**Author(s):** Gaydarska, H. and Matsuo, M.

**Abstract:** This paper evaluates transitions in gender differences and parenthood penalties in the chance of business travel, focusing on variations by occupation and technology usage. Although literature documents that women and parents of small children are substantially less likely to travel for business, particularly long ones, little research has explored changes in the gap. Moreover, not much attention has been given to whether they vary by business travel distance, occupation, or technology adaptations. This study analyzes domestic intra-regional business travel likelihood by different distance thresholds, using three U.S. National Household Travel Surveys from 2001 to 2017. By employing the Probit model, our analysis finds narrowing gender gaps and parenthood penalties in business mobility, thanks to the shrinking travel needs. Internet-savvy workers, in particular, experienced narrower gender gaps, especially among those without small children. The conditional prediction suggests a disappearing gender gap and parenthood gap for the sales and service workers, even for trips over 50 miles per day. Contrary, the gender gap in business mobility among the professional and managerial workers persistently remained in 2017 for long-distance trips. The declining trend in the gender gap and parenthood penalty for the business travel likelihood is a vital sign for reducing inequalities and work-life balances.

**Subject Areas:** Business travel; Gender gap; Internet (non) savvy; ICT development

**Availability:** Gaydarska, H. and Matsuo, M. (2023). *Gender Gap and Parenthood Penalties in Business Travel from 2001 to 2017: Occupational Variations and Associations with Technology Use*. Discussion Paper Series, DP2023-02, Kobe University, Kobe, Japan. <https://www.rieb.kobe-u.ac.jp/academic/ra/dp/English/DP2023-02.pdf>

**11.5. Title: America on the Move: How Urban Travel Has Changed over a Decade**

**Author(s):** Galoustian, G.

**Abstract:** Blog.

**Subject Areas:** Urban travel trends; Trip mode share; Trip frequency; Trip distance; Vehicle ownership; Socioeconomic groups

**Availability:** Galoustian, G. (2023). "America on the Move: How Urban Travel Has Changed over a Decade." *News Desk*, Florida Atlantic University, Boca Raton, FL.  
<https://www.fau.edu/newsdesk/articles/urban-travel-trends-study>

## 11.6. Title: **The Future of Working Away from Work and Daily Travel: A Research Synthesis**

**Author(s):** Speroni, S. and Taylor, B.D.

**Abstract:** This research synthesizes literature on the relationship between working from home and travel. This relationship is a pertinent one because transportation planners and policymakers have long hoped that increased remote work, sometimes called telecommuting or telework, will reduce driving, traffic congestion, and vehicle emissions. This question is especially pertinent today because working from home increased dramatically early in the COVID-19 pandemic and has remained at substantially elevated levels since then. To examine this issue, we review nearly 100 research articles, reports, and some popular accounts of telecommuting and travel prior to and during the pandemic. In conducting this review, we arrive at five principal findings. First, remote work increased dramatically with the onset of the pandemic and appears likely to remain elevated for many years to come. Second, while not everyone can work remotely, for those who have the option to do so, at least part-time, this hybrid option is extremely popular with most workers. Third, employers tend to be skeptical of the benefits of remote work, but the research does not support fears of declining productivity in the near term, and the tight post-pandemic labor market has given workers leverage to insist on remote work options. Fourth, telecommuting has long been touted as a potential solution to chronic transportation problems such as traffic congestion and vehicle emissions, but the research has consistently found that it is more likely to increase rather than decrease overall driving among remote workers. This extra driving is due both to hybrid workers living farther from work, on average, than non-remote workers and to all remote workers making more household-serving and personal trips when they work from home. And fifth, public transit systems, in contrast to street and highway systems, have been dramatically affected by the pandemic, likely due substantially to the rise in remote work it has engendered. The future of many public transit systems, which draw an outsized share of their riders from commuters to downtowns and other major job centers, will depend on whether and to what extent those job centers redensify with workers in the months and years ahead.

**Subject Areas:** Travel; Remote work; Telecommuting; Telework; Work from home

**Availability:** Speroni, S. and Taylor, B.D. (2023). *The Future of Working Away from Work and Daily Travel: A Research Synthesis*. Research Report, UC-ITS-2022-13, University of California, Los Angeles, CA. <https://doi.org/10.17610/T64W3D>

## 11.7. Title: Pre- and Post-Pandemic Seafood Purchasing Behavior in the U.S.

**Author(s):** Engle, C., van Senten, J., Kumar, G., and Dey, M.

**Abstract:** The global COVID-19 pandemic resulted in an unprecedented economic shock in current times. Previous literature on consumer shopping behaviors during economic downturns is limited, and studies specific to seafood focused primarily on supply-side shocks. A national survey was conducted using an online platform from February 22 to April 6, 2021, that targeted 100 seafood consumers in each of 20 market areas across the U.S. Following data cleaning, 1908 usable responses were obtained. Results documented significant changes in consumer shopping behaviors. Significantly greater percentages of meals (generally and of seafood) were consumed at home and fewer away from home, as expected. Demographic differences were found in shopping behaviors by age, education, income, and gender, but not by ethnic group. Frequency of shopping decreased in 2020, but the expenditure per shopping trip did not, resulting in less overall spending for groceries as compared to 2019. Respondents were less likely to purchase seafood for takeout or for home delivery of prepared meals as compared to general meals because of concerns over quality, freshness, and safety of seafood. Half of respondents consumed approximately the same amount of seafood as before the pandemic, with 31% reporting decreased seafood consumption and only 19% increased seafood consumption. Thus, study results provide evidence of a pandemic-imposed shift to consuming greater proportions of seafood meals at home than away from home and not an overall increase in seafood consumption. The choice of species eaten most often did not differ pre- and post-pandemic. Those respondents who reported decreased seafood consumption in 2020 did so primarily because of 1) its expense, given reduced incomes from working fewer hours or being laid off; 2) unwillingness to prepare fish at home for the smell and “mess” or being uncomfortable preparing it; or 3) simply not preferring or liking seafood well enough to eat it more frequently. Those who reported increasing seafood consumption did so primarily because it was considered to be a healthy food choice. Additional work is needed to further examine consumption and shopping behaviors throughout the recovery in 2021 and 2022.

**Subject Areas:** Consumer behavior; Seafood markets; Seafood purchases; Pandemic; Shopping behavior

**Availability:** Engle, C., van Senten, J., Kumar, G., and Dey, M. (2023). “Pre- and Post-Pandemic Seafood Purchasing Behavior in the U.S.” *Aquaculture*, 571.

<https://doi.org/10.1016/j.aquaculture.2023.739491>

## 11.8. Title: Consumption Segregation

**Author(s):** Boar, C. and Giannone, E.

**Abstract:** This paper introduces consumption segregation, a new margin of residential segregation, and examines its patterns and causes and discusses its aggregate consequences. We use new longitudinal and highly granular data to measure consumption segregation in the United States and document that it is high but relatively stable over the past 15 years, with substantial regional variation. We find that income segregation plays a more prominent role than other forms of segregation in driving consumption segregation, mainly due to the inability to smooth shocks to income. We illustrate a new mechanism through which, in the presence of social comparisons, consumption segregation can exacerbate wealth inequality.

**Subject Areas:** Consumption segregation; Income wealth inequality; Social comparisons

**Availability:** Boar, C. and Giannone, E. (2023). *Consumption Segregation*. Working Paper No. 31133, National Bureau of Economic Research, Cambridge, MA.  
<https://www.nber.org/papers/w31133>

### 11.9. Title: Assessing Progress and Equity in the Distribution of Electric Vehicle Rebates Using Appropriate Comparisons

**Author(s):** Williams, B.D.H.

**Abstract:** To meet aggressive transportation-electrification goals, electric vehicle (EV) sales must expand deeper into mainstream markets. To address equity concerns, EV sales must go beyond the mainstream to increase access to EV benefits. To support needed expansion in sales and equity, this research examined the characteristics of California consumers that claimed the statewide rebate for EVs purchased/leased in 2017–2020. It weighted  $n = 32,524$  survey responses to represent  $N = 193,167$  rebate recipients and focused on 2020 adoption, trends over time, and differences between consumers of battery and plug-in hybrid EVs. Importantly, incentive-recipient characteristics were compared using Market-Majority Metrics to those of California new-vehicle buyers as a more appropriate baseline. Results raise the possibility that findings about the equity of EV-rebate-recipient incomes based on comparisons to Census data could largely and more simply be findings about new-car buying rather than particular to EV-incentive recipients. Rebate-recipient incomes continued to progress toward the mainstream despite the dominance of Tesla consumers and COVID. The distribution of rebate funding by income is now roughly comparable to new-vehicle buyers. Indeed, fewer rebated PHEV consumers (52%) had household incomes greater than \$100,000 than even new-vehicle buyers (56%). Except for age, PHEV consumers are more similar to typical vehicle buyers than BEV consumers are. The characteristics most distinguishing of EV consumers are now home ownership and male sex/gender identification. Market-Majority Metric “heat map tables” are developed as an intuitive but quantitative tool to highlight the length of the road ahead that EV markets must travel toward the mainstream and beyond to priority populations.

**Subject Areas:** Electric vehicles; Incentives; Transport policy; Adopter characteristics; Equity; Consumer demographics

**Availability:** Williams, B.D.H. (2023). “Assessing Progress and Equity in the Distribution of Electric Vehicle Rebates Using Appropriate Comparisons.” *Transport Policy*, 137, pp. 141–151.  
<https://doi.org/10.1016/j.tranpol.2023.04.009>



**11.10. Title: Tesla Rules the Road: Model X Leads as the Most Driven Electric Car**

**Author(s):** Armstrong, K.

**Abstract:** Blog.

**Subject Areas:** Electric vehicles adoption; Cost; Range

**Availability:** Armstrong, K. (2023). "Tesla Rules the Road: Model X Leads as the Most Driven Electric Car." *Not a Tesla App*. <https://www.notateslaapp.com/news/1438/tesla-rules-the-road-model-x-leads-as-the-most-driven-electric-car>

### 11.11. Title: Public or Private? Optimal Organization for Incentive-Based Travel Demand Management

**Author(s):** Wu, J., Tian, Y., Sun, J., Zhang, H.M., and Wang, Y.

**Abstract:** Incentive-Based Travel Demand Management (IBTDM) strategies have received more attention in recent years because they are more appealing to commuters than penalty-based strategies and thus result in less public aversion. In IBTDM, fully time-variant positive incentives are endowed to the traveling public to encourage off-peak trips. We theoretically demonstrate the effectiveness of IBTDM in managing morning commuters with elastic demand based on Vickrey's bottleneck model. Due to the decentralization of IBTDM, incentive providers are no longer limited to public organizations because private organizations can also administrate IBTDM programs. Therefore, from the perspective of public and private organizations, maximizing social surplus and private profit can be treated as objective functions. In addition, IBTDM is usually not mandatory but voluntary. Thus, we also considered the constraint of penetration rate. We found that when commuters are relatively sensitive to changes in their actual travel costs, a low penetration rate and a small incentive budget are enough for IBTDM to reach an optimal state (for both public and private administrators), and an excessive budget actually creates negative effects. Compared with public organizations, incentive schemes administrated by private organizations are a more lightweight strategy. However, public organizations are overwhelmingly dominant in the case of high market penetration and low traveler sensitivity. Therefore, one of the most effective modes of operation is to have private organizations implement IBTDM in the early stages of promotion, and then all private-owned businesses would be integrated into public organizations when they reach a certain scale.

**Subject Areas:** Travel demand management; Bottleneck model; Incentives; Elastic demand; Market penetration; Public and private organizations

**Availability:** Wu, J., Tian, Y., Sun, J., Zhang, H.M., and Wang, Y. (2023). "Public or Private? Optimal Organization for Incentive-Based Travel Demand Management." *Transportation Research Part E: Logistics and Transportation Review*, 174. <https://doi.org/10.1016/j.tre.2023.103137>

**11.12. Title: Public and Private Transportation in Chinese Cities: Impacts of Population Size, City Wealth, Urban Typology, the Built Environment, and Fuel Price**

**Author(s):** Fu, X., Mauzerall, D.L., and Ramaswami, A.

**Abstract:** The development of urban transportation is affected by city population size, wealth, urban typology, the built environment, and fuel price and has significant implications for urban sustainability. We analyze data of 297 Chinese cities between 2017 and 2019 using both simple regressions to examine the relationships between metrics of public and private transportation and city size and multiple regressions to examine the impacts of the above urban factors on public transit use and private vehicle number. Both public transit use and private vehicle number scale super-linearly with population and sub-linearly with gross regional product. We find that the impacts of population size, city wealth, the built environment, and fuel price on transportation vary across city groups (industrial, mixed-economy, and commercial cities). We find that the relationships between urban transportation metrics and their factors extracted from intra-city variations over time are different from those derived from pooling data of multiple cities over time, indicating the importance of choosing appropriate analyses to inform local policymaking. A key finding is that to reduce private vehicle ownership, enhancing land use diversity, increasing rail transit, and expanding taxi fleets are more effective than increasing density in already dense Chinese cities. Our findings improve understanding of the drivers of public and private transportation in urban China that are needed to promote sustainable growth of Chinese cities.

**Subject Areas:** Public and private transportation; Urban transportation; Sustainable growth; Urban size

**Availability:** Fu, X., Mauzerall, D.L., and Ramaswami, A. (2023). "Public and Private Transportation in Chinese Cities: Impacts of Population Size, City Wealth, Urban Typology, the Built Environment, and Fuel Price." *Environmental Research: Infrastructure and Sustainability*, 3(2). <https://doi.org/10.1088/2634-4505/acd419>

### 11.13. Title: Anticipating Current and Coming Technologies That Affect U.S. Travel Choices

**Author(s):** Hawkins, J., Kockelman, K.M., and Huang, K.

**Abstract:** Understanding the preferences for new and future transportation technologies is important to ensure an efficient and equitable future transportation system. A survey was conducted of Americans' preferences for several such technologies. Americans are concerned about vehicle range and charging station availability for electric vehicles (EVs) and hesitant about autonomous vehicle (AV) safety. Opinions about many transportation technologies, such as vertical takeoff and landing (i.e., air taxis), shared parking, and air-drone delivery, are mixed. These less familiar technologies require continued tracking of preferences. A 55% increase is estimated in the probability of an individual choosing a battery electric vehicle (BEV) pickup truck if its fuel economy increases by about 9%. This result supports a market for BEV pickup trucks currently under development by many automakers. The preference for vehicle automation appears to depend on the use case. Driving task automation is preferred by residents of low-density, car-dependent areas where long commutes are common. In contrast, automated parking technologies are favored by those living in denser communities. Intermittent bus lanes are favored by those living in high population-density areas but not among those in areas with high shares of zero-vehicle households. These results provide indications of where to direct future research in the field.

**Subject Areas:** Intelligent transportation systems; Advanced technology; Automated/autonomous vehicles; Planning and analysis; Effects of information and communication technologies (ICT) on travel choices; Communications/communications technology; Emerging technology; Technology adoption

**Availability:** Hawkins, J., Kockelman, K.M., and Huang, K. (2023). "Anticipating Current and Coming Technologies That Affect U.S. Travel Choices." *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/03611981231168856>

#### 11.14. Title: Going Nowhere Fast: Might Changing Activity Patterns Help Explain Falling Travel?

**Author(s):** Morris, E.A., Speroni, S., and Taylor, B.D.

**Abstract:** The inexorable rise in personal travel in the 20th century has given way to stagnation in the 21st, a phenomenon some call “peak travel.” We use 2003–2019 data from the American Time Use Survey to explore whether and why personal travel per capita has stopped growing. We show that time spent on personal travel has been dropping consistently over these years and suggest that one important cause is likely a dramatic and ongoing decline in the time Americans spend on out-of-home activities. We find significant changes in time spent on many of the 34 activities conducted inside and outside of the home that we examine. Many of these changes appear related to advances in information and communications technology (ICT) because this period saw the quality of in-home ICT continually rising and its real cost falling, resulting in ever-improving gaming, surfing, watching, and streaming options. For example, our data suggest that out-of-home work and shopping time fell significantly during our study period, while in-home time spent on work and education rose. Game playing (presumably mostly computer games) and TV watching in the home both increased dramatically, while attendance at live entertainment, arts, and sports activities fell. Reading and writing fell substantially both inside and outside the home, perhaps replaced by electronic communication. Our findings suggest that increased in-home ICT use may have been associated with 25–30% of the reduction of out-of-home time. We also find a significant increase in sleeping and a decrease in time spent eating and drinking both inside and outside of the home. Although we deliberately chose to examine time use and travel prior to the COVID-19 pandemic, we suspect that, even as the pandemic fades, the trend toward more time at home and less time spent traveling may well increase further.

**Subject Areas:** Activity locations; Peak travel; Information and communications technology; Time use; Activity patterns

**Availability:** Morris, E.A., Speroni, S., and Taylor, B.D. (2023). “Going Nowhere Fast: Might Changing Activity Patterns Help Explain Falling Travel?” *Journal of Transport Geography*, 110. <https://doi.org/10.1016/j.jtrangeo.2023.103620>

## Chapter 12. Emerging Travel Modes

### 12.1 Title: Curb Allocation and Pick-Up Drop-Off Aggregation for a Shared Autonomous Vehicle Fleet

**Author(s):** Hunter, C.B., Kockelman, K.M., and Djavadian, S.

**Abstract:** Advances in information technologies and vehicle automation have birthed new transportation services, including shared autonomous vehicles (SAVs). Shared autonomous vehicles are on-demand self-driving taxis, with flexible routes and schedules, able to replace personal vehicles for many trips in the near future. The siting and density of pick-up and drop-off (PUDO) points for SAVs, much like bus stops, can be key in planning SAV fleet operations because PUDOs impact SAV demand, route choices, passenger wait times, and network congestion. Unlike traditional human-driven taxis and ride-hailing vehicles such as Lyft and Uber, SAVs are unlikely to engage in quasi-legal procedures, such as double parking or fire hydrant pick-ups. In congested settings, such as central business districts (CBD) or airport curbs, SAVs and others will not be allowed to pick up and drop off passengers wherever they like. This paper uses an agent-based simulation to model the impact of different PUDO locations and densities in the Austin, Texas, CBD, where land values are highest and curb spaces are coveted. In this paper 18 scenarios were tested, varying PUDO density, fleet size, and fare price. The results show that for a given fare price and fleet size, PUDO spacing (e.g., one block vs. three blocks) has significant impact on ridership, vehicle-miles travelled, vehicle occupancy, and revenue. A good fleet size to serve the region's 80 core square miles is 4,000 SAVs, charging a \$1 fare per mile of travel distance, and with PUDOs spaced three blocks of distance apart from each other in the CBD.

**Subject Areas:** Pickup and drop-off locations; Shared autonomous vehicles; Autonomous taxis; Ridesharing stations; Dynamic ride-sharing; Curb management

**Availability:** Hunter, C.B., Kockelman, K.M., and Djavadian, S. (2023). "Curb Allocation and Pick-Up Drop-Off Aggregation for a Shared Autonomous Vehicle Fleet." *International Regional Science Review*, pp. 1–28. <https://doi.org/10.1177/01600176231160498>

## 12.2 Title: Land Use Analysis on Vertiports Based on a Case Study of the San Francisco Bay Area

**Author(s):** Wei, W., Rohrmeier, K., Martinez, T., Winans, M., and Park, H.

**Abstract:** Vertiport research and development trails in the emerging commercial air taxi sector known as Advanced Air Mobility (AAM). Published scholarship remains limited as federal, state, and local governments have yet to create or implement policies for the rapidly progressing larger AAM ecosystem, which is designed around autonomous electric vehicle takeoff and landing aircraft. With the potential for frequent low-altitude flights, long-range planning must demonstrate awareness, knowledge, and utilization of geographic information science to select safe and just vertiport locations. This study summarizes the AAM literature and offers planners a set of stakeholder-informed parameters to use in a no-cost preliminary GIS analysis when applied to urban, suburban, and exurban site suitability models. Parameters for this case study were identified under the considerations of safety, access, and equity for vertiport placement and given a high-, medium-, or low-priority level to determine site suitability. The goals of this study are to establish a framework for the systematic approach to vertiport site selection and to provide recommendations for how a region might plan its AAM network, regulations, or best practices. The approach established by this framework would ensure general consistency in AAM land use planning for a region while remaining flexible enough to allow for other considerations that may differ between regions, such as local zoning or state regulations. The study also highlights the importance of integrating a focus on land use planning when implementing AAM, especially as it relates to a case study of the San Francisco Bay Area.

**Subject Areas:** Advanced air mobility (AAM); Land use planning; GIS; Transportation planning Sustainability

**Availability:** Wei, W., Rohrmeier, K., Martinez, T., Winans, M., and Park, H. (2023). *Land Use Analysis on Vertiports Based on a Case Study of the San Francisco Bay Area*. Technical Report, CA-MTI-2122, Mineta Transportation Institute, San José State University, San José, CA. <https://doi.org/10.31979/mti.2023.2122>

## Chapter 13. Passive OD Data Product Usage

### 13.1 Title: Introducing a Novel Tour-Based Trip Identification Algorithm for Mobile Device Location Data: Methodology Framework Developed for 2020 Next-Generation National Household Travel Survey Passenger Origin-Destination Data

**Author(s):** Darzi, A. et al.

**Abstract:** The emergence of new data sources such as mobile device location data (MDLD) provides a unique opportunity for transportation planners and analysts to better understand human mobility behavior patterns using continuous, more accessible, passively collected data at a lower cost. Despite many advantages of the MDLD, a rigorous methodological framework is needed to extract mobility information from the raw trajectory data. This study proposes a novel tour-based trip identification algorithm to enhance the current state-of-practice and state-of-art methods in trip identification. The introduction of the tours enabled us to differentiate between short-distance and long-distance trips in a systematic approach and to apply different trip identification methods for each tour to better capture the trips. In addition, the proposed algorithm in this study provides more flexibility for identifying unlinked and linked trips based on the applications. This feature is of significant importance for achieving a more consistent trip definition compared to the ones usually employed in traditional travel surveys or travel demand modeling applications. The proposed algorithm was successfully applied to the national-level integrated MDLD of 2020 to produce the national passenger origin-destination data for the Next Generation National Household Travel Survey (NextGen NHTS) program launched by the U.S. Department of Transportation Federal Highway Administration (USDOT FHWA). The national-level trip summary for 2020 is provided in the result section of this paper which demonstrates the ability of the proposed method to capture the unique pattern of human mobility amidst the COVID-19 pandemic.

**Subject Areas:** Mobile device location data; Behavior patterns; Trip identification; Unlinked and linked trips

**Availability:** Darzi, A. et al. (2023). *Introducing a Novel Tour-Based Trip Identification Algorithm for Mobile Device Location Data: Methodology Framework Developed for 2020 Next-Generation National Household Travel Survey Passenger Origin-Destination Data*. Transportation Research Board 102nd Annual Meeting, Washington, D.C.

<https://annualmeeting.mytrb.org/OnlineProgramArchive/Details/19298>



### 13.2 Title: Residency and Worker Status Identification Based on Mobile Device Location Data

**Author(s):** Pan, Y., Sun, Q., Yang, M., Darzi, A., Zhao, G., Kabiri, A., Xiong, C., and Zhang, L.

**Abstract:** Mobile device location data (MDLD) have been widely recognized for their rich human mobility information and thus considered as a supplementary data source for the current travel data bank consisting of travel survey data and traffic monitoring data. However, the lack of ground truth information about the device owners raises concern about the biases and representativeness of the nonprobability MDLD sample and significantly limits the applications of MDLD. This paper focuses on identifying two important socio-demographic characteristics for the MDLD sample devices: residency and worker status, including four worker types (normal commuters, professional drivers, mobility-for-work workers, and nonworkers/home-based workers). Based on the spatial-temporal patterns of location sightings and derived trips from MDLD, a comprehensive imputation framework is proposed with parameters calibrated against public domain ground truth data. A national-level case study in the U.S. based on a commercial MDLD dataset further evaluates the performances of the proposed heuristic rules. The multi-level validation results indicate a satisfying match against the ground truth data and prove the effectiveness of the proposed methods. As one of the earliest efforts to identify the residency and worker status information for a large-scale national-level MDLD dataset, mobile workers, including professional drivers and mobility-for-work workers, are also identified from MDLD for the first time.

**Subject Areas:** Mobile device location data; Daily life center; Home and workplace imputation; Worker type imputation; Mobile workers; Professional drivers; Travel demand

**Availability:** Pan, Y., Sun, Q., Yang, M., Darzi, A., Zhao, G., Kabiri, A., Xiong, C., and Zhang, L. (2023). "Residency and Worker Status Identification Based on Mobile Device Location Data." *Transportation Research Part C: Emerging Technologies*, 146. <https://doi.org/10.1016/j.trc.2022.103956>.

### 13.3 Title: Toward a More Sustainable Mobility

**Author(s):** Pallonetto, F.

**Abstract:** The transport sector is the second most important source of emissions in the EU. It is paramount to act now toward the decarbonisation of our transport system to mitigate climate change effects. Waiting for future technological advancements to minimise the existing anthropogenic emissions and dramatically boost its sustainability is risky for human survival. The current chapter highlights how the path toward a sustainable transport system is a whole stakeholders' effort involving the mass deployment of available technology, changing user behaviours, data-driven legislation, and researching and developing future disruptive technologies. The author analyses and classifies the available data on various transport modals and assesses the impact of the technologies and policy measures in terms of potential reduction of carbon emissions, challenges, and opportunities. It also exemplifies outstanding test settings across the world on how already available technologies have contributed to the development of a lower-carbon transport setting. The chapter considers developing countries' economic and infrastructural challenges in upgrading to a low-carbon transport system and the lack of data-driven decisions and stakeholders' engagement measures in addressing the sector sustainability challenges. It also emphasised how a sustainable transport system should lay the foundation on data harmonisation and interoperability to accelerate innovation and promote a fast route for deploying new and more effective policies.

**Subject Areas:** Decarbonization; Transport modals; Technologies; Sustainable transport system

**Availability:** Pallonetto, F. (2023). "Toward a More Sustainable Mobility." In: Bertoni, E., Fontana, M., Gabrielli, L., Signorelli, S., and Vespe, M. (Eds.), *Handbook of Computational Social Science for Policy*, pp. 465–486. Springer, Cham. [https://doi.org/10.1007/978-3-031-16624-2\\_24](https://doi.org/10.1007/978-3-031-16624-2_24)

### 13.4 Title: A Big Data Driven Framework for Duplicate Device Detection from Multi-Sourced Mobile Device Location Data

**Author(s):** Kabiri, A., Darzi, A., Namadi, S.S., Pan, Y., Zhao, G., Sun, Q., Yang, M., and Ashoori, M.

**Abstract:** Mobile Device Location Data (MDLD) has been popularly utilized in various fields. Yet its large-scale applications are limited because of either biased or insufficient spatial coverage of the data from individual data vendors. One approach to improve the data coverage is to leverage the data from multiple data vendors and integrate them to build a more representative dataset. For data integration, further treatments on the multi-sourced dataset are required due to several reasons. First, the possibility of carrying more than one device could result in duplicated observations from the same data subject. Additionally, when utilizing multiple data sources, the same device might be captured by more than one data provider. Our paper proposes a data integration methodology for multi-sourced data to investigate the feasibility of integrating data from several sources without introducing additional biases to the data. By leveraging the uniqueness of travel pattern of each device, duplicate devices are identified. The proposed methodology is shown to be cost-effective while it achieves the desired accuracy level. Our findings suggest that devices sharing the same imputed home location and the top five most visited locations during a month can represent the same user in the MDLD. It is shown that more than 99.6% of the sample devices having the aforementioned attribute in common are observed at the same location simultaneously. Finally, the proposed algorithm has been successfully applied to the national-level MDLD of 2020 to produce the national passenger origin destination data for the Next-Generation National Household Travel Survey (NextGen NHTS) program.

**Subject Areas:** Mobile device location data; Data integration; Device deduplication

**Availability:** Kabiri, A., Darzi, A., Namadi, S.S., Pan, Y., Zhao, G., Sun, Q., Yang, M., and Ashoori, M. (2023). *A Big Data Driven Framework for Duplicate Device Detection from Multi-Sourced Mobile Device Location Data*. arXiv preprint, arXiv:2302.14742v1 [cs.CY].  
<https://doi.org/10.48550/arXiv.2302.14742>

**13.5 Title: Optimizing Mobility and Community Engagement for Older Clients**

**Author(s):** Stav, W.

**Abstract:** Text-based course article.

**Subject Areas:** Driving; Community mobility; Community engagement; Older people

**Availability:** Stav, W. (2023). "Optimizing Mobility and Community Engagement for Older Clients." *OccupationalTherapy.com*. <https://www.occupationaltherapy.com/articles/optimizing-mobility-and-community-engagement-5597-5597>

### 13.6 Title: Revealing Human Mobility Trends During the SARS-CoV-2 Pandemic in Nigeria via a Data-Driven Approach

**Author(s):** Luo, W. et al.

**Abstract:** We employed emerging smartphone-based location data and produced daily human mobility measurements using Nigeria as an application site. A data-driven analytical framework was developed for rigorously producing such measures using proven location intelligence and data-mining algorithms. Our study demonstrates the framework at the beginning of the SARS-CoV-2 pandemic and successfully quantifies human mobility patterns and trends in response to the unprecedented public health event. Another highlight of the paper is the assessment of the effectiveness of mobility-restricting policies as key lessons learned from the pandemic. We found that travel bans and federal lockdown policies failed to restrict trip-making behaviour but had a significant impact on distance travelled. This paper contributes a first attempt to quantify daily human travel behaviour, such as trip-making behaviour and travelling distances, and how mobility-restricting policies took effect in sub-Saharan Africa during the pandemic. This study has the potential to enable a wide spectrum of quantitative studies on human mobility and health in sub-Saharan Africa using well-controlled, publicly available large data sets.

**Significance:**

- The mobility measurements in this study are new and have filled a major data gap in understanding the change in travel behaviour during the SARS-CoV-2 pandemic in Nigeria. These measurements are derived from high-quality data samples by state-of-the-art data-driven methodologies and could be further adopted by other quantitative research related to human mobility.
- Additionally, this study evaluates the impact of mobility-restricting policies and the heterogeneous effects of socio-economic and socio-demographic factors by a time-dependent random effect model on human mobility. The quantitative model provides a decision-making basis for the Nigerian government to provide travel-related guidance and make decisions in future public health events.

**Subject Areas:** SARS-CoV-2; Human mobility; Trips; Policy; Nigeria

**Availability:** Luo, W. et al. (2023). “Revealing Human Mobility Trends During the SARS-CoV-2 Pandemic in Nigeria via a Data-Driven Approach.” *South African Journal of Science*, 119(5/6). <https://doi.org/10.17159/sajs.2023/14727>

**13.7 Title: Exploring the Effects of Population and Employment Characteristics on Truck Flows: An Analysis of NextGen NHTS Origin-Destination Data**

**Author(s):** Uddin, M., Liu, Y., and Lim, H.

**Abstract:** Truck transportation remains the dominant mode of US freight transportation because of its advantages, such as the flexibility of accessing pickup and drop-off points and faster delivery. Because of the massive freight volume transported by trucks, understanding the effects of population and employment characteristics on truck flows is critical for better transportation planning and investment decisions. The US Federal Highway Administration published a truck travel origin-destination data set as part of the Next Generation National Household Travel Survey program. This data set contains the total number of truck trips in 2020 within and between 583 predefined zones encompassing metropolitan and nonmetropolitan statistical areas within each state and Washington, D.C. In this study, origin-destination level truck trip flow data were augmented to include zone-level population and employment characteristics from the US Census Bureau. Census population and County Business Patterns data were included. The final data set was used to train a machine learning algorithm-based model, Extreme Gradient Boosting (XGBoost), where the target variable is the number of total truck trips. Shapley Additive ExPlanation (SHAP) was adopted to explain the model results. Results showed that the distance between the zones was the most important variable and had a nonlinear relationship with truck flows.

**Subject Areas:** Truck transportation; Extreme Gradient Boosting; Shapley Additive ExPlanation; Population and employment characteristics; Truck flows

**Availability:** Uddin, M., Liu, Y., and Lim, H. (2023). “Exploring the Effects of Population and Employment Characteristics on Truck Flows: An Analysis of NextGen NHTS Origin-Destination Data.” In: Wei, H. (Ed.), *International Conference on Transportation and Development 2023*, pp. 503–513. American Society of Civil Engineers, Reston, VA.  
<https://ascelibrary.org/doi/abs/10.1061/9780784484883.044>

**13.8 Title: STUDY: Rail between San Antonio-Austin Could Have Highest Ridership Out of Any City Pairs in Texas**

**Author(s):** Not available.

**Abstract:** Blog.

**Subject Areas:** Rail system; Train network; Ridership; Origin and destination

**Availability:** Not available. (2023). "STUDY: Rail between San Antonio-Austin Could Have Highest Ridership Out of Any City Pairs in Texas." *RESTART Lone Star Rail District*.

<https://www.restartlonestarraildistrict.org/post/study-rail-between-san-antonio-austin-could-have-highest-ridership-out-of-any-city-pairs-in-texas>